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Sawah Technology (5) Kebbi Rice Revolution, Nigeria

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1. Could Kebbi State achieve the annual paddy production of 1.85 million tons in 2015-2016 and become the No. 1 state in Nigeria?

It is hard to believe the data on the annual paddy production of 1.85 million tons in 2016. But there are many reports of Kebbi Rice Revolution in Nigeria's various newspapers and the internet since 2015, so it is unlikely to be a complete groundless fact. We could confirm some facts by Google Earth image by chance at the end of August 2017. The Google earth images at Sangelu and Suru towns area of the Rima River floodplain in the central Kebbi state showed that small pump irrigated sawah system development by farmers self-help efforts reached at least 2000 ha (10% of the total area of the flood plain) in 5 years from 2012 to 2016. The total length of the Rima River and the Niger River flood plain from Sokoto state to Niger state is about450 km in the whole of Kebbi state, the two rivers' width is 3 - 15 km, and if it is 10 km on average, it is about 450,000 ha in total. Since Sangelu and Suru flood plains occupy only about 20 thousand ha, the total area of irrigated sawah become 45 thousand ha (10% of the total flood plain area). Although this is a simple extrapolation, the 2000 ha of sawah development was the fact and it has been realized by countless farmers on their own efforts in the five years 2012 - 2016.

In Nigeria it is a remarkable increase in paddy production from the level of 4 million tons before 2010 to 6.7 million tons in 2014, but it is becoming clear that the increase in production after 2015 - 16 is even more remarkable. Although official agricultural statistics of the government of Nigeria (NAERLS and FDAE 2014) have published only rice production data for rainy season so far, it is estimated that 6.1 million tons in 2013 and 6.73 million tons in 2014. FAOSTAT basically relies on data of NAERLS and FDAE and does not include paddy production in dry season which started seriously from 2013 through full-scale policy support. According to the report of the Federal Ministry of Agriculture in Nigeria (Table 1, Johnson and Masias 2017), dry season rice production (from around November to May) was estimated to be about 1 million tons in the first fiscal

year of 2013. Apart from the Jigawa, Kebbi, Sokoto, Zamfara, and Kano states, the dry season cropping is also expanding in various states such as Niger, Kogi, Bauchi, Gombe and other states since 2016. In Kebbi state, this dry season production has been based on the small pump irrigation using tube well (1-2 units of pump per ha and using shallow groundwater less than 8 m) in individual farmer's sawah fields developed by farmers' self-help efforts. However in other states, majority of the irrigation schemes were implemented mainly by the government in large-scale 5000-15000ha.

According to the report of Kebbi State ADP in 2017 (Shehu and Lolo 2017) and NAERLS and FDAE (2014), annual paddy production for 2011-2012 was about 60 thousand tons only. But after 2013, the incredibly big increase in production began. It was the sum total of 190,000 tons of rainy season work in 2013, 200,000 tons in dry season, total of 390,000 tons. In dry season of 2014, it was 330,000 tons, rainy season was 190,000 tons, total 520 thousand tons. In 2015 total of dry season and rainy season was 750 thousand tons. As shown in Fig. 1, the total was 1.85 million tons (rainy season 107 thousand tons, dry season 780 thousand tons) and became No.1 paddy production state in Nigeria (Shehu and Lolo 2017, Tene 2017, Essiet 2016, Yombe 2016). It increased by more than 30 times, reaching 60,000, 390,000, 520,000, 750,000, 1.85 million tons in the four years from 2012 to 2016. The percentage of paddy production of the Kebbi state in the whole Nigeria, it was 2.3% in 2000 (Project Synergy 2004), 1.3% in 2011, 1.2% in 2012, 8.1 % in 2013, 6.7% in 2014, 20.3 % in 2016. It can be said that this is an astonishing increase in production. Although the reliability of the statistical data in the figure below needs to be verified in the future, the realization of the rice revolution by the Kebbi state is also a word in the neighboring Niger state (On October 16, 2017, Niger State Deputy Governor's remark the Kebbi Rice revolution to Dr. YS. Ademiluyi, the author of the report and the national coordinator of Sawah team of National Center for Agricultural Mechanization (NCAM) who visited the Niger state for the explanation of the sawah technology dissemination plan in Niger state).

What is noteworthy in this recent major increase in production is the promotion of the dry season work of irrigated rice fields as mentioned above. Only in Kebbi state, there are no large-scale irrigation projects led by the government like other states, but as described below, Kebbi state has used farmers' based small pump irrigation schemes. The development of the numerous irrigation systems has been done by farmers' own power. Fadama I (1993-1999), II (2004-2009), and III (2008-2019) have supported these farmers' efforts under the World Bank/African Development Bank schemes over the past 30 years. At the time Nigerian sawah team started sawah technology dissemination, more than 100,000 pumps have been installed and have been carried out by over 100,000 farmers for vegetable cultivation such as onion and irrigated rice production by micro sawah plots. From 2011 onwards, it was effectively linked to the sawah technology. After 2013, the promotion of dry season work that can avoid flooding accelerated farmers' self-help sawah field development. Meanwhile, in states other than Kebbi such as Jigawa, Sokoto, Zamfara, Kano, etc., dam based a large-scale irrigation schemes of thousands to more than tens of thousands ha was developed in each state by government project during last few decades. For example, Wurno irrigation project in Sokoto State, Bakolori irrigation project in Zamfara State, Hadeija irrigation at Jigawa, Kano rivers irrigation site, and etc.

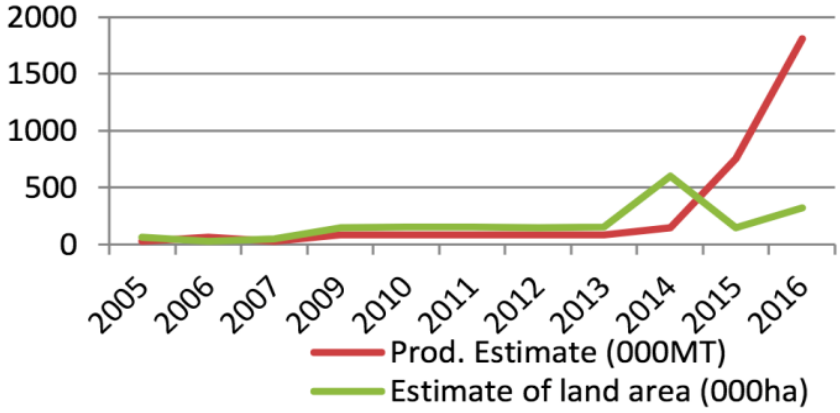

Fig. 1. Trend of Rice(Paddy) Production and Land Area in Kebbi State. Data Source: Kebbi State Agricultural Development Project (2017)

(By Bello Shehu and Abubakar Lolo, 2017, Promoting Rice Productivity in Kebbi State: Linking Data and Policy , USAID, Michigan State Univ, IFPRI, and FMARD)

- In 2013, for first time ever, we launched Dry Season farming of rice to take advantage of irrigation capacity in the North of Nigeria
- For first time ever, Federal Government provided massive support for dry season rice cultivation in 10 states(by Minister of Dr. A. Adesina)
- 267,491 farmers received 50kg seeds, two bags of 15-15 NPK and one bag Urea
- This has added an additional 1,070,364 MT of food in 2013. This is one-third of total paddy needed to be self-sufficient by 2015

State	Number of farmers	Estimated paddy production (MT)
Bauchi	5,822	23,288
Gombe	9,664	38,656
Jigawa	74,972	299,888
Kano	31,491	125,964
Kastina	3,334	13,336
Kogi	7,355	29,420
Niger	1,002	4,008
Sokoto	46,087	184,348
Zamfara	32,391	129,564
Kebbi	55,473	221,892
TOTAL	267,591	1,070,364

Table 1. Estimation of Dry season paddy production in 2013 based on the policy supports of seeds and fertilizer. Assuming one farmer can produce paddy 4t per 50kg seeds+100kg of 15-15+50kg of urea.
Data source if Federal Ministry of Agriculture and Rural Development, FMA&RD, Nigeria. Johnson M and Masias I (2017): Agricultural Policy Project, Assessing the state of the rice milling sector in Nigeria: The role of policy for growth and modernization, IFPRI Research the Future Innovation Lab for Food Security Policy, Research Paper 59, 1-35pp, Feed The Future, USAID, Michigan State University, FMARD. Data source: FMARD (2014)

As shown in Table 1, it was estimated that about 1 million tons of additional dry season paddy production mainly in the northern states of Jigawa, Kebbi, Sokoto, Zamfara, Kano during November 2013 – June 2014 (Johnson and Masias 2017). This means that Nigeria's total paddy production in 2014 was 7.8 million tons, i.e., which is the total of FAOSTAT data of 6.73 million tons (original data uses NAERLS and FDAE 2014 for wet season) plus dry season paddy production of 1.07million tons (Table 1). Although no official data has been obtained since 2015, according to an informal survey (Mapping of rice production clusters in Nigeria reported in May 2017 by GEMS 4, an international NGO supported by UKAID in the UK), it is estimated that the total amount of paddy production in the dry season and rainy season total amounted to 9.1million tons in 2016-2017 (Tene 2017, Chika 2018), which is equivalent to 5.7million tons of milled rice. Based on the 5.7 million tons of the milled rice, we re-calculated the paddy amount using milled rice/paddy rice conversion ratio, 0.625, in this paper. According to GEMS 4, Kebbi state was No.1, which produced 2.8million tons (1.6 million in wet and 1.2 million in dry season) and No.2 was Kano with 2.3 million (1.49 million in wet and 0.77million in dry season). The following state followed the third place, Kaduna, Jigawa, Taraba, Sokoto, Zamfara, Niger and the northern states were dominated.

2. Governor of Kebbi State Dakingari declared Kebbi Rice Revolution at September 2013 at the economic summit of the capital, Abuja

As shown in Fig. 2 below, in June 2010, the Nigerian Lowland Agricultural Development Project, i.e., Fadama III approved the demonstration and training to incorporate Sawah Technology as a project technology. Under the approval of the World Bank, during March 2011 - December 2012, Nigerian sawah team under National Center for Agricultural Mechanization (NCAM) and Kinki University/Shimane University team collaborated with the World Bank-supported Fadama III / ADP (State Agricultural Development Programme). The operational fund (Fig.4) was supplied through Ministry of Education, Culture, Sports, Science, and Technology (MEXT)/Japan Society for the Promotion of Science (JSPS) assisted grant-in-aid Specially Promoted Research on "Materialization of West African rice green revolution by Sawah eco-technology and the creation of African Satoyama systems, 2007-2011", which project leader was T. Wakatsuki, the author of this report.
The team demonstrated and trained Sawah Technology in 6 local government areas of Arugungu, Birinin Kebbi, Jega, Sangel, Suru, and Bagudo (Fig.3) covering major rice cultivation areas distributed in the floodplains of major rivers in the state. By the end of April 2012, the farmers' groups could develop 18 ha standard sawah systems at 18 sites at 6 local government areas, 1 ha each. They improved their traditional

The World Bank
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June 21, 2010

Mr. Bukar Tijani
National Project Coordinator
Third National Fadama Development Project
NFRA – National Fadama Coordination Office
Nafisah Plaza, Plot 502, off Constitution Avenue
Central Business Area, Abuja

Dear Mr. Tijani,

Nigeria – Third National Fadama Development Project (Cr. 4494 – UNI)
Re: Request for No Objection for the MOU on Incorporation of NCAM SAWAH Technology into Third National Fadama Development Project

We acknowledge the receipt of your email dated June 8, 2010 requesting for the Bank's no objection on the above subject matter. We have reviewed your request and based on the information provided, the Bank has no objection to the incorporation of NCAM SAWAH Technology into Third National Fadama Development project.

Sincerely,

Abimbola Adubi
Task Team Leader

Fig. 2. MOU between Nigerian Sawah Team and Fadama III for the incorporation of Sawah Technology.

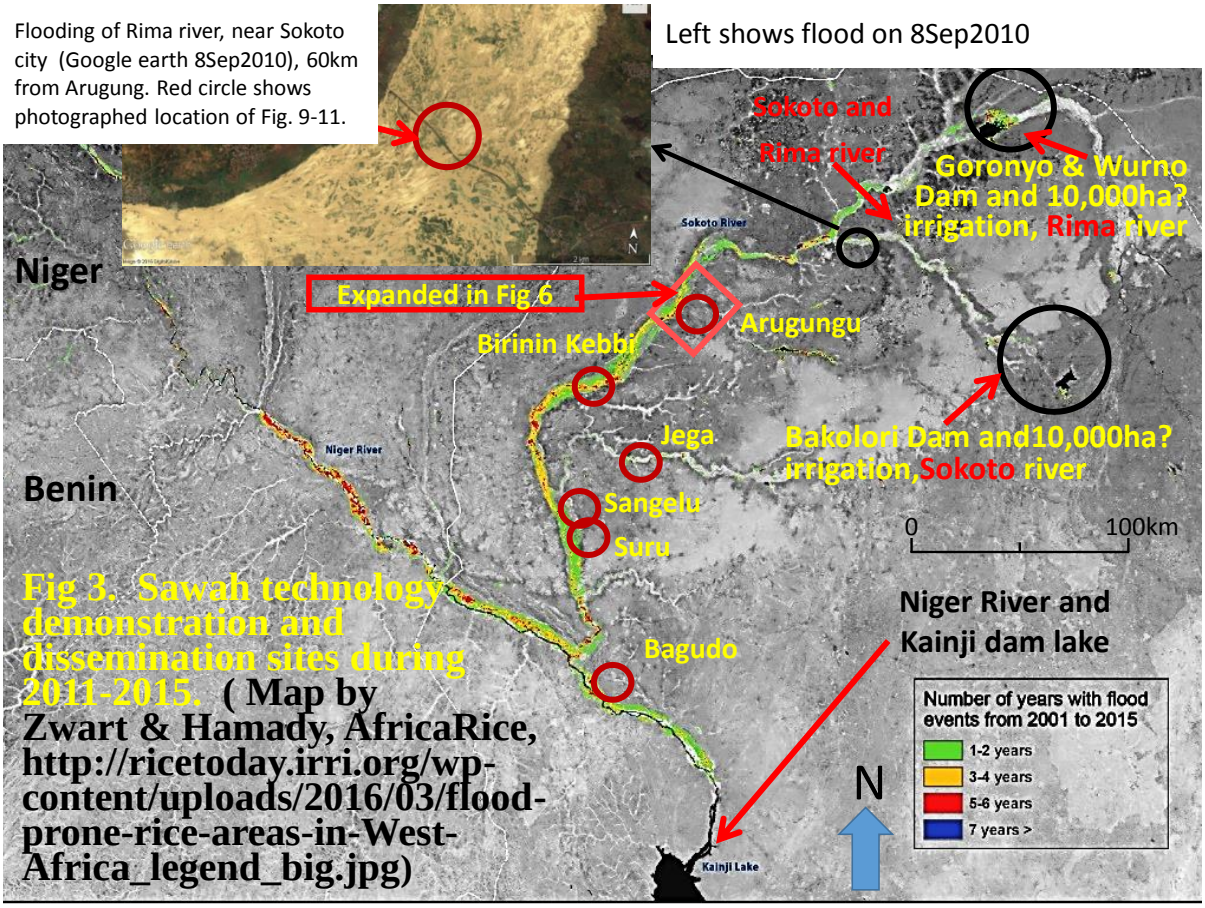


Fig 3. Sawah technology demonstration and dissemination sites during 2011-2015. (Map by Zwart & Hamady, AfricaRice, http://ricetoday.irri.org/wp-content/uploads/2016/03/flood-prone-rice-areas-in-West-Africa_legend_big.jpg)

Fig. 4. Powertillers supplied by JSPS fund for Sawah Technology training at Kebbi, Ebonyi, FCT, Benue, Delta and Lagos states during 2010-2011. ① 12 sets of Dong Feng powertiller ready to deploy to the six states at NCAM storage warehouse, ② Rotavator for cultivation, ③ Anti Skid wheel, ④ Other power tillers used for Sawah technology development, Shakiti from India and Kubota from Japan, at NCRI storage.

GROWING AGRICULTURE IN KEBBI STATE:

A PAPER PRESENTED BY THE EXECUTIVE GOVERNOR OF KEBBI STATE, HIS EXECELLENCY, ALH. SA' IDU USMAN NASAMU DAKINGARI AT THE 19TH NATIONAL ECONOMIC SUMMIT GROP (NESG) HELD IN ABUJA ON THE 4TH SEPTEMBER, 2013.

RICE REVOLUTION

- Three hundred and eighty thousand (380,000) hectares of land has been brought under rice cultivation during the wet season.
- sixty thousand hectares under irrigation.
- 150,000 farmers participating .
- Target for 2013/2014 - 500,000 farmers
- The State has a large number of vibrant registered cooperative rice farming associations
- The State was able to obtain the highest national yield of 7.6tonnes per hectare in the year 2010 under the SAWAH/FADAMA programme using power tillers and proper agricultural practices.

Fig. 5. Governor of Kebbi State, Dakingari, declared the Kebbi Rice Revolution at the Economic Summit at Abuja, Nigeria, 4th of September, 2013

FADAMA III PROJECT:

- Kebbi State Government in collaboration with the World Bank implemented the Fadama I & II and is presently implementing the third National Fadama Development Project.
- The Programmes provided wash bores, tube wells, water pumps; small earth dams, Fadama access roads, rural market infrastructures, and other needs as required by the communities,
- 45,000 farmers benefited
- disbursement - N1.7bn

CONCLUSION

In conclusion our collective effort to date has resulted in;

- Making agriculture more attractive to the youth,
- Reducing unemployment and restiveness among the youth,
- increasing food production, providing food security, wealth creation and reducing poverty
- Increase in hecterage under cultivation to 45% from 35% during the wet season and 35% from 20% in the dry season.
- Dry season rice production increased to about 170,000 metric tons
- Wet season rice production is estimated at about 760,000 metric tons.

Micro rudimentary sawah plots to the standards sawah plots and got 128 tons (average paddy yield 7.1 t/ha against traditional paddy yield of 1.5-2.5 t/ha). The results of technology transfer and dissemination in Kebbi state are shown in Table 4. Governor of Kebbi, in September 2013, at the economic summit of the capital Abuja, called the result Kebbi Rice Revolution (Fig. 5, Dakingari 2013).

The Governor also reported that Kebbi state cultivated rainy season rice 380,000 ha in 2013 - 14 and got 700 thousand tons of paddy and also announced an estimate of 170 thousand tons of paddy production in the dry season work (from around October to July). It is slightly different from the data shown in Fig. 1, because it crosses the year, and there is a possibility of over estimation, because it is a political presentation at Abuja, Nigeria. But it is estimated that there was innovation and popularization to farmers. Revolutionary production technique might expand for rice cultivation in Kebbi state during 2013-2015 as shown in the Fig. 1. The first 18 ha demonstration and training during the 2010 to 2012 were the contribution by the Nigerian Sawah team, but after purchasing 20 numbers of powertillers at farmers' own expense and expanded the dry season sawah based rice cultivation to 199 ha by the end of May 2014, realizing production of 1260 tons (6.3 t/ha) of rice which were shown in Table 4. Those were done almost all by self-help efforts of the farmer group and the Kebbi state Fadama III/ADP.

With the above results, the Kebbi state government purchased 1000 tillers and started a farmers' self-help sawah improvement project of more than 10,000 hectares from May 2015. Aapart from the state government, purchasing of powertillers by rural farmers themselves and sawah system improvement and development have also been expanded. In November 2012 and June 2014, the Nigeria Sawah team investigated the progress of sawah system development on the flood plains. In July 2015, the team made advanced sawah technology training using Mold board Plow of KHS Co., Ltd. of Indonesia (Kubota), G1000 Boxer with Puddler and Leveler with cage wheels (Cage Wheel) for muddy wetlands to promote the farmers' self-powered sawah system development (Various photographs shown later in this supplement).

The figure attached on the left side of the upper part of the Fig. 3 is a picture of Google Earth on September 8, 2010, showing how the Rima River was flooding near the city of Sokoto. The city is located at the junction of the Rima and the Sokoto River (Fig. 3). Shallow flooding spreads throughout the flood plain with a width of 2-3 km. Normally the flooding period is July to September, and flooding may continue for a few months in some cases as shown in Fig. 9 below in 30 years ago at Birinin Kebbi area, which rice growing sites were investigated by T. Wakatsuki in 1987. Deep water rice cultivation had been carried out in 30 years ago as shown in the nearby picture of ③ in Fig. 9. But such deep and long flooding hardly occur in recent times. The floods usually continues for several weeks due to the numerous dams built upstream in Sokoto, Zamfara, Katsina state. However, some flooding caused by destruction of poorly managed dams and water discharge also occurs. There are no flood control banks, but flooding beyond the floodplain rarely occurs. As shown in Fig. 3, the areas where flooding became a problem in the period of 2001-2015 were the floodplains of the Niger River from Birinin Kebbi and Bagudo to Benin, but even such mild floods the occasions will be less than once in 7 years in majority of the entire floodplains in the Kebbi state (Zwart et al. 2016, Fig. 3). Also, unlike Asia, the destructive power of flooding is not pronounced. Thus sawah systems developed on the floodplains are not subject to major damage.

Numerous small-scale small pump irrigated sawah plots developed by farmers on their own in the floodplains of Kebbi state are easy to repair and recover from flooding damages. Because it is irrigation with 1-2 pumps per hectare of sawah plots, there is no long irrigation and drainage canals. Repair of the bunding systems will be the major works, which can be done by farmers' personal works. Changes in height differences of sawah plots due to siltation by flooding are not a big problem in the pump irrigation system. In the gravity irrigation, however, the height difference of the sawah plots becomes big problem which relate to the adjustment work on both irrigation and drainage canal. All of these works need community works which is not easy in majority of Sub Saharan Africa (SSA). The problem is the fuel cost due to pump irrigation. However, relatively higher soil fertility and the easiness of water management in sawah plots by pump irrigation in flood plains give higher paddy yields by 2-3tons/ha than the yield in the gravity irrigation system in the small inland valleys. Since the cost of pump irrigation is usually 150-200 dollars/ha, it is possible to recover with an increment of 0.5 tons of paddy, which increase the additional selling price of 100-200 dollars.

i **Partnership for Innovative activities:** About thirty identified innovative activities were introduced into the project implementation across the States through partnerships. These activities increase the level of benefits to FCAs/FUGs, enhance the achievement of the PDO and also ensure sustainability of sub-projects. These innovative activities can be categorized as collaboration/partnership and sole initiatives. Such collaborations are with research institutes, donors, regional bodies, agro firms, and other units within the World Bank, etc. The sole efforts include bio-gas production, improved use of ICT services, …

Fig. 6. Document of The World Bank Report No: ICR00003895, IMPLEMENTATION COMPLETION AND RESULTS REPORT (IDA-44940IDA-52930 IDA-58490). ON A CREDIT IN THE AMOUNT OF SDR 153.4 MILLION (US$ 250 MILLION EQUIVALENT) TO THE FEDERAL REPUBLIC OF NIGERIA FOR A THIRD NATIONAL FADAMA DEVELOPMENT (FADAMA III) PROJECT, November 2nd, 2016, http://documents.worldbank.org/curated/en/956751479735474649/text/FADAMA-III-ICR-P096572-Nov-2-2016-11162016.txt

… Region VPU Award in 2013. The project also collaborated with National Center for Agricultural Mechanization (NCAM)/Kinki University, Japan in 2010, on Sawah Ecotechnology for Rice Farming (SERIF) in five pilot States of Benue (North Central), Delta (South South), Ebonyi (South East), Kebbi (North West), Lagos (South West) as well as FCT. Results obtained from the demonstration sites was very positive and it indicated that it is possible to have paddy yield increase of 6.5t/ha and 7.2t/ha as witnessed in the demonstration sites in Ebonyi and Kebbi States respectively, against traditional paddy yield of 1.5-2.5t/ha. The adoption by farmers increased yield of rice in states.

10

In the past 20 years in Kebbi state, the Fadama development project I (1993 - 2002), II (2003 - 2010), III (2010 - 2019) have been supported by the World Bank. The very characteristics of these Fadama projects are the style of their irrigation, which is not a large dam based but shallow groundwater based using less than 8 m depth in flood plains and of the inland Delta. Shallow ground waters have been used for irrigation by hundreds of thousands of farmers' individually with a small pump (1-2 units per hectare, 250-500 dollars per unit) of tens of hundreds of thousands. Paddy and onion cultivation are common. If avoiding the flooding season-July to September, shallow groundwater (usually less than 8 m) can be used by small pumped for irrigation during October to July, double cropping in a year.

It can be said that this Fadama style irrigated farming method and our sawah technology could be docked in good timing (World Bank 2016, Fig. 6 above). Sawah Technology, which had been targeting small inland valleys originally, has been able to develop floodplains and inland deltas by practicing in Keebi state (Wakatsuki 2009). It was Bida of Niger State that started the first on-farm research on irrigated sawah system development by farmers self-help efforts under the IITA's Wetland Research project in 1986 (IITA 1986, 1987, Wakatsuki 1989, 1997). But in terms of state wide development it was far behind Kebbi state. However, in the demonstration and training of sawah technology during 2011-2015 at various villages in Kebbi state, Nupe farmers of original sawah technology on farm research site at Bida (Ejeti and Shese Bikun villages etc.) have been working together with NCAM's Sawah staffs. Bida sawah farmers had contributed to the transfer the sawah technology to Kebbi farmers. Conversely, Bida sawah farmers were trained on the well digging technique for dry season pump irrigation by the farmers in Kebbi state. By this, Bida began rice farming in dry season in 2014, but stayed only limited to few village. Thus state-wide dissemination has not been realized so far in Niger state.

The reason for this difference partly come from the fact that the integration of Hausa rice farmers and Fulbe nomads had realized long years ago in Kebbi State, but in Niger state the ethnical division of Nupa rice farmers and Fulbe is still large. In Kebbi state, cooperation of the royal family, the Fadama staffs, ADP (agricultural development project), farmers' association has been wonderful. Although the political power is held by Fulbe, Gwari and Hausa, majority of rice farmers are Nupe people who have little access to such political power

(funds) in Niger state. For this reason, there is a movement aimed at independence as Nupe state from the Niger state. The cooperation between Nupe rice farmers and the state government is not so good. Noteworthy in Kebbi province is not only the farmers' group, but also that Fadama III and ADP, under the state agriculture ministry, and traditional chiefs were all very enthusiastic to promote rice production. As a fact of supporting it, the staying expenses etc. of the Japanese and NCAM sawah staffs who carried out such sawah technology demonstrations and training were spent by Kebbi state budget. All the salary and accommodation expenses of the powertiller operators who accompanied Nupe villages at Bida were spent by the Kebbi state or private rice farmers. The will of Kebbi state for self-help effort was very clear.

As shown in Fig. 6, the World Bank evaluates the technical evaluation of Sawah Technology in 2016 in the implementation completion report of the Fadama III project "Evaluate the results of demonstrations and training in six provinces that represent the six geographical zones of Nigeria, and Sawah Eco-Technology has made it possible to increase yield from 1.5-2.5 t / ha up to 6.6 - 7.2 / ha at the farmers' level. According to our observations, only Kebbi province was able to disseminate this technology to farmer level out of the six states. In the other five states, such as FCT, Benue, Kwara, Ebonyi, Delta and Lagos states which carried out similar training at the same time, the positive intention toward self-help efforts shows less clearly in action. Thus there have been no serious endogenous efforts observed so far. In Lagos State and FCT there are few professional rice farmers, in Delta and Benue states the demonstration sites were destroyed by flooding. The training and demonstration progresses relatively smoothly in Ebonyi province, but the operations in all other states were not smooth, and the results to be seen have not been obtained so far.

3. Rice cultivation before the introduction of Sawah technology in the flood plains of Kebbi State: Field observation in 1987 and 2011

Fig. 7 is the enlarged view of the main road crossing the floodplain near Arugungu City in the Fig. 3. The first survey by Wakatsuki had done on December 14-16, 1987, which is as a part of the guidance of doctoral research at IITA (Oyediran 1990).

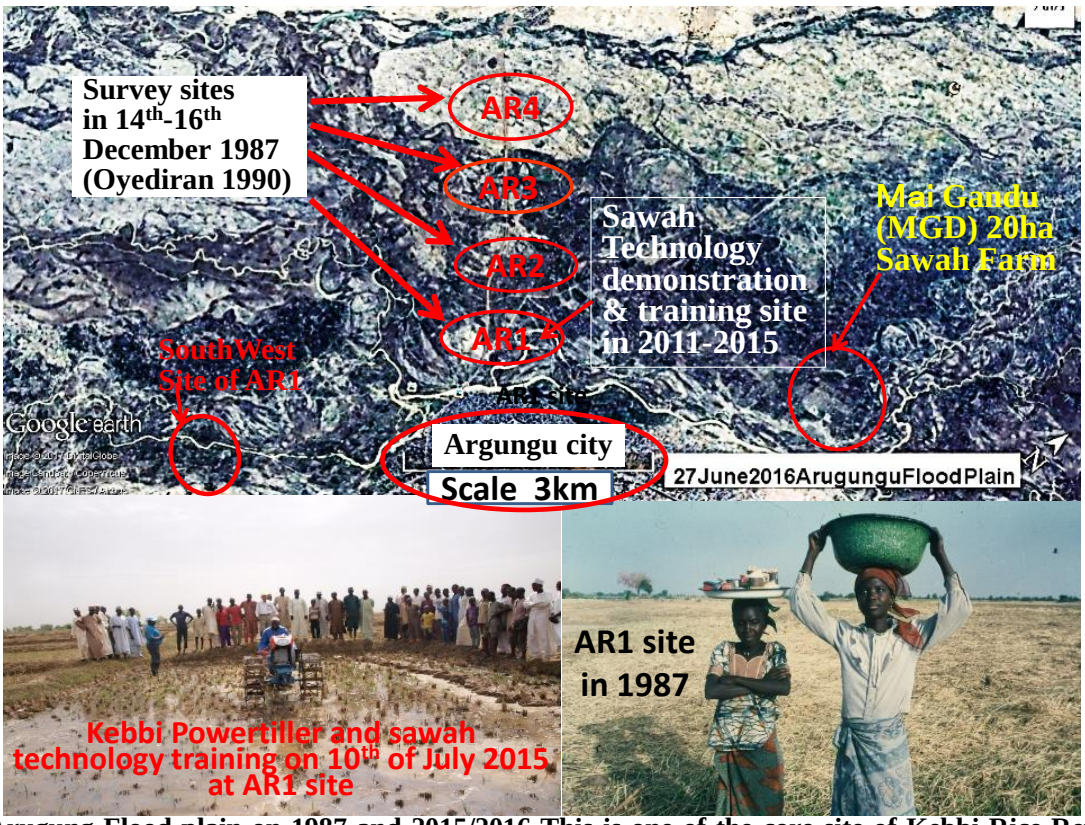


Fig. 7. Arugung Flood plain on 1987 and 2015/2016 This is one of the core site of Kebbi Rice Revolution through the evolution of Sawah System plat form by sawah technology operated by Arugungu farmers.

The area around Arugungu city has been the center of rice cultivation in Kebbi state since and still now. The Fishing Festival has been also carried out in this nearby floodplain since at that time and till now. At that time, African rice (*Oryza Glaberrima)* had been widely cultivated on non sawah fields as shown in the picture on the bottom right of Fig. 8. In March and October 2011, Wakatsuki made field survey trips on the training and demonstration of Sawah Technology.

3-1. Non-sawah rice farming on Arugungu flood plain in 30 years ago, 1987

① Photo from the bridge, which is crossing the Rima river, just outside of Arugungu town, to the direction of AR1 to AR4, ②&③ Two picture were taken in the vicinity of AR3 site in the Figure 6 during 14-16th of December, 1987

Fig. 8. Overview of Arugungu flood plain from on the bridge from Arugungu town heading toword AR1-AR4 sites(See Fig. 7) during the survey of December 1987. The road traversing the flood plain was nearly the same position as the current road in Fig. 7. You can see the Rima River in the dry season on the right side of the ① photo, which was taken from inside the car. The lower two are near AR 3. African rice and wild rice were grown. Mr. GB Oyediran (now Prof. LAUTEC University) is investigating.

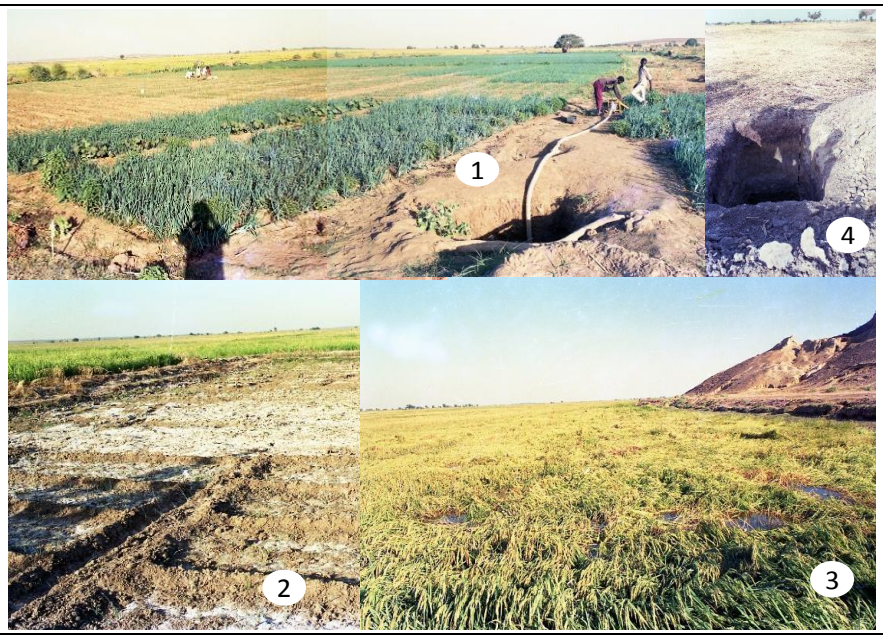


Fig. 9. Photo continued in 1987.
Upper left ① is an hand made well and pump irrigation to micro plots of onions along the Rima river in the east of AR1. This seems to be the origin of micro sawah plots. African rice cultivation on non sawah fields in the far distance. The lower left ② is the accumulation of salt on the topsoil of the onion irrigated plots. Upper right ④ is a flood plain soil profile near AR1 and non sawah paddy cultivation of African rice. Bottom right ③ Cultivation deepwater rice near Birinin Kebbi.

3-2. Rudimentary Micro-Sawah based rice cultivation in Kebbi state just before the training of the Sawah Technology, 2011

Fig. 10-15 show the rice farming of the Rima river flood plain from Sokoto to Birinin Kebbi and Jega on the Zamfara river flood plain. These survey was done just before the start of Sawah Technology training and deployment on May 2011, which was 24 years after the survey in 1987. When Wakatsuki re-examined in May 2011, as shown in Fig. 10 and 14, rice and onions were cultivated in micro rudimentary sawah plots using small pumps lifted shallow ground water shallower than 8 m. The total area on the Rima river floodplain

between Arugungu-Birinin Kebbi was estimated to be more than tens of thousands of hectares. Fig. 10 and 11 were taken on early May 2011 at the road crossing the flood plain near Sokoto and the red circle at the center of the bridge (the red circle in the pasted photo on top of Fig. 7). Groundwater is sucked up from a shallow well by a small pump and irrigated in micro sawah plots to cultivate rice, tomato and onion. Because it is an extension of upland irrigation, both bunds and canals were poor. Since leveling and puddling were also insufficient. It can not control flooding depth, weed and nutrient management are difficult. The water use efficiency was very low. It was estimated that the average yield was 2.5 t / ha or less (Fig. 6, World Bank report) at this micro rudimentary sawah plots stage.

The left photo is the expansion of the red circled area above. Irrigation water is pumping up and suppying using horse to the central canal of the micro rudimentary sawah.

Fig. 10. Micro rudimentary sawah plots with shallow tube well and small pump irrigation along the road crossing both Rima and Sokot river floodplains(see Fig. 3). Both bund and canal are poor. Photographed on May 2011 at the A position of Fig. 3

Fig. 11. Rice cultivated in micro rudimentary sawah plots, the opposite side of the road in Fig. 10 (Photo was at the B position). Attention should be paid to a human who bends to the upper right (red circle).

Dry season vegetable cultivation in inland valley bottom by manual irrigation, Burkina Faso, 1987

Fig. 12. Rice planted on the ridge with pump irrigation. Just next plot of the Fig. 10. The photo on the right is a small section of a typical irrigation vegetable field in West Africa.

Fig. 13. Photos of Fig. 10 and 12 were taken at the A position and Fig.11 was taken at the B position of the Google earth on 2015 above. Please note our field survey and photographs were done on 2011.

Fig. 11 shows rice cultivated in micro sawah plots, the opposite side of the road in Fig. 10 (Fig. 12 B position). Attention should be paid to a human who bends to the upper right (red circle). The size of one micro sawah plot is about 15 - 30 m^2 (See Fig 13, which maker length is 90m in left Google photo and 50 m in the right). It is very similar to the micro sawah plots in the early Yayoi era, ca2500 years ago, in Japan. Fig. 12 shows rice planted on the ridge with pump irrigation. This type of rice cultivation has been also common till now at Sokoto flood plains, which can be seen at the C position of the Fig. 13 below. The photo on the right is a small section of a typical irrigation for vegetable cultivation in West Africa. The micro sawah plots irrigation might have been on the extension line of such upland field crop irrigation (Furukawa 2011). Fig. 13 shows the Google earth photo on 2015. Please note our field survey had done .on 2011. As described in this report, Kebbi state had similar rice farming before 2011 but has evolved rapidly to the standard sawah system during 2011-2016. But Sokoto state has been no such evolutionary change during 2011-2015 as seen in recent Google earth photographs.

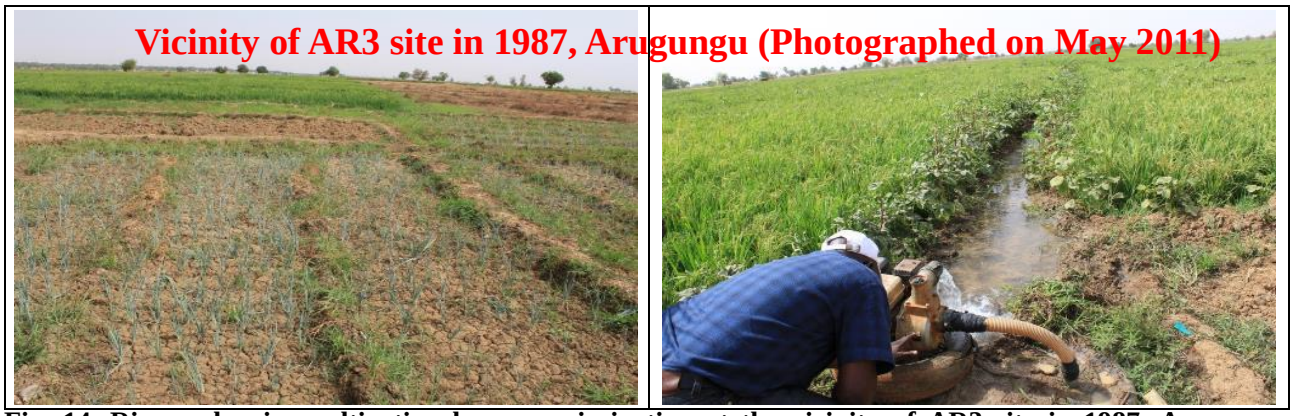


Fig. 14. Rice and onion cultivation by pump irrigation at the vicinity of AR3 site in 1987, Arugungu. Photographs were taken on May 2011.

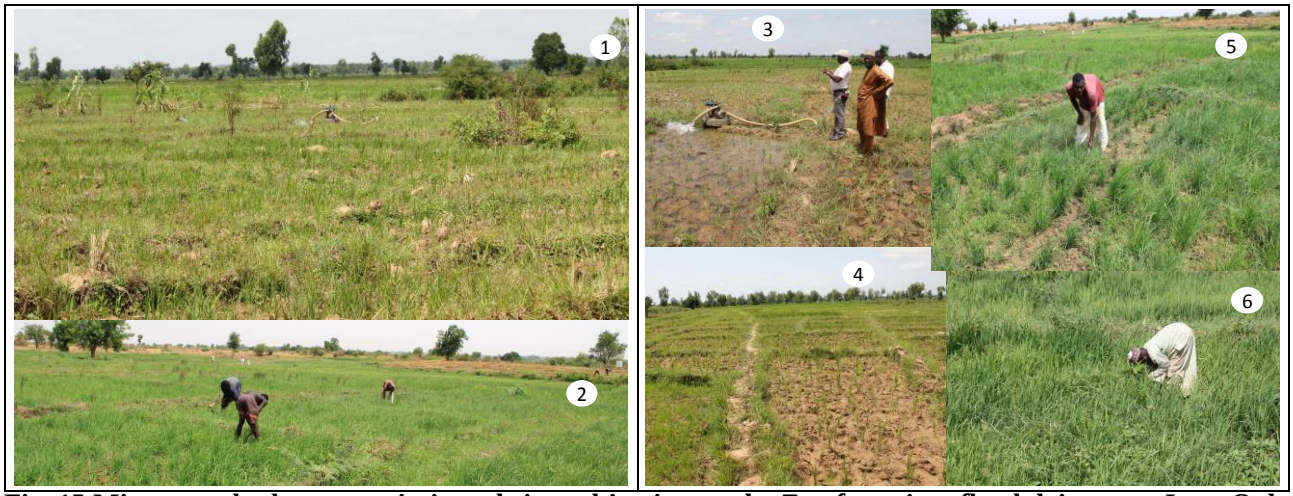


Fig. 15 Micro sawah plots pump irrigated rice cultivation on the Zamfara river floodplains near Jega. Only the ⑥photo was taken from the flood plain at Birinin Kebbi area. Photos were taken on May or Sep, 2011.

Fig. 14 shows rice and onion cultivation by pump irrigation at the vicinity of AR3 site in 1987, Arugungu. These photographs were taken on May 2011. Rice and onion were cultivating in micro sawah plots and or elongated section with a width of 1-2 m and a length of ten and several meters. These field condition were similar to those of the Sokoto flood plain as shown in Fig. 10-13. Fig. 15 shows poor rice cultivation under micro sawah plots at Zamfara river flood plain where is just a few km south from Jega town. As shown in the photographs even under pump irrigation, the growth of weeds is fast and the growth of rice is poor due to rudimentary sawah stage, it is difficult to manage water and weeds. Even under Birinin Kebbi's local government-developed irrigated rice field, which is shown as B photograph in the Fig. 15, we see very poor weed management. All photographs were taken on early May 2011, just before the sawah technology training and demonstration.

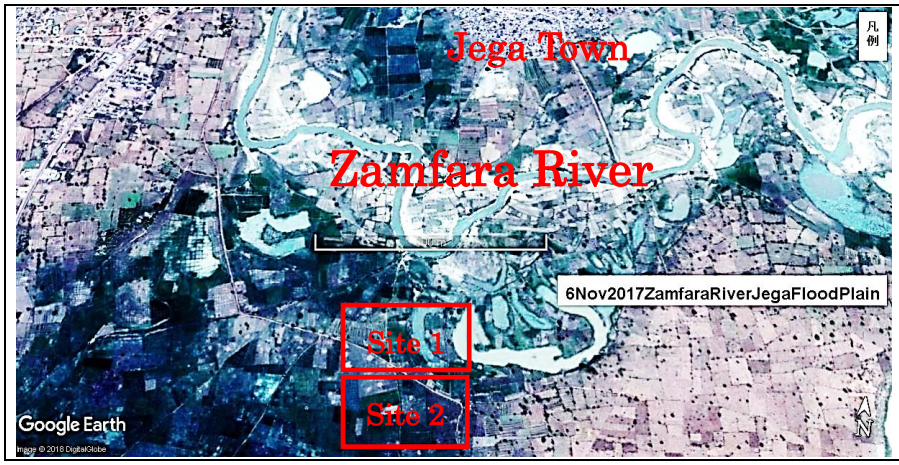


Fig. 16. Zamfara river flood plain. Length of the scale marker is 800m. The sawah technology training and demonstration were done at the site 1 and site 2, which are described later in the section 6 during March 2011 to December 2012. Following 6 Google earth photographs during 2003-2017 are the expanded image of the site 1 area to show how farmers' rice fields platform had changed before sawah technology and after sawah technology.

Fig. 17. Expansion of the site 1 in the Fig. 16. The length of the scale marker is 50m. The shooting dates of the same site 1 are 5th April, 2003 for A, 8th October 2007 for B, 28th of December 2011 for C, 22nd January 2014 for D, 3rd July 2016 for E, and 6th November 2017 for F, respectively. Around 1ha section surrounded by red by a red line is a sawah technology demonstration place in March-December 2011.

Fig. 16 shows the Zamfara river flood plain near Jega city. Length of the scale marker is 800m. The sawah technology training and demonstration were done at the site 1 and 2, which are described later in the section 6, during March 2011 to December 2012. Following 6 Google earth photographs during 2003-2017 are the expanded image of the site 1 area to show how farmers' rice fields platform had changed by sawah technology. As show in the Fig. 17C, about 1 ha section surrounded by a red line is a place where training and demonstration of Sawah Technology was carried out in March - December 2011. We created standard sawah system platform by farmer's own power and trained sawah based rice production both in rainy season and dry season.

The following can be read from the time sequence images of Google earth from 2003 to 2017 shown in Fig. 17A to F. In the Fig. 17A, a part of the flow of the stream of the Zamfara River is visible in the upper right of the figure. In the image of 2003, Fig. 17A, there were no traces of the lines showing the sections of agricultural land use artificially drawn on farmland like sawah plots in this area of the floodplain. In the image of 2007, Fig. 17B, however, micro sawah plots of 10 - 40 m^2, one section 3-6 m length, were to be seen. As shown in the 2011 image, Fig. 17B, we can see the standard sawah plots were developed almost entirely except for some depressions and river beds. This change was resulted by our Sawah technology training, which had been carried out in March-December 2011. In the image of 2014, Fig. 17D, we can clearly identified that sawah system platforms have completed in almost everywhere. Each sawah plot has leveled well, enlarged, and enclosed by reinforced bunds. On the other hand, in the image of July 2016, Fig. 17E, it is understood that some sawah plots developed in the depressed part of the flood plain were submerged. However, as can be seen in the image of November 2017, Fig. 17F, except for the riverbed part at the upper right, the improved sawah platform developed by farmers were not damaged or rebuilt and it can be seen that sawah based rice production is being carried out sustainably.

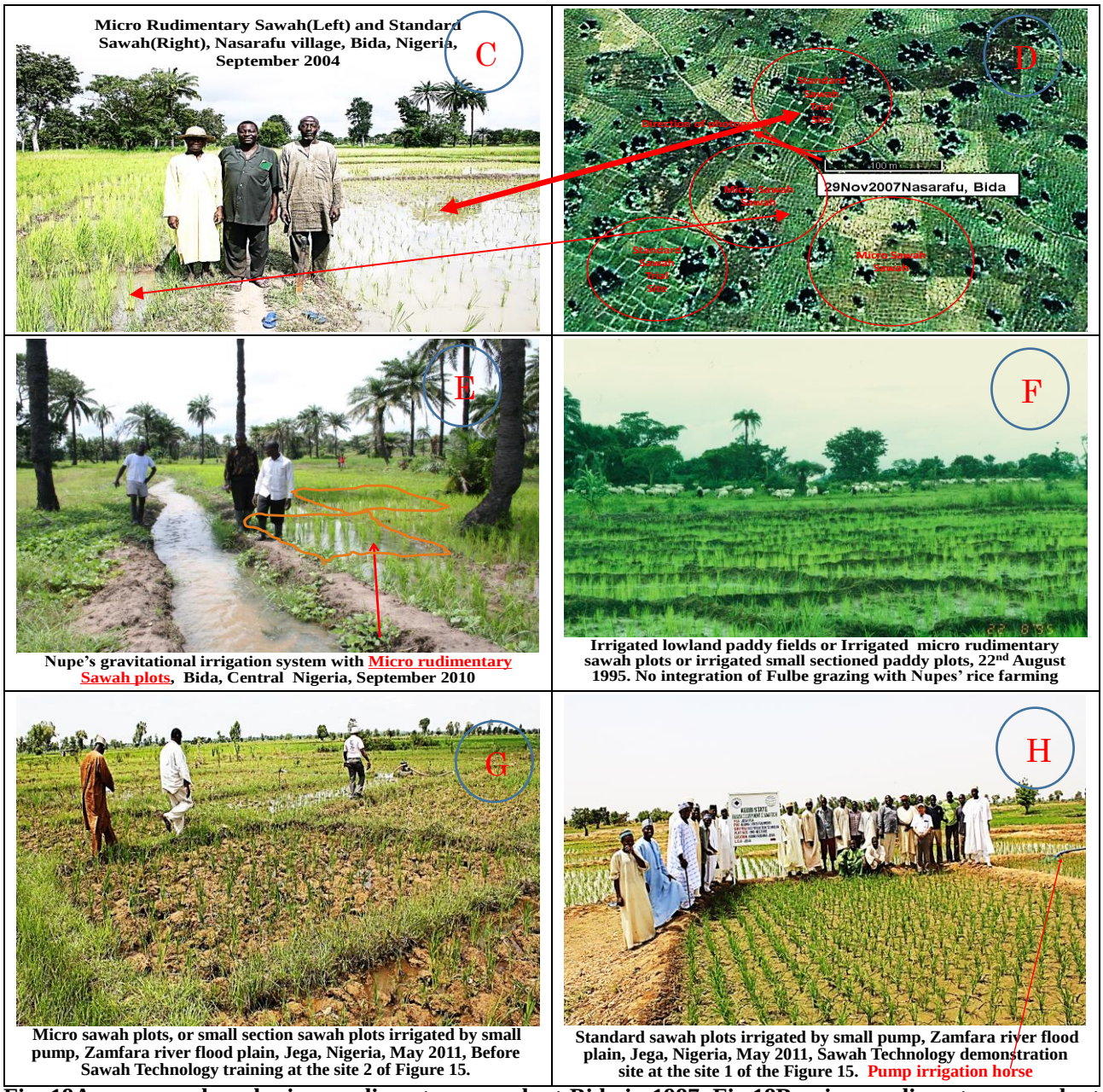
(Note) Fig. 18A-H: Tentative definition: ①Micro-rudimentary sawah plot(field), ②Small-section sawah plot(field), ③Standard sawah plot(field), and ④Paddy field(plot)

The right side of the Fig. 18A shows micro rudimentary sawah plot fields. The left side is non sawah rice field. Fig. 18A is also paddy fields. Fig. 17B, left side of the Fig. 17C, Fig. 17E and F are also micro rudimentary sawah plot field. The right side of the Fig. 18C and Fig. 18H are the standard sawah plot fields. Although there is no particularly clear criterion for the sawah plot's size, if the size of one sawah plot is usually 50 m^2 or less, we define tentatively micro sawah or small section sawah. If sawah plot bunds are weak and small so as to make impossible human to walk on the bund without any damage of water control of the sawah plot, we use the adjective "rudimentary", thus ①micro rudimentary sawah. However, if strong and big enough to allow easy walk, we use ②small section sawah plot. The ③standard sawah plots have following characteristics. The plots have irrigation and drainage facility and the size are normally larger than 50 m^2. The surrounded bunds are strong, big and compacted to make possible easy walk and to prevent water leaking. Each sawah plot surface soil is puddled (normally) and leveled within 10cm height difference in a plot.

All of these rice fields of ①-④ we can be described as paddy field. Thus as long as if we use the term "Paddy fields", we cannot distinct the different characteristics of rice fields described above, i.e., ①-④. Thus the term of "Paddy" can not be defined scientifically at least in SSA.

(Left)Non Sawah rice cultivation (Right)Micro rudimentary sawah (Bida, 1987)

Irrigated Micro rudimentary sawah system, Sokoto, Nigeria, May 2011



Nupe's gravitational irrigation system with Micro rudimentary Sawah plots, Bida, Central Nigeria, September 2010

Irrigated lowland paddy fields or Irrigated micro rudimentary sawah plots or irrigated small sectioned paddy plots, 22nd August 1995. No integration of Fulbe grazing with Nupes' rice farming

Micro sawah plots, or small section sawah plots irrigated by small pump, Zamfara river flood plain, Jega, Nigeria, May 2011, Before Sawah Technology training at the site 2 of Figure 15.

Standard sawah plots irrigated by small pump, Zamfara river flood plain, Jega, Nigeria, May 2011, Sawah Technology demonstration site at the site 1 of the Figure 15. Pump irrigation horse

Fig. 18A, non-sawah and micro rudimentary sawah at Bida in 1987, Fig.18B, micro rudimentary sawah at Sokoto in 2011, Fig.18C, micro rudimentary and standard sawah at Nasarafu village, Bida 2004, Fig.18D, Google earth on 2007 at Nasarafu village, Bida, Fig.18E, Shabamaliki village irrigation canal and micro rudimentary sawah, Bida, Fig.18F, micro rudimentary sawah and Fulani nomad at Gadza village, Bida, in 1995, Fig.18G, micro or small section sawah, Jega, in September 2011, Fig.18H, standard sawah demonstration site at Jega, Site 1, May 2011.

4. Demonstration and training of Sawah Technology by NCAM Sawah team during 2011 to 2015

Based on the agreement of Fadama III in June 2010 and Nigerian Sawah team of National Center for Agricultural Mechanization (NCAM) and the JSPS's research project of Kinki University (Fig. 2, 4 and 6), Kebbi, Ebonyi, and Benue states began activities from February - March 2011. The other three states, FCT (Federal Capital Territory), Lagos, and Delta Stated had been started activities in 2010. Nigeria Sawah Team was divided into 4 groups to cover these six states for training and demonstration. Mr. Joshua Aliyu who is Nupe and fluent in Hausa language led the operation at Kebbi state. Mr. Suleman from Ejeti village (the first sawah village established in 2001) at Bida joined Mr. Joshua's operation at Kebbi. Since good powertiller

operator like Mr. Sleiman can also instructs farmers the layout and development of Sawah system, who becomes an important key person for the sawah technology transfer from farmers to farmers. Incidentally, Mr. Suleiman has been employed by Kebbi farmers' association since the first operation in 2011 to till now in 2018. He has been living in villages throughout the state of Kebbi and has been directing sawah technology operation.

The outline of the on-the-job training and demonstration of the Sawah technology conducted at Kebbi state during 2011-2015 is shown in Fig. 19-24 below. Details are shown in Sawah Technology (4): Practices and Potential of Irrigated Sawah System Development and Sawah Based Rice Farming by Farmers' Self-help Efforts.

Firstly, during March 2011-December 12, we set up six demonstration sites of 100 x 100 m at 2 places total of 12 ha in three local government areas of major rice centers of Arugungu, Birinin Kebbi and Jega as shown in Table 2. NCAM/Kinki university sawah team lead by Prof. T Wakastuki, Dr. YS Ademiluyi and Mr. J Aliyu developed a standard quality irrigated sawah system demonstration plot and sawah based rice farming through on-the-job training of ADP and Fadama III staffs as well as rice farmers' association members.

The photo on the top of the Fig 19① shows one of the demonstration plot at the site 1 at Jega shown in Fig. 16. Fig. 19② shows shallow tube well, pump and suction and extension horses for irrigation at the same site. These are taken on May 2011. Fig. 19③ and ④ were filmed in July 2015 at Arugungu's AR1 site (Fig. 7).

Fig. 20 show some leveling operations to get standard height difference, i.e., <±5cm in one plot of sawah. When the height difference of one sawah section is within 10 cm, we make rice seedlings of standard plant height of about 15 cm, which is normally within three weeks after germination, can be transplanted to the whole one section of sawah plot. In the case of SRI (System Rice Intensification) farming method and direct sowing cultivation, it is necessary to further increase the degree of leveling to within 5 cm height difference in one sawah plot. ① shows powertiller and wooden board method for leveling (The Photo was taken on 2002 in Biemso No.1 village of Ghana). ②Wooden board for powertiller levelling. ③Manual leveling by wooden leveler(Photo at Bida) and iron rake(④ at Jega). Powertiller attached leveler operation at Arugungu (June 2015).

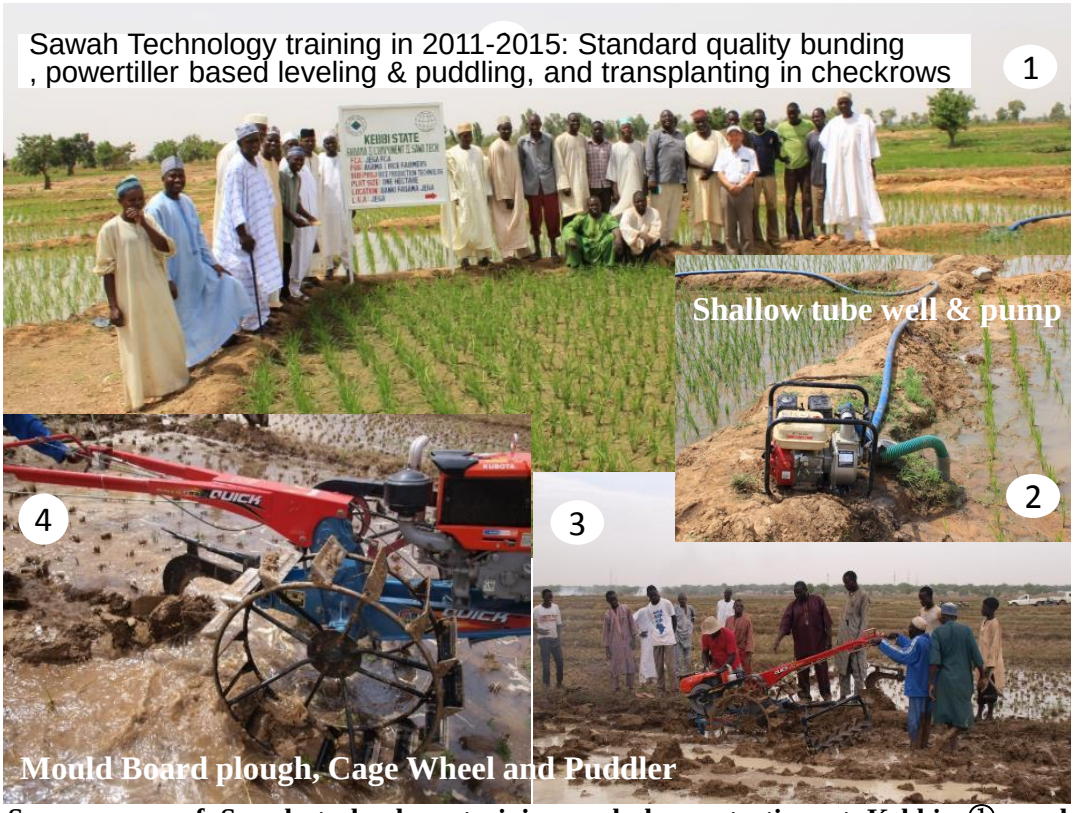


Fig. 19. Some scenes of Sawah technology training and demonstration at Kebbi. ① and ② are demonstration plots at Jega site 1, May 2011. ③ and ④ are advanced sawah technology training using KHS Indonesia's Quick G 1000Bower power tillers (8.5Hp and 11 Hp equipped with Kubota engine) attached a mould board plough, puddler, leveler and cage wheel, at AR1 site, Arugungu, on July 2015.

Fig. 20. Leveling operations to get standard height difference, i.e., <±5cm in one plot of sawah. ① and ② powertiller and wooden board (①is taken in 2002 in Biemso No.1 village of Ghana. Manual leveling by wooden leveler(③ at Bida) and iron rake(④ at Jega). Powertiller attached leveler operation at Arugungu (June 2015).

Fig. 21. Advanced Sawah Technology training using mould board plough, leveler, and pddler attached to powertiller for ① and ④ bunding, ② and ③ soil moving, and ③ and ④ canal cutting.

Fig. 21 shows the new training contents of sawah technology using plows and levelers attached to the powertiller conducted in 2015-2017. As a result, the work efficiency of leveling, bunding, and irrigation and drainage canal construction were improved. Thus the sawah technology was upgraded. ① and ④ are supplementary works for bunding using plows and cutting of canals. The powertiller work efficiency improves by combining with manpower of African hoe or cutlass's works. ② and ③ show how to use the leveler to move the soil (②) for leveling of relatively larger sawah plot, it is possible to move the soil even at a distance of about 10 - 20 m). ③ shows the moving the liquefied soil of 50-100 m by using soil liquefaction (Thixotropy) using properly prepared canals. With these tasks it is possible to create a relatively large, long bund and waterway. It will be a substitute for heavy machinery such as bulldozers and backhoes, and promote farmer's own irrigation sawah development.

Leveling quality is very important but manual leveling is hard work. The power tiller based leveling has work efficiency equivalent to 30 to 40 manpower. The labor cost per day is about 3-5 dollars (500-1500 Nigerian naira in 2013-2017), so the labor cost of 30-40 man power will be around 100-200 dollars and the rent of the tiller will be around $ 50/day, so mechanization like a powertiller is advantageous and be realized even in the current economic situation in Nigeria.

Fig. 22. The site of advanced sawah technology training on 8th-12th of July 2016 at the AR1 site of Arugungu. The ① photo was taken from the direction of 1 of the red arrow and the ② photo from the 2 direction. Google earth is 27th of June, 2016.

Fig. 22 shows the place of advanced training and demonstration of sawah technology using Indonesian KHS Quick G 1000Bower power tillers (8.5Hp and 11 Hp equipped with Kubota engine) attached with a mould board plough, puddler, leveler and cage wheel, at AR1 site, Arugungu, on July 2015. It is carried out in the vicinity of the "T" area of the Google Earth in 2016 as shown above. The ① photo was taken from the direction of 1 of the red arrow and the ② photo from the 2 direction. The position of the AR1 site is shown in Fig. 7.

Fig. 23 shows pictures of the new skills of the sawah technology practices at the AR1 site of the Arugungu flood plain on July 2015. ① Power tiller attached with standard cage wheel for wetter, deeper and ultra wetter soil. Please compare the Anti Skid wheel for drier soil condition (Fig. 4 and ③ of Fig. 31, Dong Feng, made in China). ② Pump irrigation from shallow pipe well in front. ③ Work by leveler after substitution. ④ Commemorative photo shoot.

Please compare the Fig. 7(1987) and Fig. 22/23(2015 and 2016). These are the same AR1 site. In the vicinity of AR1 site there was no sawah fields in 1987.During 2011-2015 these area have covered with standards sawah system everywhere developed by farmers' self-help efforts.

Fig. 23. Advanced sawah technology training on 8th-12th of July 2016 at Arugungu. ① power tiller attached with standard cage wheel. ② small pump is irrigating suctioning shallower ground water, <8m, through pipe well. ③ memorial photo after quick puddling and leveling. ④ Leveler operation.

Fig. 24. Advanced sawah technology training on 8th-12th of July 2016 and the way of powertiller deployment at Kebbi. ①KHS power tiller packed on pick up track. Puddler, leveler and cage wheel are packed, too. ② and ③ motor bike can transport heavy Dong Feng, 15HP, powertiller at any small villages in Kebbi. ④ Plowing operation by mould board plough by KHS G1000 boxer.

Fig. 24 shows the continuation of pictures in training in 2015. ① Transporting the tiller on the pickup truck bed. The tooth like equipment of the comb of the loading platform is a leveler, the equipment with the rotating teeth is a puddler. This tiller was sold by KHS company in Indonesia using KUBOTA's engine. ② Transport the powertiller made by Dong Feng in China by motorcycle and cart under the project of Kebbi state. ③ Dong Feng rotavator of tiller. ④ Plowing operation by mould board plough by Indonesian KHS G1000 boxer at AR1. Before 2015, we had been used rotavator like ③ in Fig. 24(also see the Fig.4). Rotavator was good for cultivation of the sawah plots that was already developed, but it was found that Mould board plough (see ④ of Fig.19) is more suitable for new sawah system development. The operation performance of Indonesia's 8.5 horse power tiller, G1000Boxwer of 297kg weight, with a cage wheel was better than the heavy Chinese 15 horse power tiller, Dong Feng of 570kg weight. The G1000Boxer did not sink even in deep wetlands. So it performed better in wetland condition. New skills for canal digging and bunding using powertiller plow as well as puddling, leveling and soil movement using powertiller puddler are very important new skills for Sawah technology.

5. Sawah Technology training and demonstration in 2011-2015 on the Rima River floodplain near Arugungu

As already mentioned and as shown in Fig. 10-14, innumerable irrigated micro rudimentary sawah systems using shallow tube well and small pump for onion and rice cultivation had been developed by individual farmers in the flood plain of this area by 2011. This irrigation system was evaluated as the most successful irrigation system in Nigeria under the Fadama project with the support of the World Bank, Nigeria, the Government of Kebbi State. It is estimated that the whole Kebbi state had developed about 30,000 ha. However, until the sawah technology became popular, the rice yield remained at the level of 1.5-2.5 t / ha (Fig. 5 in World Bank report in 2016, Fig. 4 by the state governor's, Dakingari, report in 2013).

5-1. Training in the vicinity of AR1 site on the main road crossing the Rima River close to Arugungu city

As shown in the picture of ① in Fig. 25, we accessed the site set up near A after crossing flooded wetland of B in Fig. 26A, B, C with boat. In this picture you can see the bridge and main road appeared in the Fig. 26 A, B, and C. ②-④ show the demonstration sawah plots. Healthy seedlings were transplanted in lines. Bunds were strengthened and each sawah plots was puddled and leveled using power tiller. A pump that pumps shallow groundwater from the PVC pipe can be seen at the foot of the person shown in the photo of ④ in Fig. 18. These 4 pictures were taken at the end of September 2011. Before the training of Sawah Technology in 2011, onion and rice cultivation had been done in pump irrigated micro rudimentray sawahs as shown in Fig. 14 and 10 as well as ① and ② of Fig. 9.

Fig. 25. Sawah Technology demonstration at AR1 site of Arugungu in 2011. ①The bridge, road and the wetlands are shown in Fig. 26 of Google earth images. ②-④ are demonstration site and on the job training site which is the A position in the Fig. 26B and C. The wetland is the B positon and the bridge is the D position in the Fig. 26B and D.

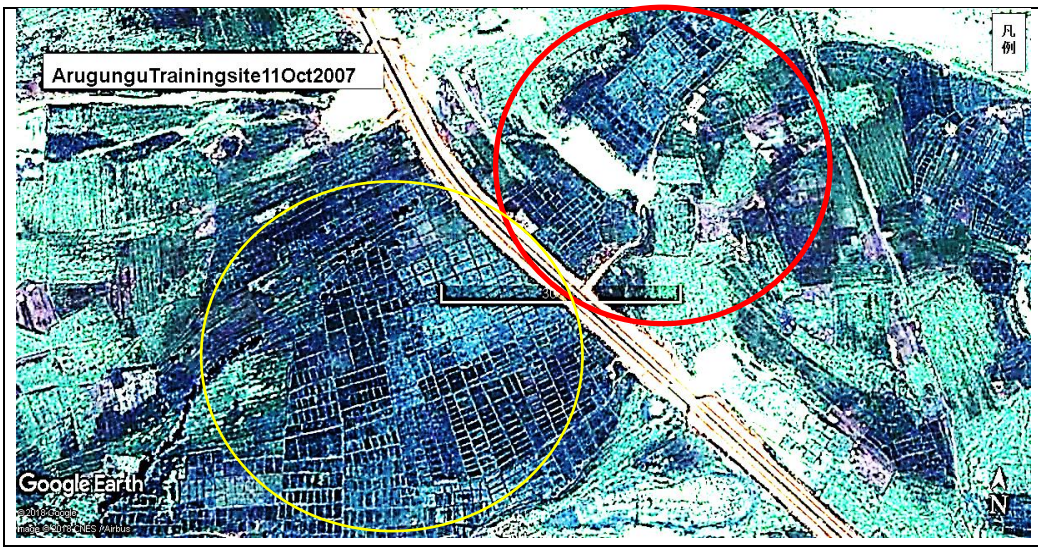


Fig.26A. Google earth on 2007 before sawah technology at Arugungu AR1 Site.
Red circled area was used for sawah technology training and demonstration in 2011. Yellow circled area is Arugungu Emir's rice field equipped with sawah system. All the other areas have no standards sawah systems in 2007.

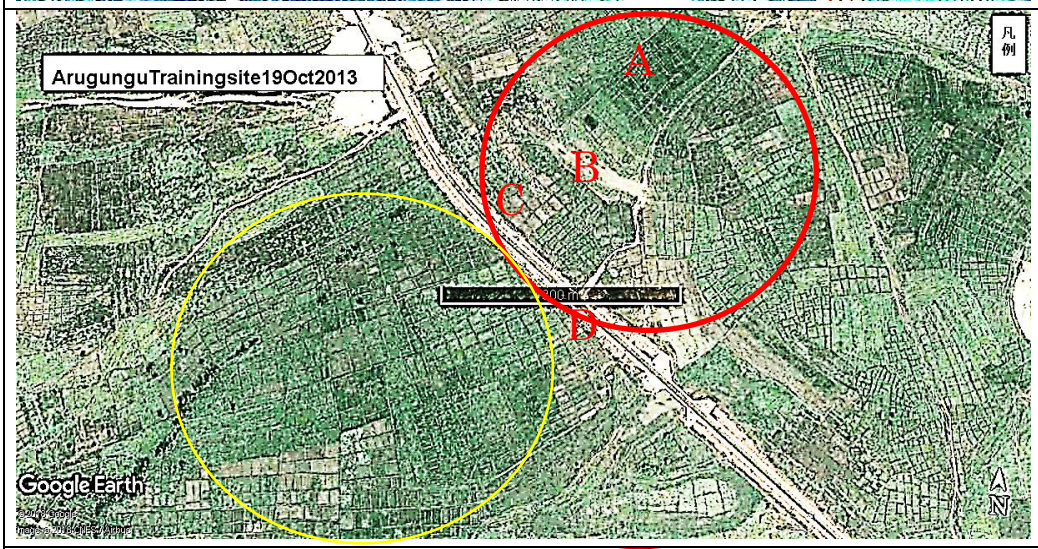


Fig. 26B. The position A shows demonstration plot in 2011. B is wet depression. C shows the position used new sawah technology training in 2015. D shows the bridge position. The marker length in center is 300m. Total area of the photographed is about 90ha. Not only the Emir farm, other areas were covered with sawah in 2013.

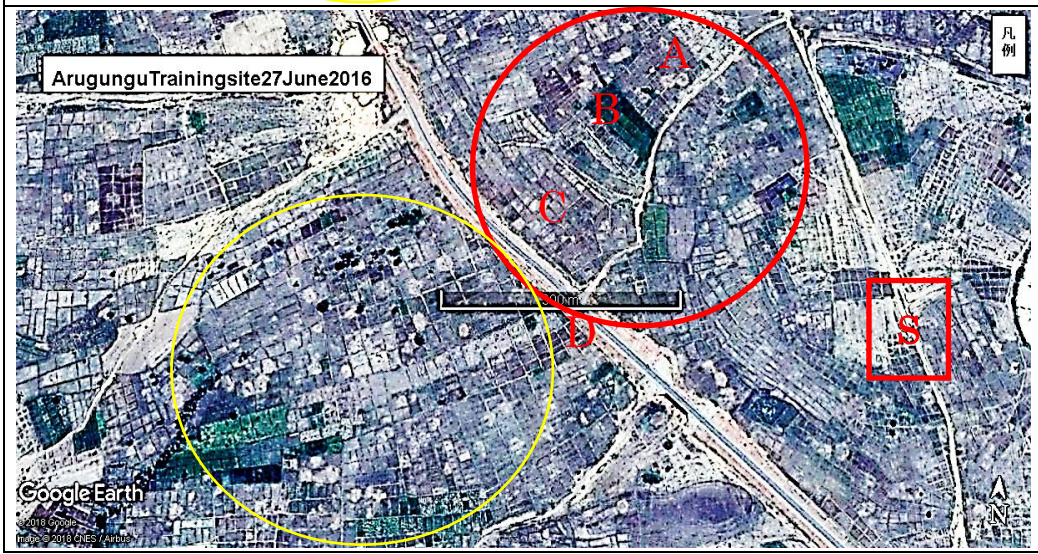


Fig. 26C. Almost 100% of the flood plains are covered with standards sawah systems in 2016. This is the essential difference of the Sokoto flood plains as shown later.
At the C position Nigerian sawah team conducted advanced sawah technology training in 2015.

5-2. Maigandu farm, 2009-2017

The position of Mr. Maigandu's rice paddy fields in the Arugungu floodplain is shown in Fig. 7. This field seems to be a typical place of Kebbi Rice Revolution which has been realized through the co-evolution of appropriate level of mechanization and the development as well as the improvement of sawah system platform.

These make possible the synergistic effect of improvement of yield and expansion of acreage area. Fig. 27 is a picture of May 2014. ① is a large reception room of Mr. Maigandu's house. He began rice farming after retiring as officials of Ministry of Agriculture in Kebbi state. He has 150 ha of farmland in the flood plain which inherited as heritage. Currently he is one of the leaders of the rice farmers' association in Kebbi state and is in a position to be able to advice rice development promotion to the governor. In order to reach his farm we tried to use the muddy farm road which entered the flood plain from the AR 1 position, but as shown in the picture in Fig. 27② the car was stuck in a muddy point within hundreds of meters drive from the AR1 position. Since there was no choice, as shown in pictures ③ and ④ of Fig. 27, we crossed the Rima river by boat, which is very close to the town of Arugungu. Since the farm is very close from the town, powertiller was disassembled and carried by boat, assembled on the farm and used.

Fig. 27. ① Dr. Ademiluyi and Mr. Aliyu at the reception room of Mr. Maigandu Arugungu, ② Pickup truck was stuck in a muddy road of the flood plain, which location is at the S of the Fig. 26C. ③ and ④ show the Rima river. Maigandu farm can only reach using the stuck road of ② or crossing the river by boat.

Fig. 28 upper shows the Google Earth image taken on November 2009, before sawah technology training. The area surrounded by larger red circle, which is about 20ha, is the Mangadu Farm. The location of the farm is shown in Fig.7. As shown in the figure, although the platform level of Maigandu's farm even in 2009 was clearly higher than surrounding rice fields, i.e., each sawah plot is small, but rectilinearly organized, still somewhat similar to the level of micro sawah plots in surrounding area. Average area of sawah plots of the Maigandu farm was about 77 m^2 in 2009 as showin in Table 2 below. As of 2009, except for the Maigandu farm, most of the rice fields in the Fig. 28 were non sawah rice fields. Only less than 10% were micro rudimentary sawah plots as shown in Fig. 30①-⑤.

Fig. 28 below is a Google Earth image taken on June 2016 at the same place of the Fig. 28 above. The white scale marker line is 500 m, the total area of this picture is about 150 ha. The development and improvement of sawah system platform by sawah technology conducted in 2011 - 2012 is clear. The quantitative evaluation by sawah technology is shown in Fig. 29A, B, C, D, and E. Not only Maigandu farm but also most of surrounding rice farms in this photographed areas have also improved to the level of standard sawah plots as shown in Fig. 30①-⑤. The sawah platform improvement are still on-going both in the Maigandu and surrounding farms.

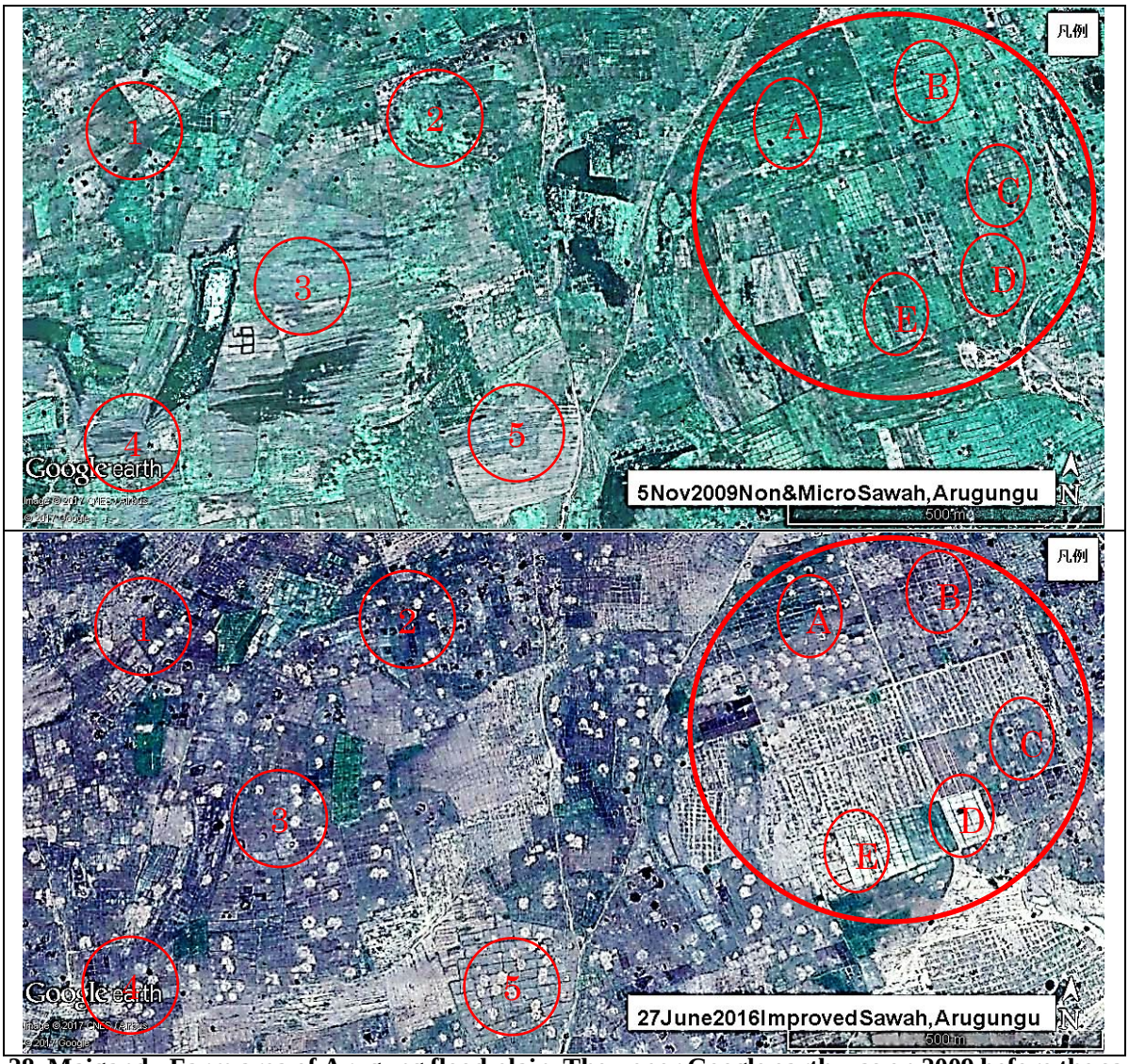


Fig. 28. Maigandu Farm area of Arugung flood plain. The upper Google earth was on 2009 before the sawah technology training, the lower was taken on 2016 after the training. Length of scale maker is 500m, total photographed area is about 150ha. The area surrounded by lager red line is the core part of Mangadu Farm and it is about 20ha. In order to quantify the sawah plots improvement during 2010-2017, the 5 smaller red circle areas, A-E, were enlarged in Fig. 29 below. Another 5 areas outside the farm, ①-⑤ were also enlarged in Fig. 30

The five points of ABCDE in Fig. 28 were sampled, enlarged and compared between 2009 and 2016/2017, which are shown in Fig. 29ABCDE and Table 2. The mean number of sawah plots in the mean area of 1.16ha in 2009 was 152 and the average area was 77 m^2. In 2016/2017, sawah plot number was reduced to 46 and the average area was 270 m^2.

Table 2 Comparison of sawah plot size between 2009 and 2016/2017 in Maigandu farm

Sampling site	Compared area (m2)	Plot No in 2009	Plot size (m2)	Plot No in 2016/2017	Plot size (m2)
A	10587	156	68	38	278
B	12632	130	97	31	407
C	12602	147	86	56	225
D	9600	131	73	40	240
E	12503	198	63	67	187
Mean	11584.8	152.4	77.4	46.4	267.4

By sawah technology using powertiller, the average area of sawah plot was expanded 3.5 fold. Bund and leveling quality have improved too (although can not show quantitatively). The utilization efficiency of pumped water has improved as shown in Table 3. In addition, the pump irrigation becomes inevitable to appropriate intermittent irrigation, and thus the mechanism similar to SRI (System Rice Intensification) is operate to improve nutrient supply such as nitrogen. As a result, the puddle yield 1.5-2.5 t / ha before Sawah technology introduction doubled to 6 t / ha or more (Table 4).

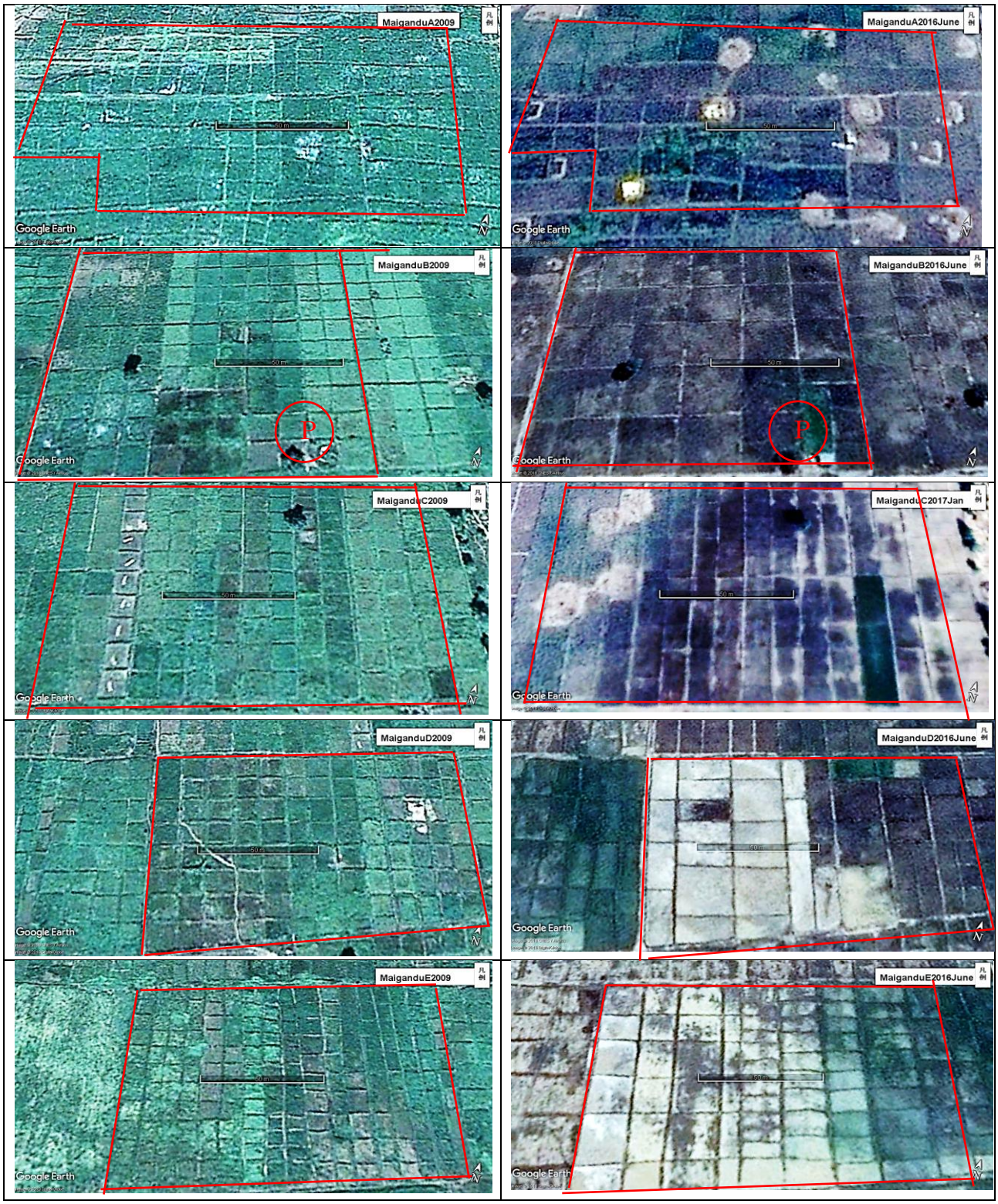
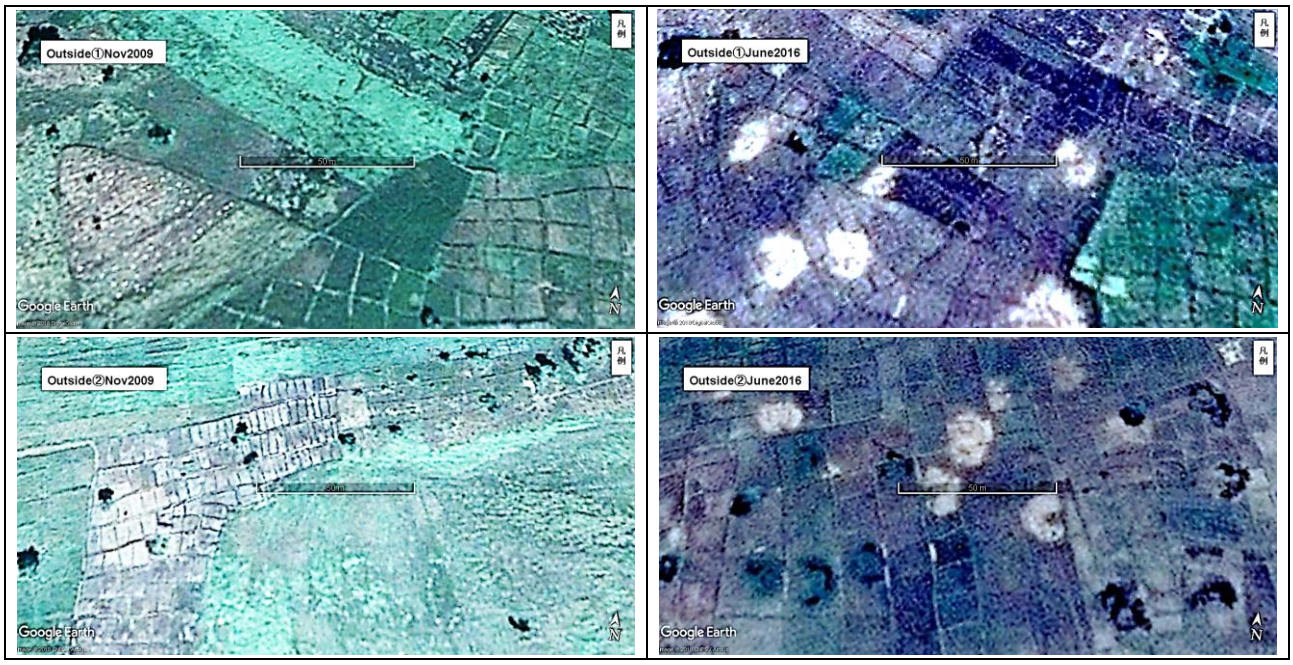


Fig. 29ABCDEF. Google earth 2009 and 2016/2017 showing the enlarged 5 sampling points, A, B, C, D, and E of Maigandu Farm. Each Point has about 1ha. Detailed data are shown in Table 2.

Fig. 30. Maigandu farm. Photographed location is the P of the Fig. 29B

The sawah area, paddy production and paddy yield are shown in Table 4, at the top of line, which is described as Arugungu, MGD (Maigandu) farm. Maigandu farm shown in Fig. 30 is one of the typical sites of sawah technology training and demonstration, which triggered the Kebbi rice revolution. ① showed the made in China, Dong Feng, powertiller we used for training during 2011-2012. This is 15 horsepower with anti-skid wheel instead of cage wheels. ② shows shallow tube well and small pump. The sawah plots are ready for harvest in dry season rice. ③ The whole view of the Maigandu farm. Mr. Onche (2014), the reporter of Daily Independent described as follows, "At Arugungu, the result of rice cultivation was clearly obvious. Mr. Maigandu is a professional rice farmer and co-ordinator of the rice outgrower scheme of GAWA Seed Company. He said that he can give you these stockpile of about 10,000 bags of paddy everyday for the next two months. He stated that the local rice production business attained dramatic level of profitability in the last two years and attributed this to the competent and scientific leadership of Dr. Akinwumi Adesina". Mr. Daniel (2016), the reporter of The Nation described the contributing technology as Sawah Technology.



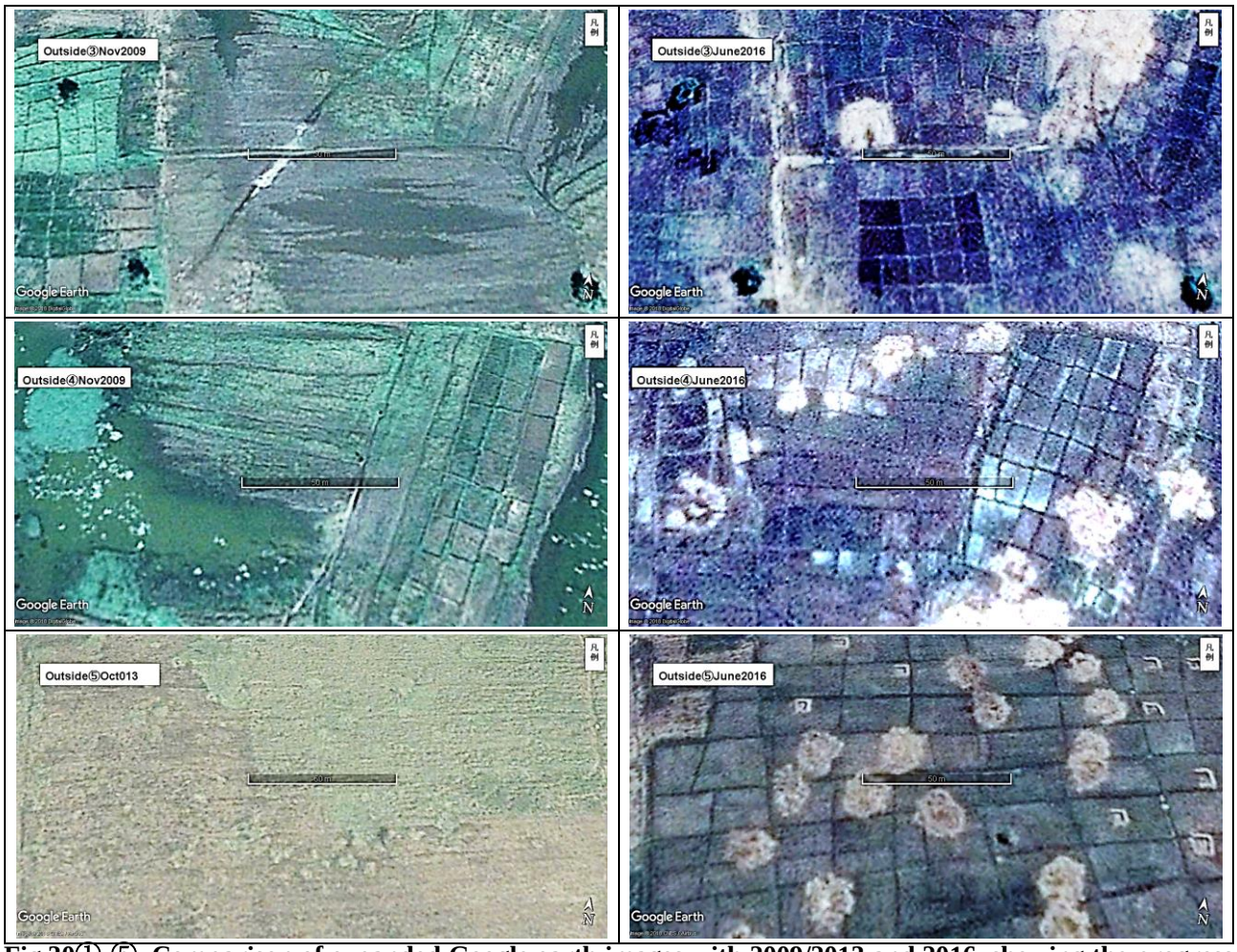


Fig.30①-⑤. Comparison of expanded Google earth images with 2009/2013 and 2016, showing the progress of sawah system development at ①-⑤ areas, outside of the Maigandu farm in Fig.28. Each pointed area has about 1ha, 10000m^2.

As shown in (1) - (5) in Fig. 30, sawah system development and improvement have been rapidly progressed between 2009 and 2016 even around the Maigandu farm. The length of the central marker is 50 m, and the area of each Google earth image is about 2 ha. The position of ①-⑤ is the western part of the Maigandu farm shown in Fig. 28. At the point of ①, as of 2009, 40% had a standard(?) sawah plots, but in 2016 standard sawah plots had covered the whole area. The micro rudimentary sawah plots of about 15% can be seen in the ② area in 2009, but in 2016 everywhere is covered with sawah plots. In ③ and ④ in 2009, standard(?) sawah plots occupied about 25% area, but in 2016 sawah plot occupied 100%. In ⑤ area, there were no sawah plots until 2013, but in 2016, sawah plots occupied 100% of the site.

Table 3 summarizes the merits of improvement of the quality and area of sawah plots through the improvement and strengthening of bunds, and improving leveling quality of sawah soil surface.
(1) By increasing the size of the sawah plot surrounded by a straight line, the work efficiency of agricultural machinery such as a powertillers machine is improved. In the future, when expanding the use of tractors etc., it is necessary to further improved high-standard sawah platforms. Agricultural mechanization and sawah platform co-evolve.
(2) Reinforcement of the bunds, improvement of sawah fields, appropriate puddling will increase the efficiency of pumping water, so we can reduce the fuel cost required for paddy production. Since the pump usage time can be reduced, maintenance and management costs and renewal costs of the pump can be reduced.
(3) Since water management in sawah rice fields can be improved, soil management and weed management are improved, and fertilizer utilization efficiency is increased. Therefore, we can use excellent varieties more effectively, and we can also use excellent agronomic techniques such as System rice intensification (SRI) farming method effectively. Since the groundwater level is shallower than 8 m, sufficient irrigated rice

production is possible with such a simple suction type pump. In addition, it is inevitably intermittent irrigation, which is similar to SRI style water management. The intermittent irrigation had been practiced by the bets rice farmer in Japanese No.1 competition during 1950-70 (Honya 1989). Thus nitrogen use efficiency also increased.

(4) In Kebbi state, integration of Hausa farmers and Fulbe nomads has been progressing. The use of cow dung in combination with chemical fertilizer has been common especially for onion cultivation. Thus both Fadama/ADP staff and farmers in Kebbi state had sufficiently high agronomic understanding and skills,

(5) All those factors above ①-④ contributed to realize the specially high yield. These will make sustainable productivity even higher through the further improvement of ①-④ practices.

Table 3. Improvement of Pumping Water Use Efficiency by Sawah Plots Improvement*

	Before	After
1. No. of Pump necessary per ha using 3 inches discharge pipe 600 liter / min	400-500 $/ha (2 sets/ha)	400-500 $/ha (2 sets/ha)
2. Operational time per day: 8 am to 4 pm	Same	Same
3. No. of times used per week**	> 2-3	2
4. Fuel consumption: 5 liters per pump	> 50 $/month	50 $/month
5. Fuel need per 3 months for Faro 44	> 150 $/3months	150 $/3months
6. Fuel need per 4 months for Faro 52(Wita 4)	> 200 $/4months	200 $/4months
7. Pump management: oil and service		50-70 $/season
8. Pump durability**	< 5-10 years	5-10 years

* Water pump data were collected during 2011-2012 training and demonstration.

** In addition to the expansion of sawah plots size, reinforcement, compaction and sealing of bunds as well as leveling and proper pudding of sawah plots improved water use efficiency compared to micro rudimentary sawah and ridge rice cultivation. Because of improve the water use efficiency, the durability of pumps is improved.

Table 4. Training, Demonstration and Extension of Sawah Technology in 6 Rice Centers, Kebbi State during March 2011 to May 2014

1. Kinki University/NCAM/Fadama III Demonstration and Training, March 2011-April 2012

Local Government	Farmers	Powertillers No. supplied	Total Sawah developed (ha)	No. of 100kg Paddy bag	Paddy yield (ton/ha)
Arugungu*	Shared	2 shared	6.5	487.5	7.5
Birinin Kebbi*	Shared	2 shared	3.5	227.5	6.5
Jega*	Shared	2 shared	8	560	7
Total		shared	18	1275	7.1**

***The six sites are shown in Figure 3. Although we monitored the extension progress, no yield data were obtained**

****Mean**

2. Endogenous Extension, April 2012-October 2013 3. Dry season, Nov. 2013-May 2014

	Farmers	No. of powertiller bought	Sawah area developed (ha)	No. of 100kg paddy bag	Paddy yield (ton/ha)	No. of powertiller bought	sawah area developed (ha)	No. of 100kg Paddy bags	Paddy yield (ton/ha)
Arugungu*	MGD farm*	2	15	975	6.5	2	20	1400	7
	JUM farm	1	10	650	6.5	1	10	650	6.5
	ABK farm	1	4	260	6.5	1	8	480	6
	AK farm	1	3	180	6	1	6	360	6
	AMB farm	1	4	240	6	1	5	300	6
	Dr YA farm	1	4	240	6	1	5	300	6
	ANL farm	1	3	180	6	1	5	325	6.5
	AMI farm	1	6	390	6	1	10	650	6.5
	ASD farm	1	5	300	6	1	5	300	6
Birnin Kebbi*	ABA farm*	1	4	260	6.5	1	4	—	—
	BB farm	1	3	180	6	1	6	360	6
	AS farm	1	3	180	6	1	6	360	6
Bagudo*	ABB farm*	5	35	2450	7	5	50	3500	7
Jega*	HHJ farm*	1	7	455	6.5	1	14	910	6.5
	AUA farm	1	20	1200	6	1	40	2400	6
Suru*	Dr.UD farm	1	5	300	6	1	5	300	6
Total		22	131	8440	6.4**	22	199	12595	6.3**

6. Training and Demonstration in the Zamfara river floodplain, south of the Jega Town

The operation of dissemination of sawah technology at MGD (Maigandu) farm in Arugung is shown in 5-2. Table 2 summarizes the results of three phases of sawah technology training and demonstration in Kebbi state through 2011-2014, i.e., (1) Arugungu, Birinin Kebbi, and Jega during March 2011-April 2012, two power tillers supplice and 18 ha sawah plots, (2) In addition to Arugungu, Birinin Kebbi, and Jega, Bagudo, Sangelu and Suru show endogenous extension during April 2012-October 2013, 22 powertillers bought by farmers and 131 ha sawah plots, and (3) Dry season sawah based rice farming during November 2013-May 2014, 199 ha

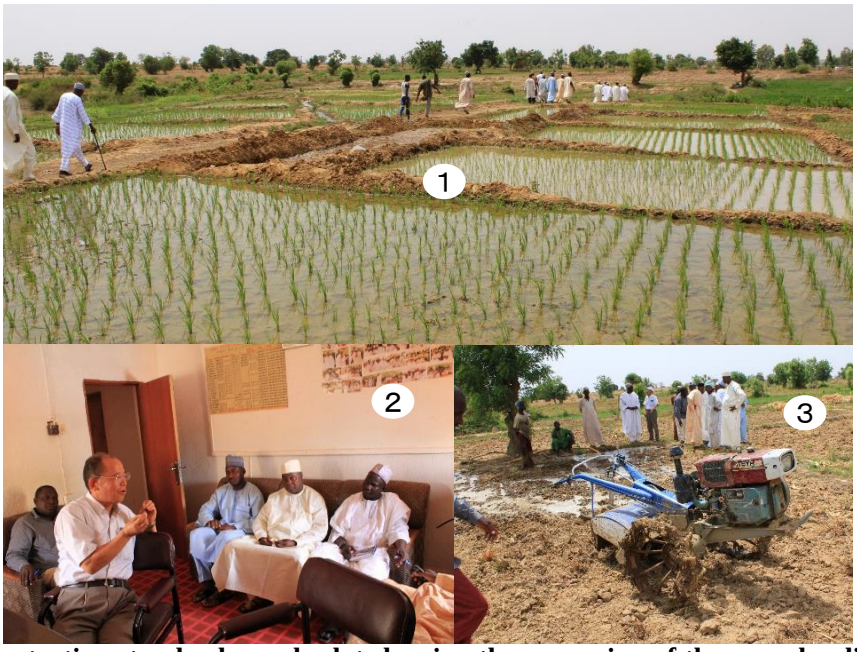


Fig. 31a. ①Demonstration standard sawah plot showing the expansion of the area, leveling, strengthening of bunds, and line planting of healthy seedlings. The photo location is the site 1 of the Fig. 16. ② Meeting based on the memorandum of understanding between NCAM/JSPS(Japan Society for Promotion of Science) project of Kinki University and the World Bank/Fadama III/ADP. ③ Granted power tiller and training. Photographs were taken on March-October 2011. (Some data are shown in Table 4).

Fig. 31b. Training and dissemination of March-October 2011 (continuation of Fig. 31a). ①② Jega's demonstration site. ② SAWA TECH is a misspelling of SAWAH TECH. ③ One of the demonstration sites transplanted by Jega at the end of April 2011 was partially dead due to the flooding in August. ④ Pumping water and small irrigation canal

of sawah plots. In Table 2, although quantitative data could not be obtained in the Sangelu area, one of the authors of this paper, Mr. J. Aliyu had visited the demonstration sites at Sangelu for the evaluation.

The following is an overview of sawah technology's demonstration and training on the Zamfara river floodplain, south of the Jega town. Fig. 30a and b show the some photographs during March to October, 2011. The ① of the Fig. 30a shows the demonstration plots of the standard sawah plot. We upgraded the traditional micro rudimentary sawah and converted it to a new standard sawah farm, which is showing the expansion of the area, leveling, strengthening of bunds, and line planting of healthy seedlings. The photo location is the site 1 of the Fig. 16. ② shows the meeting based on the memorandum of understanding between NCAM/JSPS(Japan Society for Promotion of Science) project of Kinki University and the World Bank/Fadama III/ADP. ③ shows the granted power tiller from the JSPS research fund and training. Photographs were taken on March-October 2011. (Some data are shown in Table 4). As shown in the Table 3, even the improvement of water utilization efficiency (required operation time of the pump) is just 50%, but since the yield more than doubled from about 1.5 to 2.5 t / ha to 6 to 7 t / ha, the water use efficiency as a whole is tripled or more. It can be said that this brought Kebbi rice revolution.

The Chinese-made tiller Dong Feng shown in ③ of the Fig. 31a is nominally 15 horsepower, but its weight is about 500 kg and it is heavy so it can not be mounted on wetland cage wheels, so it is an Anti-Skid wheel like the picture. Although it can be used in such dry-field environment, it will sink in wetlands with low ground tolerance. Thus the work performance will be worse on deeper wetland. Even though the powertillers of only 8-11 horse power attached with cage wheel (Fig. 19-24) made by Indonesia (Kubota engine), which is only 300 kg in weight, is work efficiency is higher for sawah plots development and sawah based rice farming. We had to use such a tiller that was not very suitable because at that time other tillers were not available in Nigeria. However those disadvantages were overcome by Kebbi farmers and Fadama III/ADP staffs.
Fig. 31b is continuation of the Fig. 31a. ①② Jega's demonstration site 2 of Fig. 16. ② SAWA TECH is a misspelling of SAWAH TECH. ③ This is the Jega's demonstration site 1 of Fig. 16. As shown in Fig.17E, which was similarly partially damaged by flooding on August 2011. ④ shows pump irrigated water and small canal.

Fig. 32A. Google Earth image of the Zamfara river floodplain near Jega City on April 2003. Some rudimentary sawah plots can be seen. April is near the end of the dry season.
Not much agricultural activities can be seen.
Those Fig 32A-E are showing wider area of Fig 17A-F.

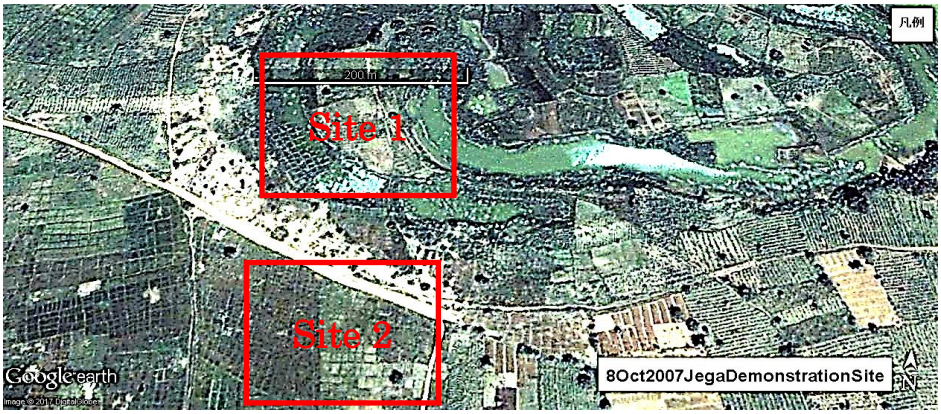


Fig. 32B. Google Earth image of the Zamfara river floodplain near Jega City on October 2007, before sawah technology training. October is the just after the flooding season. Micro rudimentary sawah and ridge rice. Onion cultivation are widely operating.

Fig. 32C. December 2011, immediately after the sawah technology training Photographs of Fig.15②&⑤, Fig.17A-F, Fig.18G, Fig.19①, Fig31a ①and Fig31b③&④were taken from the site 1. Photographs of Fig.15①, ③＆④, Fig.18G, Fig.20 ④, Fig.31a③, Fig.31b① &②were taken from the site 2. Some part of the site1 damaged by the flooding on July 2011.

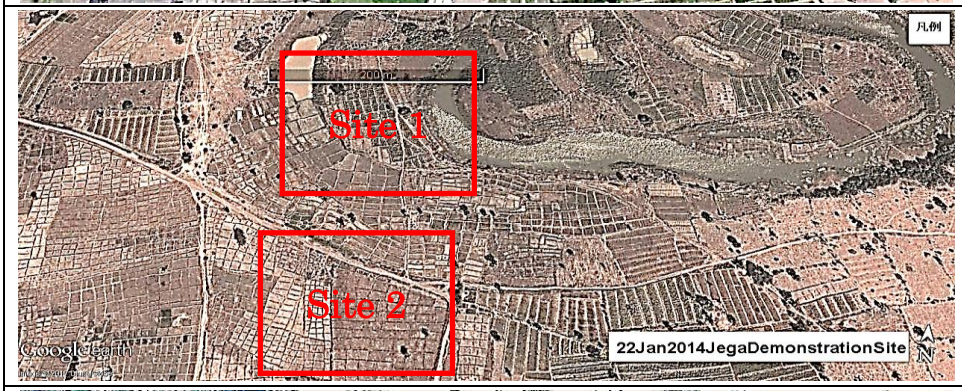


Fig. 32D. Google Earth on January 2014. We can see the progress of sawah plots improvement throughout the flood plain. However, it is difficult to distinguish between standards sawah plots and rudimentary sawah plots by the Google earth images alone. Ground Truth confirmation is necessary

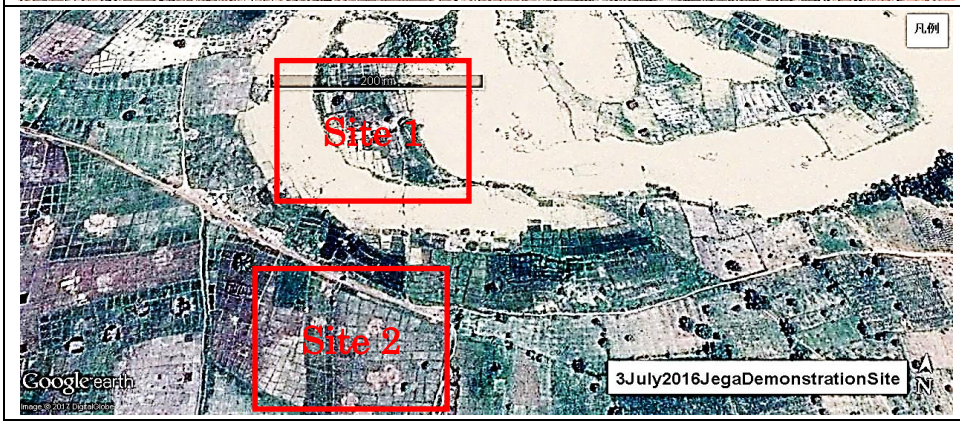


Fig. 32E. July 2016 Google earth shows the flooding, which occurred in depressions of the floodplain. It can be seen that the progress of sawah platform improvement are ongoing. With this extent of flooding the bunds of sawah system were not completely destroyed. Thus the restoration will not be so difficult.

Fig. 32A-D show the chronological improvement of the sawah system plat form on the Zamfara river flood plains in the vicinity of Jega City (see also Fig 16), which appeared on the Google earth images during 2003-2016. Fig. 32A and B show the Google Earth image of the Zamfara River floodplain south of Jega City before the sawah technology training and demonstration. The two demonstration plots, the site 1 and site 2 were established during March to December 2011, which can be seen on the Fig.32C-D. Before sawah technology training, the rudimentary sawah plots were common as seen in the photographs of Fig.15①-⑤, and Fig.18 G. Through the on-the-job training we established standard sawah system plots and standard sawah based rice farming as shown in the Fig.18H, Fig. 19① and Fig. 20①. However, it is difficult to distinguish between standards sawah plots and rudimentary sawah plots by the Google earth images alone. Ground Truth confirmation to compare the rudimentary sawah photographs of Fig.15①-⑤, and Fig.18 G as well as standards sawah photographs of Fig18H, Fig. 19① and Fig. 20① is necessary.

As shown in the Fig. 31b③ and Fig. 32E, some parts of the demonstration site 1 was damaged by flooding on July 2011(see also Fig.17E and F). Fig. 32D shows the state of flooding in July 2016. Flooding occurred in the depression of the former crescent parts of the floodplain. With this extent of flooding the bunds of sawah system were not completely destroyed. Thus the restoration will not be so difficult. It can be seen that the progress of the improvement of sawah system platform is ongoing as a whole.

7. Training and demonstration in the Birinin Kebbi area

Birinin Kebbi is the capital city. See Fig. 3 for the position. Fig. 33 of Google earth picture of 2018 shows irrigated rice fields of about 70 hectares which was developed by the Kebbi state government on the Rima River floodplain adjacent to the north of Birnin Kebbi city. The length of the scale marker on the Fig. 33 is 500 m. At the two sites of (1) and (2), Nigeria sawah team under Kinki university/NCAM project conducted on-the-job training to establish the demonstration plots, total 3.5ha, which was in collaboration with the World Bank-supported Fadama III/ADP staffs and rice farmers' association, during March-December 2011. The yield data are shown in the Table 4.1.

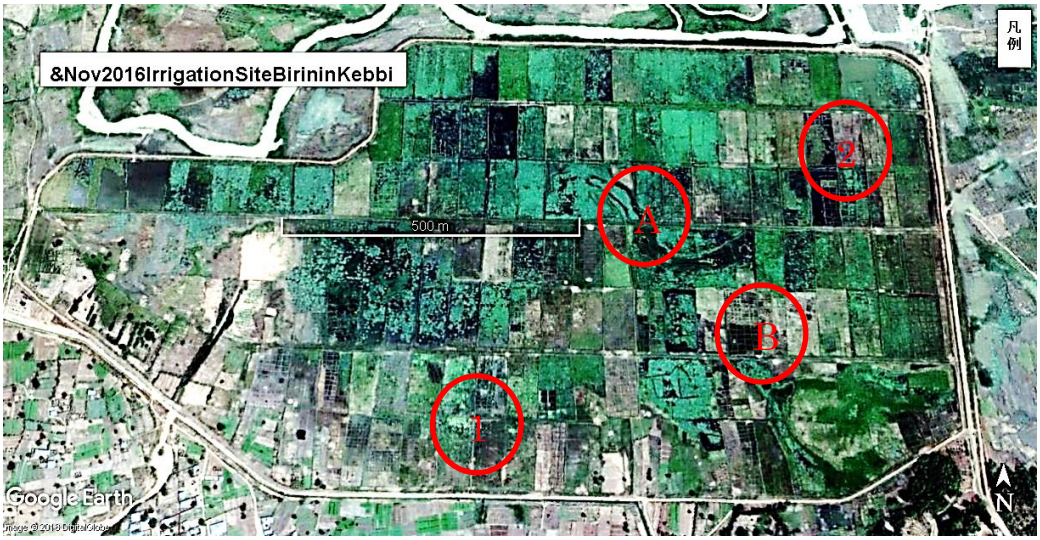


Fig. 33. Google earth picture on November 2016. Government old Irrigation site on the Rima River flood plain, just the north of the Birinin kebbi town. Length of scale maker is 500m. Total area is aboutb70 ha.

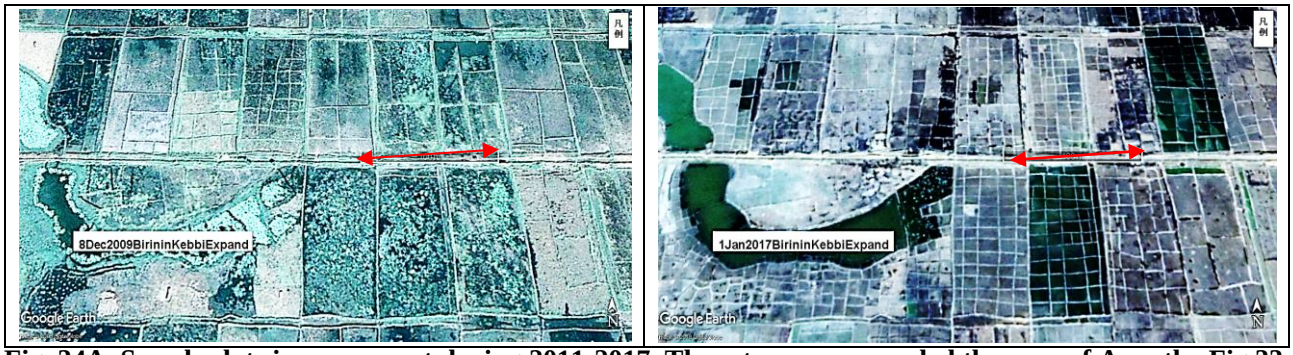


Fig. 34A. Sawah plots improvement during 2011-2017. These two are expanded the area of A on the Fig.33. Maker scale is 100m. The left picture was taken on 2009 and the right on 2017.

Fig. 34(1). Sawah plots improvement during 2011-2017. These two are expansion of ① area on Fig.33. Maker is 100m. The left picture was taken on 2009 and the right on 2017. The location was the (P) point

Fig. 34(1). Two photographs taken on May 2011. Yield data are shown in the Table 4. 1, which was 6.6t/ha.

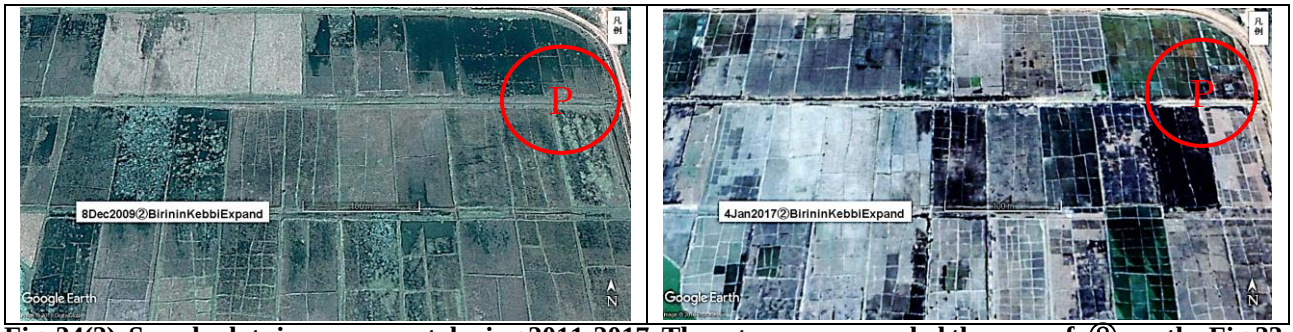


Fig. 34(2). Sawah plots improvement during 2011-2017. These two are expanded the area of ② on the Fig.33. Maker scale is 100m. The left picture was taken on 2009 and the right on 2017.

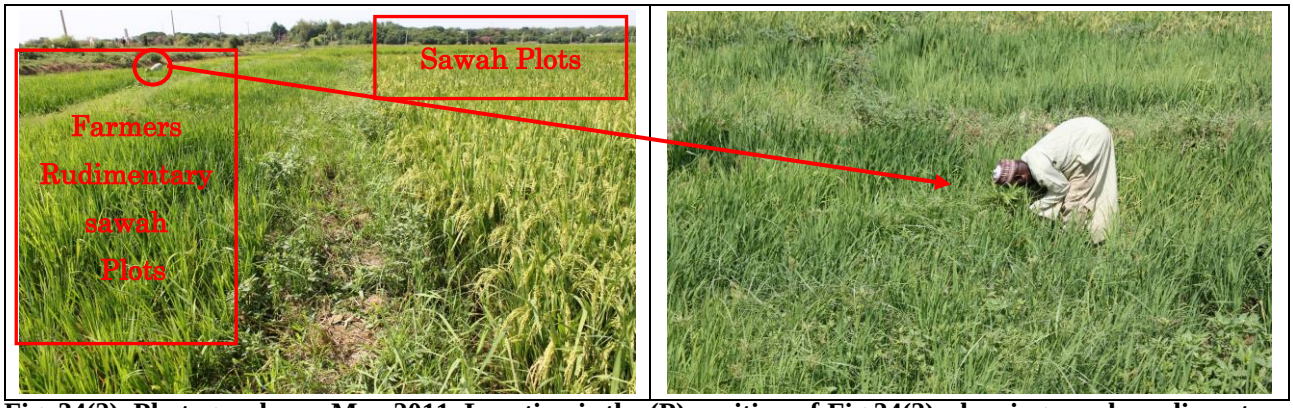


Fig. 34(2). Photographs on May 2011. Location is the (P) position of Fig.34(2), showing weedy rudimentary sawah and standard rice on demonstration plots

Fig. 34(2). Photograph (left). Location is the (P) of Fig.33②, i.e., Fig 34②

Fig. 34B. Broken irrigation intake point. Photographed location is the (B) of Fig.33.

As shown in various pictures in Fig. 34A, B, (1) and (2), before sawah technology training almost all the irrigated fields were non sawah or rudimentary sawah plots even though they have demarcation of 0.5 ha size which were created by bulldozer. However from the first, plots were not sawah plots and thus no management had been conducted as sawah plots so far. Therefore there were many plots where farmers abandoned rice cultivation because original irrigation pump was broken, the height difference was over 50cm within a plot, water management was impossible, thus poor yield. The World Bank-supported Fadama III and the NCAM Sawah team conducted sawah technology training and demonstration of 3.5 ha in two location (1) and (2) as shown in Fig. 33 during March- December 2011. The agronomic results are shown in Table 4.1.

Fig. 34A and B as well as Fig. 34(1) and (2) are the magnified images corresponding the positions of Google earth pictures on the Fig.33. Also photographs taken during evaluation trips on May 2011 are shown as Fig. 34 (1) photographs, Fig. 34(2) photographs and Fig. 34B photographs, respectively. The length of the marker of expanded images is 100 m. As seen of Google earth images in Fig. 34A, 34(1) and (2), which were just before sawah technology training, bunds for water management are not clear. Even if it was recognized within the compartment of 0.5 ha, it was rudimentary and poor. In the Google earth images of 2016 below, which are 5years after sawah technology training, almost all over the irrigation area have standard sawah plots with reinforced bunds and leveling for water management improvement. However, understanding of farmers' sawah system seems to remain at an elementary stage. Even in such irrigated land of government development, the Arugungu floodplain, which are described in former section 5, appears to be more advanced as the evolutionary stage of sawah based rice cultivation.

Red circle (1) and (2) in Fig. 33 are the demonstration sites. The photographs during the evaluation trips on May 2011 are shown in the Fig. 34(1) and (2) respectively. It is very clear contrast the good performance of sawah based rice cultivation in the sawah plots and the very weedy non- sawah plot. The Fig. 34 B shows the original concrete structure of the inflow point of pump irrigation water in this irrigated land, which was created by the government. But at that time on 2011 till now it has been no more functioning. The small pump and hose in front of the concrete structure are managed by farmers for irrigation to the right side rice fields.
Fig. 34(1) and (2) shows the demonstration sites board (point (1) and (2) in Fig. 33, respectively) and the monitoring team taken in May 2011. Yield data at this point is shown in Table 4. The board states "Kebbi State Fadama III Sawah Rice Production Technology, Plot 1, Variety Faro 44, Transplant Date and Time May 14, 2011". Although high yield of 6.5 t/ha or more has been achieved using Faro 44 of high yielding variety, contamination of other varieties was recognized during the evaluation trip on May 2011.

8. Penetration of Sawah Technology at Sangelu and Suru area of the Rima river flood pains during 2011-2014

As shown in Fig.35, the on-the-job training and demonstration were done near the ① site at Snagelu and ② site at Suru. Agronomic results at Suru were shown in the Table 4. Field observation photographs at the Sangelu site on November 2012 are shown in Fig. 36.

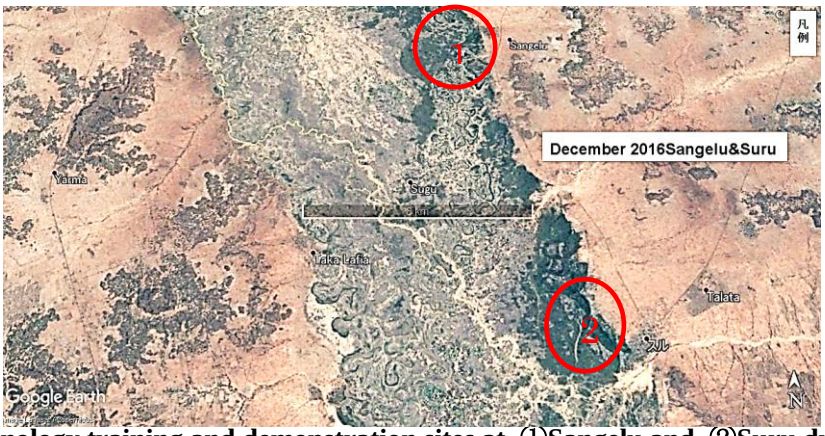


Fig. 35. Sawah technology training and demonstration sites at ①Sangelu and ②Suru during 2011-2014.

As shown in Fig. 3, Sangelu town is located on the east bank of the Rima River floodplain just below the point where the Zamfara River joins the Rima River. Fig. 35 is a Google satellite image showing the Rima river floodplain from Sangelu town to the Suru/Talata town area. The scale marker length in the figure is 8 km. The area of the floodplain in this picture is about 20,000 ha.

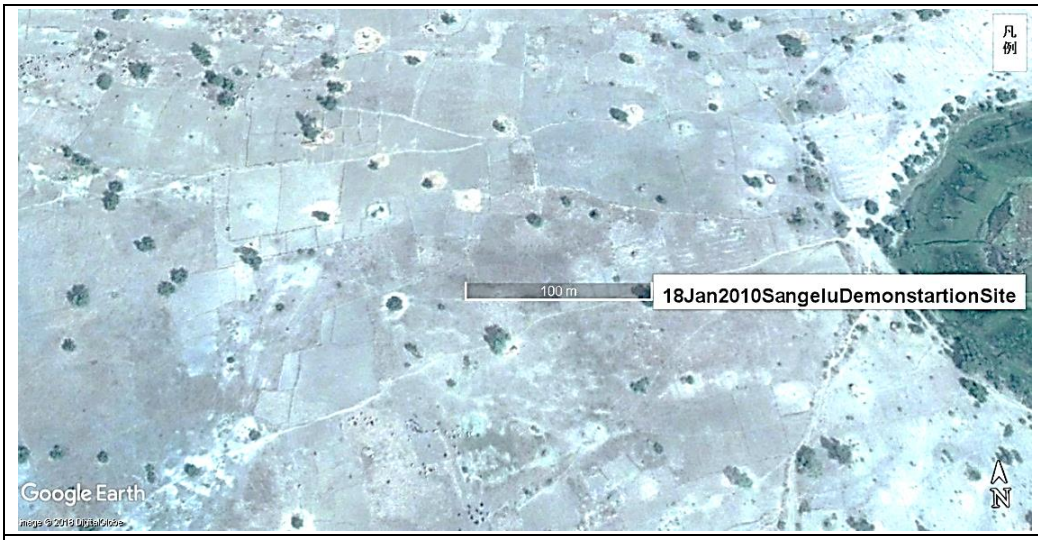


Fig. 36A. Google earth image on January 2010 at the site ① on the Rima river flood plain near Sangelu town. Scale maker length is 100m and total area of this photograph is about 16ha. Since this is before sawah technology training, there are no sawah system.

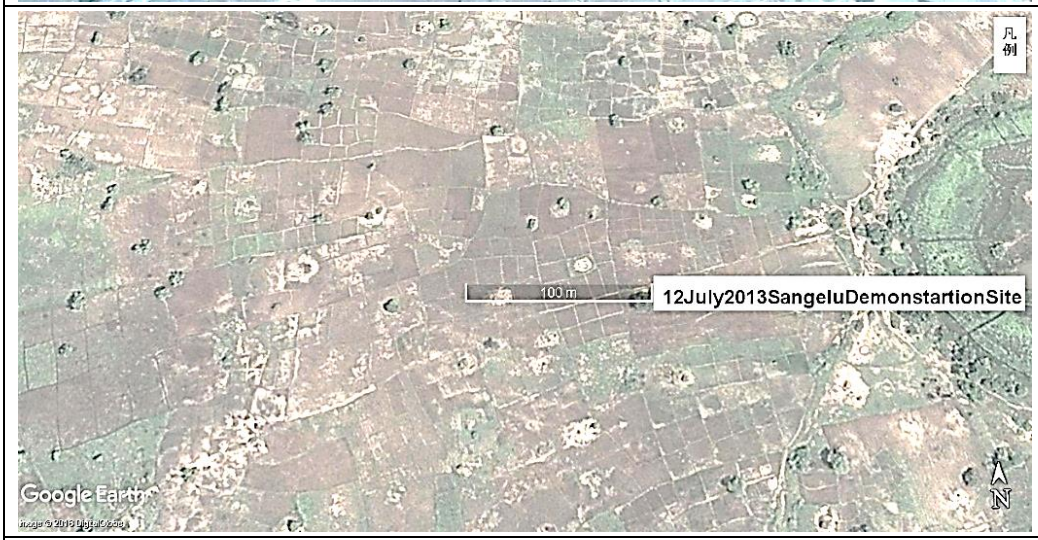


Fig. 36B. Google earth image on July 2013 at the same site of Fig. 36A above. This Google image was taken shortly after the sawah tech. training during Mar. 2011-Dec. 2012. About 40 % of this flood plain has sawah system. Evaluation photographs on Nov. 2012 are shown in Fig. 37.

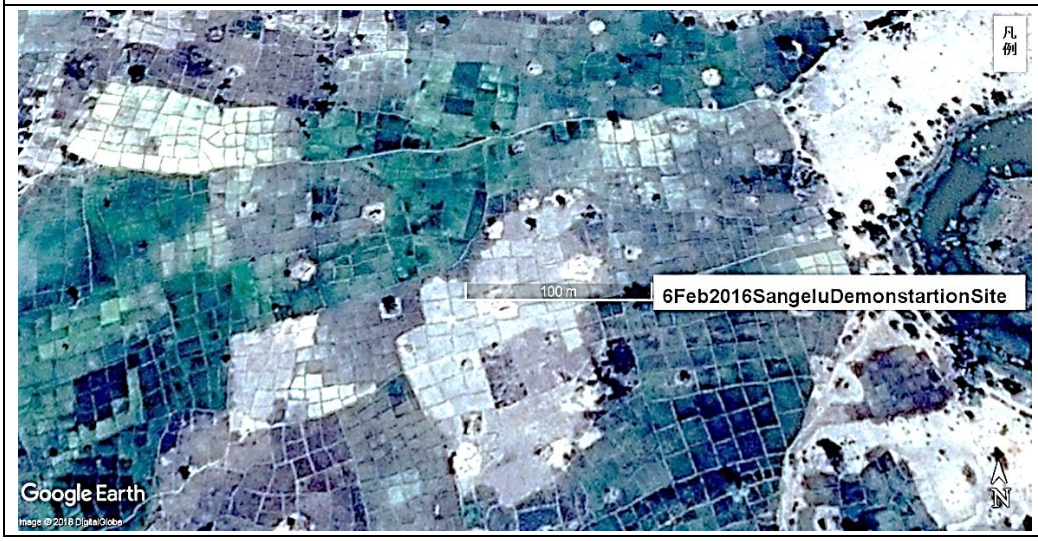


Fig. 36C. Google earth image on Feb. 2016 at the same site of Fig.36A and B above. This Google image was taken 5 years after sawah technology training during Mar. 2011-Dec. 2012. About 80 % of this flood plain has covered with the standard sawah system. Size range of sawah plots are 70-160m^2, mean 115m^2.

Fig. 37. Demonstration Sawah plots at Sangelu. Photographs were taken on Nov 2012 by J. Aliyu (who is one of the authors of this report) during Supervision trip as team leader at Kebbi sawah project.

Fig. 38A. Google earth image on December 2010 at the site ② on the Rima river flood plain near Suru town. Scale maker length is 100m and total area of this photograph is about 16ha. Since this is before sawah technology training, there are no sawah system except for rudimentary trial on the corner of the east side of the river of this floodplain.

Fig. 38B. Google earth image on July 2013 at the same site of Fig.38A above. This Google image was taken shortly after the sawah tech. training during Mar. 2011-Dec. 2012. About 80 % of this flood plain has sawah system. Paddy yield data during 2012-14 are shown in the Table 4

Fig. 38C. Google earth image on Feb. 2016 at the same site of Fig.38A and B above. This Google image was taken 5 years after the sawah technology training during Mar. 2011-Dec. 2012. Almost 100 % of this flood plain has covered with standard sawah system. Size range of sawah plots are 70-160m^2, mean 115m^2.

9. Penetration of Sawah Technology at Bagudo area of the Niger River flood plain by 2014

Fig. 39 shows the Google earth picture of the Niger River floodplain near Bagudo area on 30 March 2014. The length of the scale marker is 3 km. The flood plain width of this picture is up to 8 km. The selected sites of A, B, C, D, D2 and E are enlarged and shown in the following figures. We could not get a time series of Google earth photos except for B and D2 sites. The P position is the bridge, which photograph is in Fig. 42. In the box D2 areas we obtained time series Google Earth pictures of 2012 and 2014, which are shown in Fig. 43 and 44.

Fig. 40 shows the Google Earth pictures of the A location in the Fig. 39. The image was taken on 30 March 2014. The length of the scale marker is 300 m above and 100 m below. The sawah plot size range of this A site is 10 - 60 m^2 (average 35 m^2). Fig. 41 shows Google Earth pictures of the B location in the Fig. 39, of which left was taken on 1 February 2012 and right was on 30 March 2014. The length of the scale marker is 100 m. The sawah plots of this B site are 10 - 60 m^2 (average 35 m^2) similar to the A site. During the two years, 2012-2014, sawah evaluation was not observed at the A and B sites. These are typical micro rudimentary sawah plots. Fig. 42 shows a picture of these micro rudimentary sawah near Bagudo (source downloaded though internet but source is unknown). Fig. 43 shows NCAM/Kinki university Sawah team on the Bagudo bridge. The team was guided by Fadama III and ADP staffs and Mr. Alf. Bello Baidu (ABB) who was in charge of the demonstration with members of the rice farmers' association.

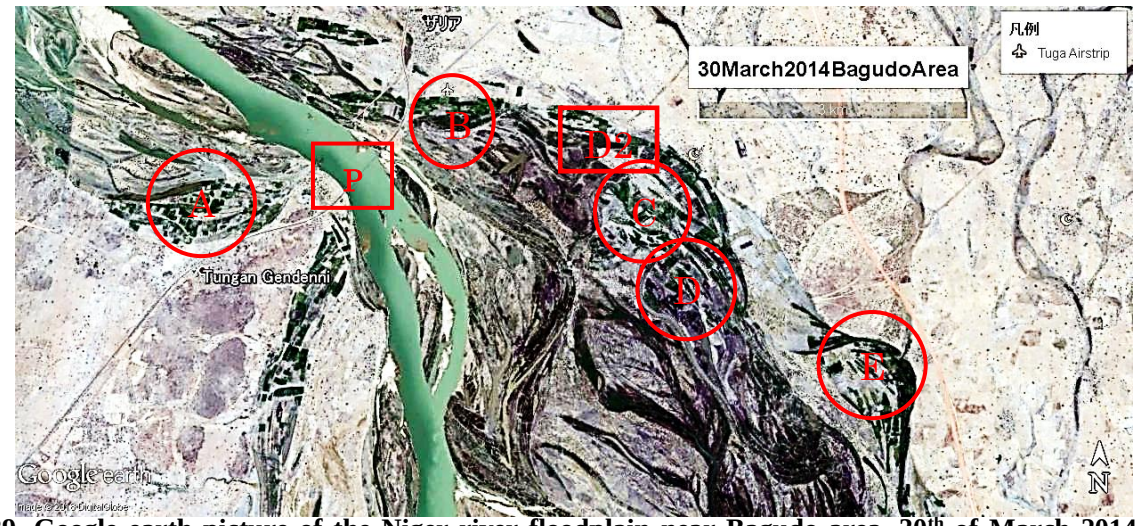


Fig. 39. Google earth picture of the Niger river floodplain near Bagudo area, 30th of March 2014. Scale marker is 3 km. The flood plain width of this picture is 3-8 km. The enlarged Google earth of A-E and of time series of 2012 and 2014 are shown in the following figures. The P shows bridge crossing the Niger river.

Fig. 40. Google Earth pictures of the A location in the Fig. 39. The image was taken on 30 March 2014. The length of the scale marker is 300 m above and 100 m below. The sawah plot size range of this A site is 10 - 60 m^2 (average 35 m^2).

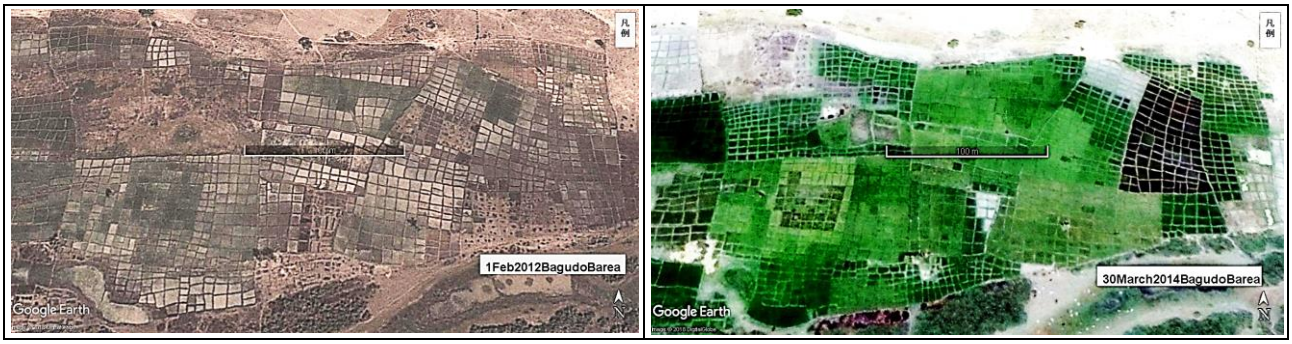


Fig. 41. Google Earth pictures of the B location in the Fig. 39, of which left was on 1 February 2012 and right was on 30 March 2014. The length of the scale marker is 100 m.

Fig. 42. The micro rudimentary sawah at Bagudo Area (downloaded through internet)

Fig. 43. Bagudo bridge of the P position in Fig. 39

Fig. 46①-③ were photographed of June 2014 at the ABB(Mr. Alh. Bello Baidu) farm. As shown in Table 4, ABB purchased five Chinese Dong Feng tillers, opened 50 hectares of sawah system and got paddy yield 7t/ha near D site in Fig.39. We could access from the Bagudo bridge to the D site by motorcycle as shown in Fig.46 ④. Mr. ABB said that he tried to use a laser leveler tractor, but in this kind of busy and swampy flood plain, the best option was the powertillers that could be disassembled and transported to the farms by ship or motorcycle.

Fig. 44. Google Earth picture of the C location in Fig. 39. The length of the scale marker is 100 m. This C site has both micro rudimentary sawah and the standard sawah plots by lead farmer of Mr. ABB.

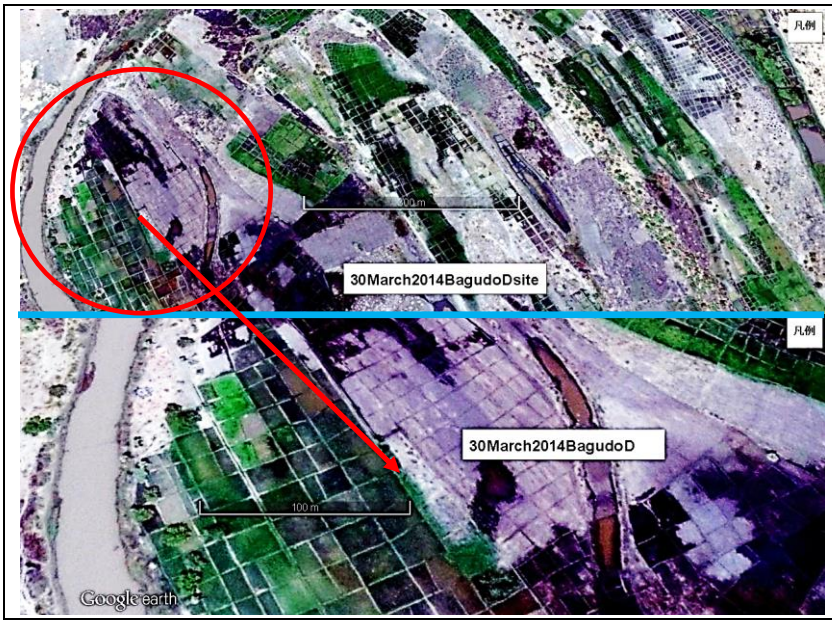


Fig. 45. Google Earth pictures at the D area in Fig. 39. The length of the scale marker is 300 m at the top and 100 m at the bottom. This D site is Mr. ABB's improved standard sawah plots development. The size range of sawah plots is 200-400 m ^{2}. As shown in the Table 4, paddy yield was 7 t/ha. The pictures shown in Fig. 46 were taken on June 2014. This Google Earth photo was taken on March 2014. On the left side of the photo is the crescent moon lake of the flood plain and access is necessary on foot, bike or boat, even in the dry season.

Fig. 46. ①-③ are photographs of ABB farm (D site) shown in Fig.45. ④ motorcycle access to the D site from the bridge (P) shown in Fig.39.

Fig. 47 shows Google Earth pictures at the E area of Fig.39. The length of the scale marker is 300 m at the top and 100 m at the bottom. The quality of the sawah plots of this E site is at the middle level between the micro rudimentary sawah and the standard sawah plots. The picture was March 2014, and it is unknown how it is expanding or evolving after 2014.

Fig. 47. Google Earth pictures near Bagudo, E region in Fig. 39. The length of the scale marker is 300 m at the top and 100 m at the bottom.

Fig. 48 shows some progress of sawah system development through the comparison of Google Earth photograph taken in February 2012 and the end of March 2014 at the D2 site in the Fig.39. The length of the center marker is 100 m. Pump irrigated sawah plots both standard and rudimentary quality have developed about 7ha in 2014 photograph but there are almost no sawah plots not in 2012 photograph.

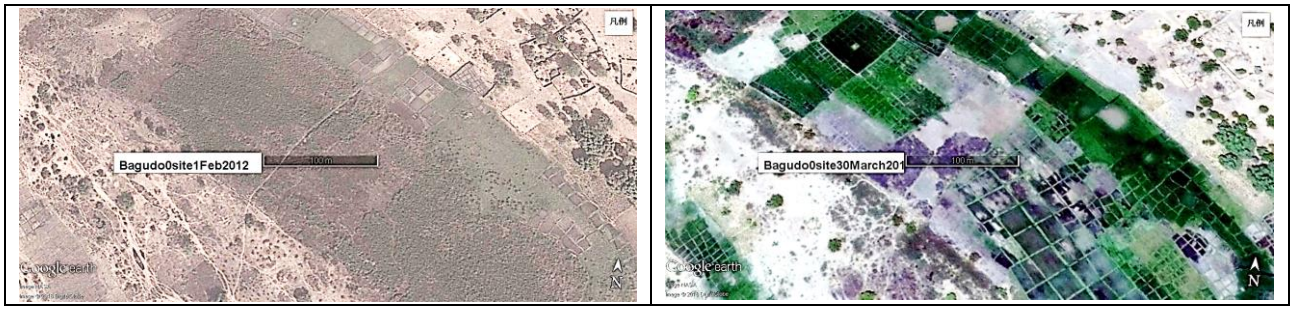


Fig. 48. Google earth at the D2 location on 2012 (left) and 2014(right). Scale is 100m.

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