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.

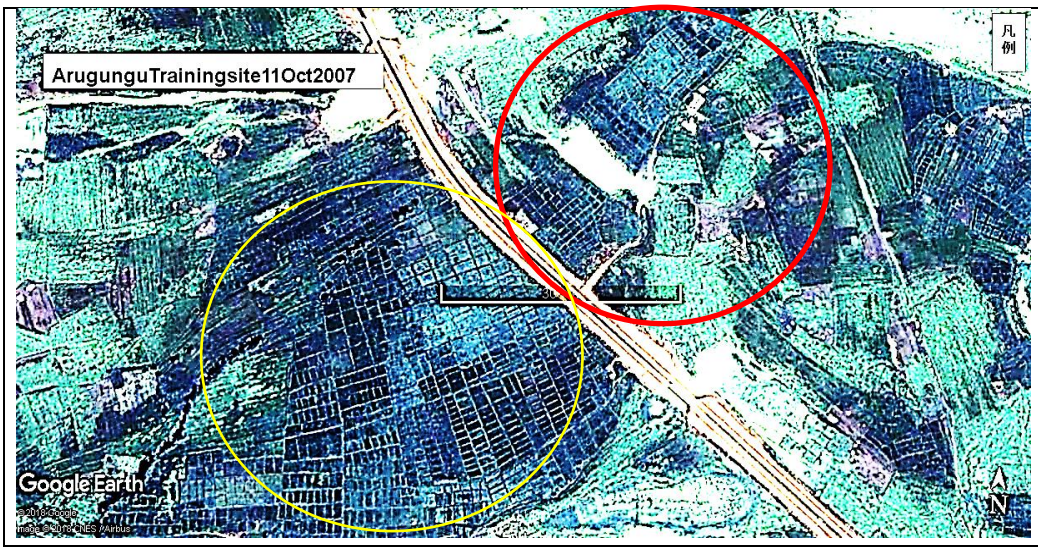


Fig.26A. Google earth on 2007 before sawah technology at Arugungu AR1 Site.
Red circled area was used for sawah technology training and demonstration in 2011. Yellow circled area is Arugungu Emir's rice field equipped with sawah system. All the other areas have no standards sawah systems in 2007.

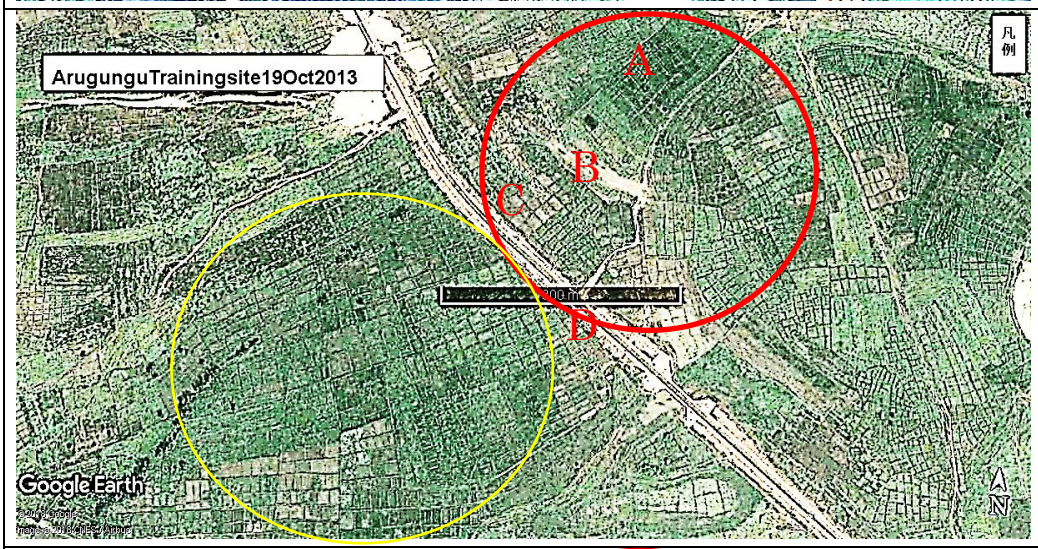


Fig. 26B. The position A shows demonstration plot in 2011. B is wet depression. C shows the position used new sawah technology training in 2015. D shows the bridge position. The marker length in center is 300m. Total area of the photographed is about 90ha. Not only the Emir farm, other areas were covered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

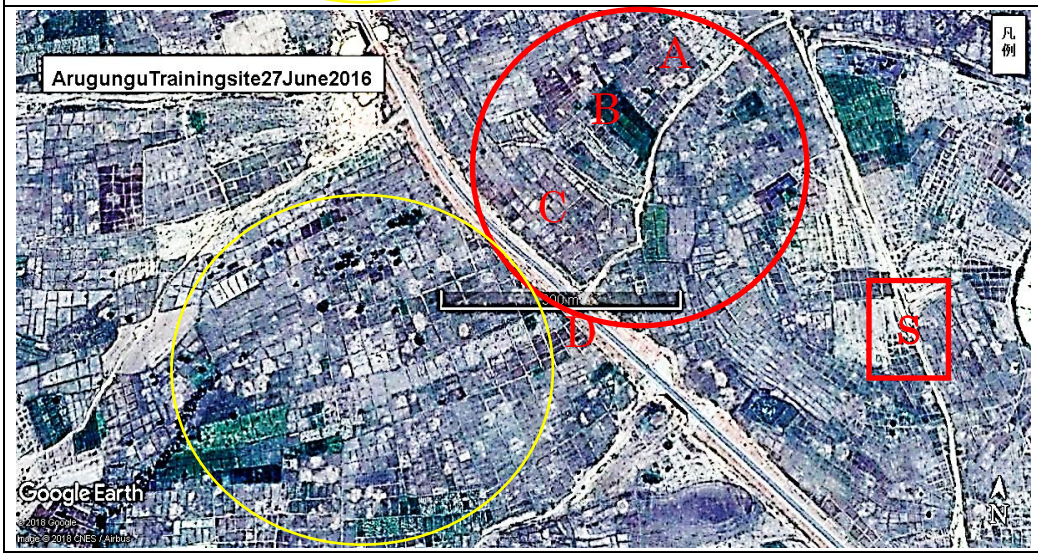


Fig. 26C. Almost 100% of the flood plains are covered with standards sawah systems in 2016. This is the essential difference of the Sokoto flood plains as shown later.
At the C position Nigerian sawah team conducted advanced sawah technology training in 2015.

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.

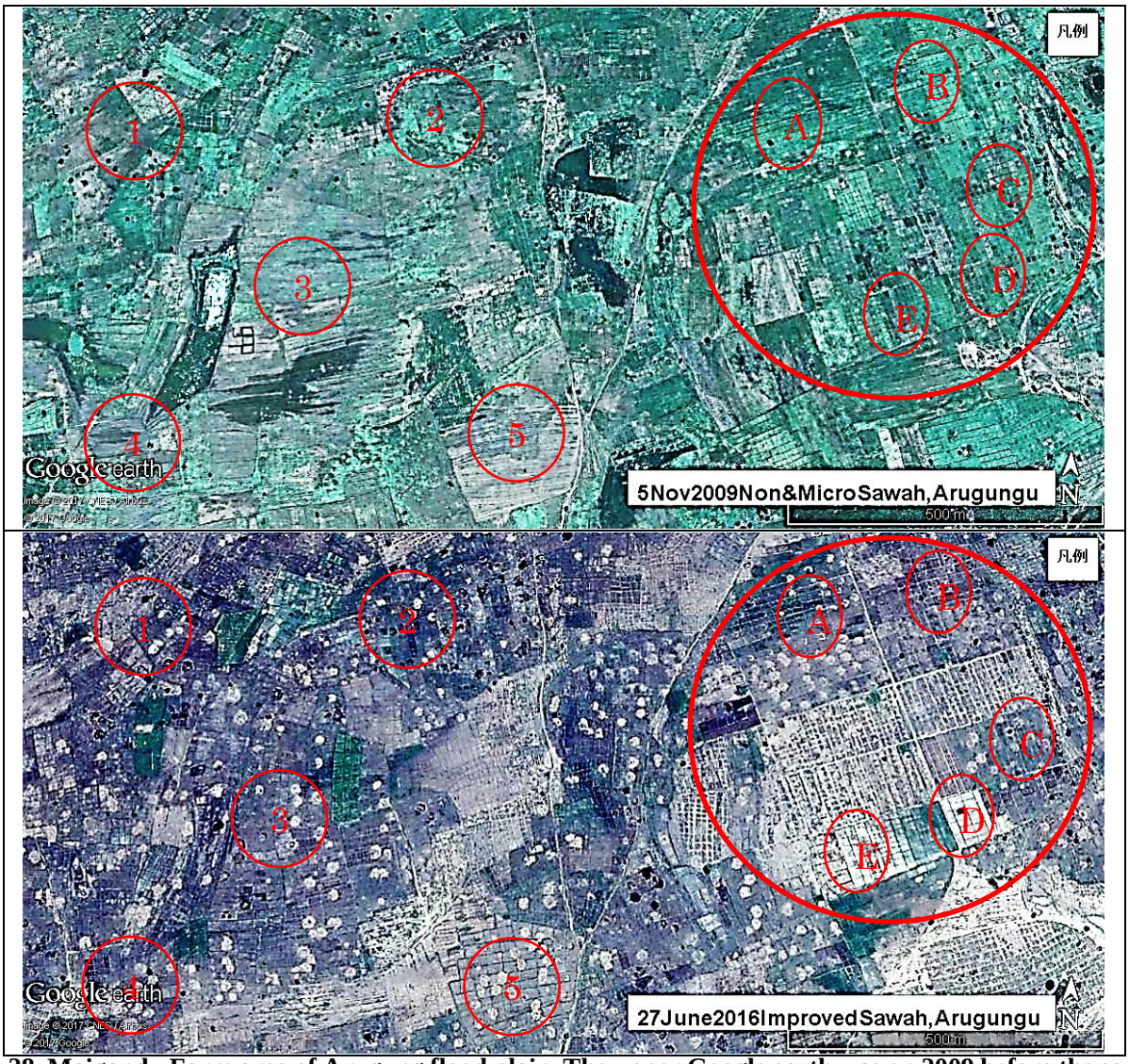


Fig. 28. Maigandu Farm area of Arugung flood plain. The upper Google earth was on 2009 before the sawah technology training, the lower was taken on 2016 after the training. Length of scale maker is 500m, total photographed area is about 150ha. The area surrounded by lager red line is the core part of 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).

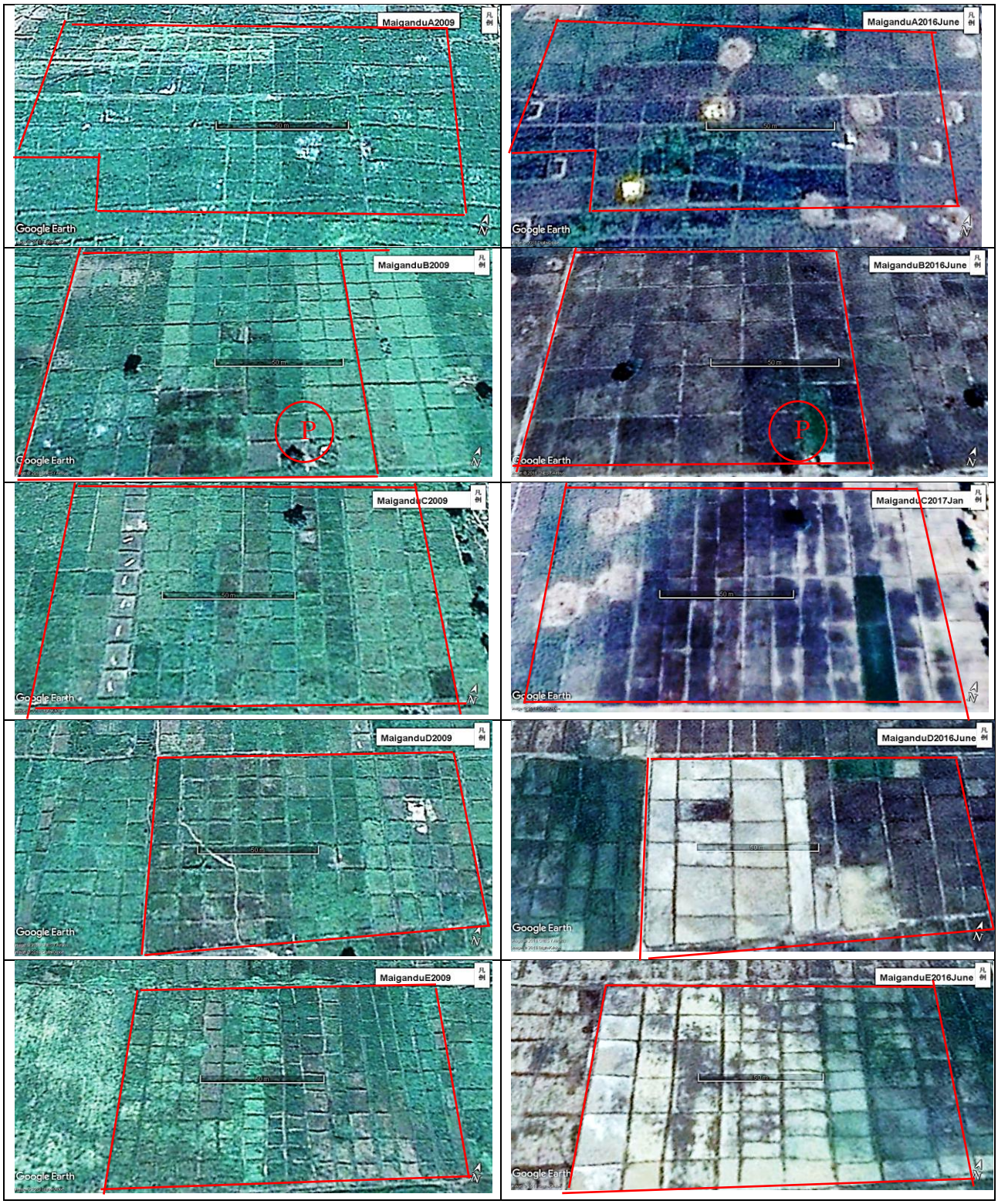
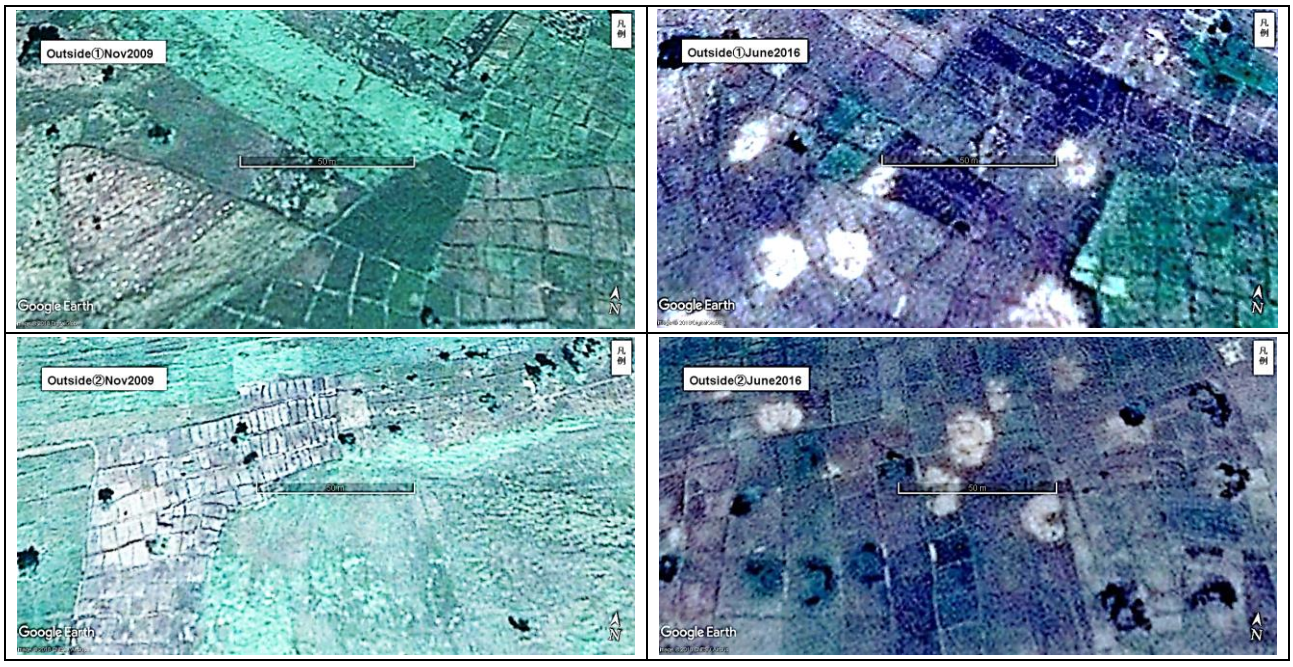


Fig. 29ABCDEF. Google earth 2009 and 2016/2017 showing the enlarged 5 sampling points, A, B, C, D, and E of Maigandu Farm. Each Point has about 1ha. Detailed data are shown in Table 2.

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.



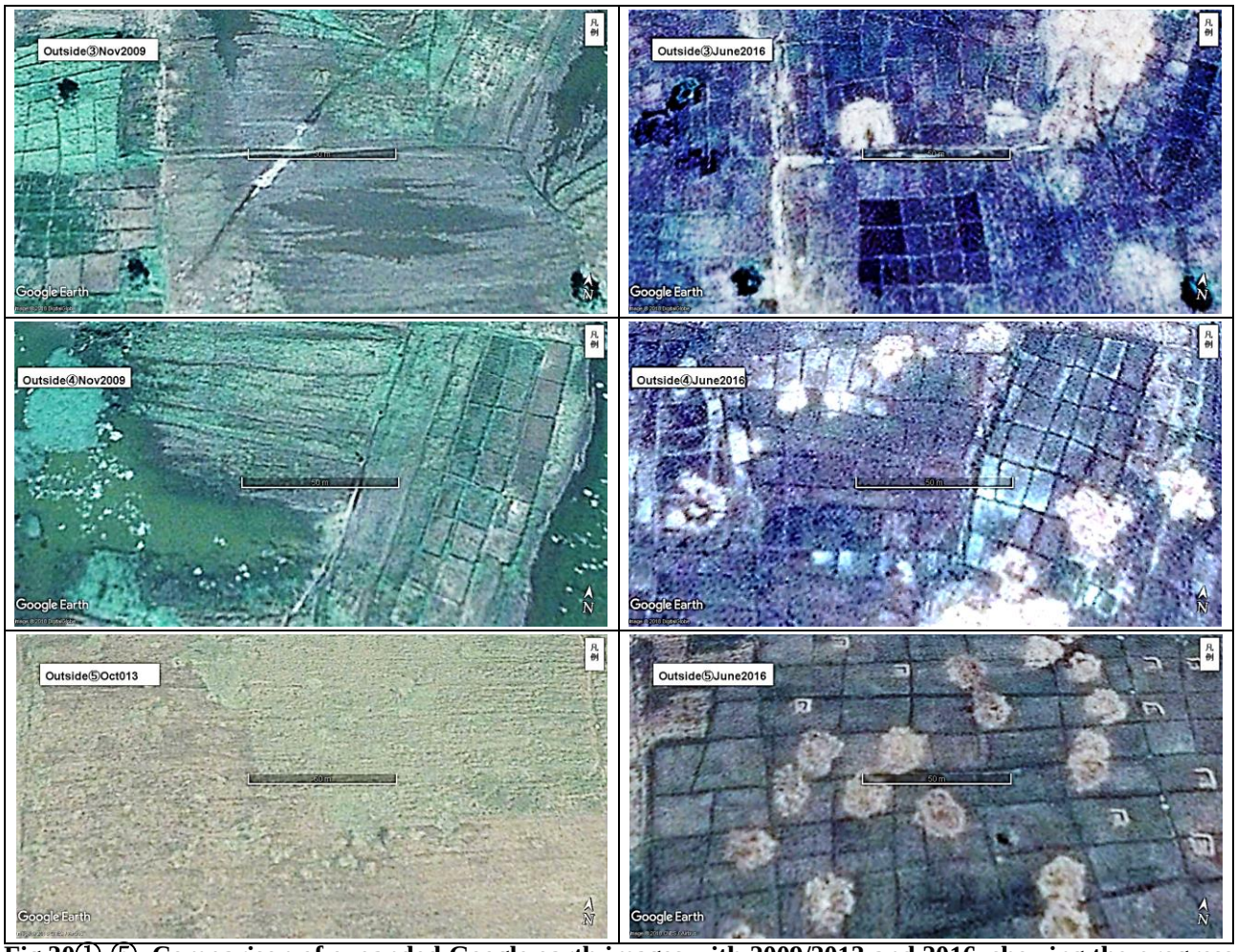


Fig.30①-⑤. Comparison of expanded Google earth images with 2009/2013 and 2016, showing the progress of sawah system development at ①-⑤ areas, outside of the Maigandu farm in Fig.28. Each pointed area has about 1ha, 10000m^2.

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

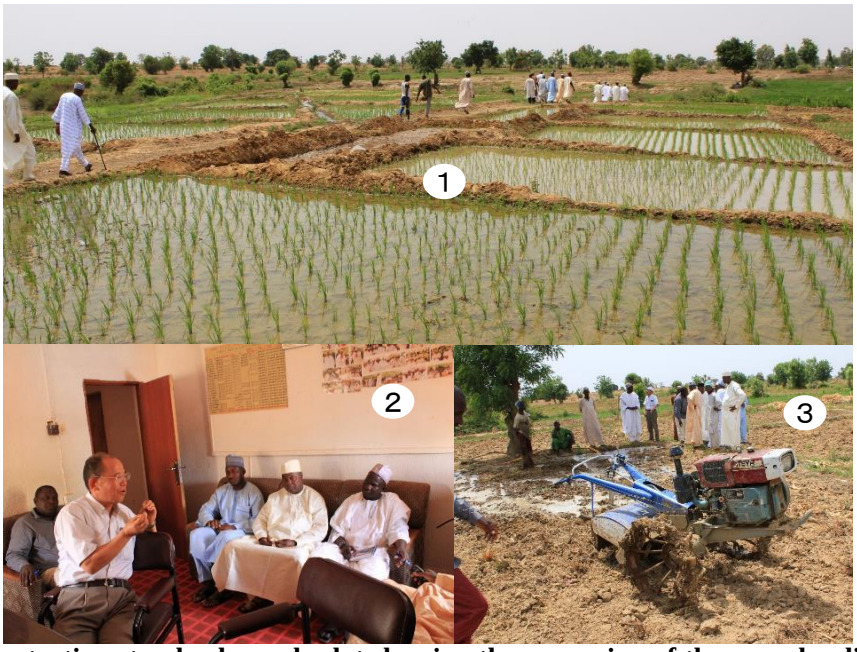


Fig. 31a. ①Demonstration standard sawah plot showing the expansion of the area, leveling, strengthening of bunds, and line planting of healthy seedlings. The photo location is the site 1 of the Fig. 16. ② Meeting based on the memorandum of understanding between NCAM/JSPS(Japan Society for Promotion of 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.

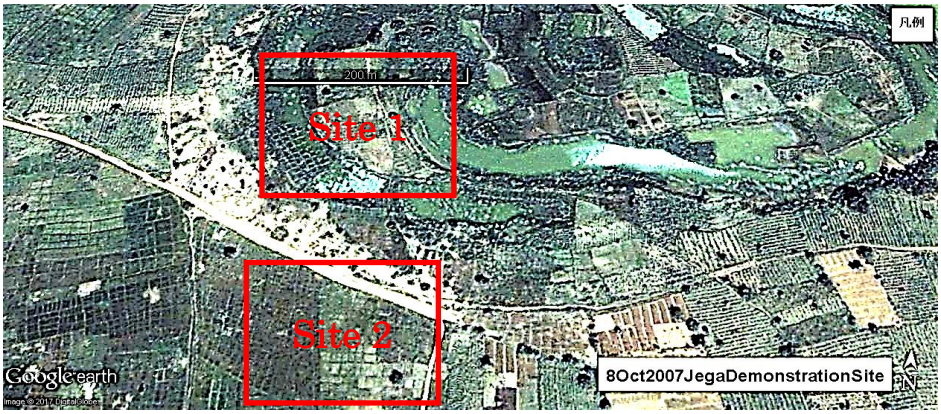


Fig. 32B. Google Earth image of the Zamfara river floodplain near Jega City on October 2007, before sawah technology training. October is the just after the flooding season. Micro rudimentary sawah and ridge rice. Onion cultivation are widely operating.