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Sawah Technology「アフリカ水田農法」(6-1) On-site mobile pump irrigated sawah based rice revolution in Kebbi State, Nigeria (1)

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1. It is becoming clear that in the 60 years since independence, sub-Saharan African countries (SSA) will leave the yoke of the West and form an Asian-African Sawah based rice-growing region by 2050.

Figure 1 illustrates the evolution of average daily energy intake (kcal) per capita in SSA from 1961-2020 from the FAOSTAT (2024) database for nine major crops: Maize, Rice (paddy equivalent), Wheat (including Barley, Oat, Rye), Sorghum, Cassava, Yam, Millet, Potatoes (including Sweat potato and Taro), and Plantain. The values shown on the left side of the figure represent the average for the period 1961-70 (total: 1327 kcal), and the values on the right side represent the average for the period 2011-2020 (total: 1782 kcal/day/person). Foods other than Rice, Yam, Potato, and Plantain include consumption as their respective processed foods (products). The population averaged 260 million during the period 1961-70, and the average daily food intake of Maize was 332 kcal/day/person in 1961-70, followed by Sorghum 220 kcal in No. 2, Cassava 192 kcal in No. 3, Millet 160 kcal in No. 4, Wheat 136 kcal (91 produced, 45 imported) in No. 5, Rice 132 kcal (106 produced, 26 imported) in No. 6, Yam 59 kcal in No. 7, Potato 59 kcal in No. 8, and Plantain 41 kcal/day/person, with an extremely diverse staple food composition. The total was 1327 kcal/day/person. Imported wheat and rice totaled 71 kcal/day/person, for a calorie-based food self-sufficiency ratio of 94.6%. This is approximately equal to the basic metabolic rate required per capita for survival, depending on the composition of the population.

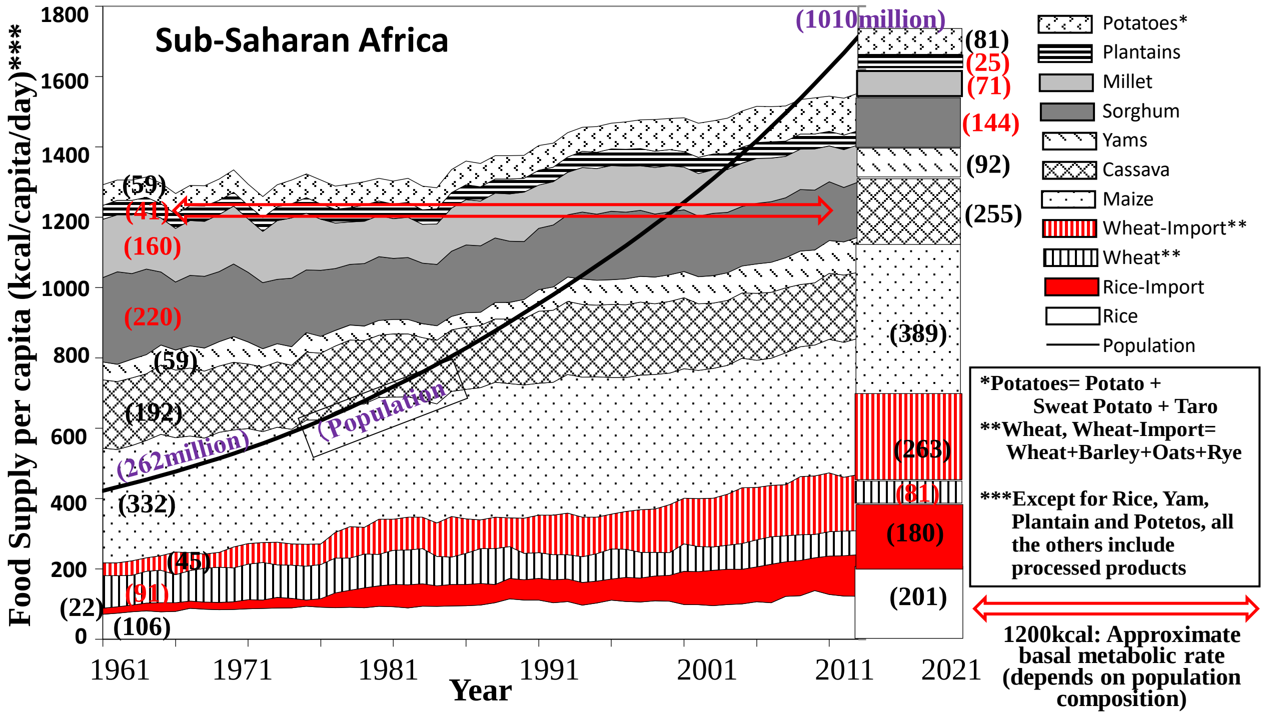

Fig. 1. Population growth curves and per capita food supply (kcal/capita/day) for sub-Saharan Africa (SSA) from 1961-2020, illustrated for nine major crops: maize, rice, wheat, sorghum, cassava, yams, millets, potatoes, and plantain (edible banana). The values shown on the left side of the figure represent the average for the period 1961-70 (total 1327), and the values on the right side represent the average for the period 2011-2020 (total 1782). Rice is shown in terms of paddy, hulled, rice (conversion rate: 0.65 paddy rice = milled rice).

The average population during 1961-1970 was 260 million, and during 2011-2020 it was 1.01 billion, a 3.88-fold increase. The last 10-year average daily food intake during the 2011-2020 was Maize 389 kcal/day/person in No.1, followed by Rice 381 kcal (201 kcal produced and 180 kcal imported) in No. 2, Wheat 344 kcal (81 kcal produced and 266 kcal imported) in No. 3, Cassava 255 kcal in No.4, Millet 144 kcal in No. 5, Yam 92 kcal in No.6, Potato 81 kcal in No.7, Millet 71 kcal in No.8, and Plantain 25 kcal in No.9. The total was 1782 kcal/day/person. Imported wheat and rice totaled 443 kcal/day/person, a marked decrease in food self-sufficiency in calorie terms to 75%. The total food self-sufficiency of 1339 kcal/person/day is roughly equal to the required basal metabolic rate, which means that the food production situation in SSA has not improved in the past 60 years.

However, notably, the No. 2 food intake calorie source in the most recent 2011-2020 period was rice, with the No. 1 increase in subsistence production per capita averaged over the 10-year period 1961-70 and 2011-2020 at 1.90 times (a production increase factor of 7.4 times, taking into account a population growth rate of 3.88 times) for rice. , and No. 2 at No. 2 was yam at 1.56x (6.1x), No. 3 was potatoes at 1.37x (5.3x), No. 4 was cassava at 1.33x (5.2x), and No. 5 was maize at 1.17x (4.54x). Wheat, sorghum, millet and plantain decreased. It is important to note that imports of wheat and rice are also increasing. However, compared to wheat, the ecological environment (soil, topography, hydrology, and temperature) of SSA is suitable for the expansion of irrigated sawah based rice cultivation, so there is a strong possibility that subsistence production will surpass maize as the number one food crop by 2030-35, and imports will also begin to decline.

Figure 2 below shows the population growth and annual per capita production of staple food crops and imported wheat and rice in kg in SSA countries since 1961 according to FAOSTAT (2024) data. When historical trends of SSA's diverse food crops are presented in FAOSTAT weight units (Kg or tons), the large differences in moisture content and postharvest losses for each crop can be misleading when comparing their importance as food. The data in the following chart was plotted by adjusting the FAOSTAT data using a first approximation of one-eighth of the grain equivalent factor for Cassava and Plantain and one-fifth for Yam and Potato. The difference in moisture content between grains and other crops such as Cassava, which is not included in the FAOSTAT weight data (around 10% for grains and 60-80% for others, a difference of 6-8 times), is the main factor, but the difference in postharvest losses (30-65%) was also taken into account in the estimated approximation. See Sawah Technology (1) for details.

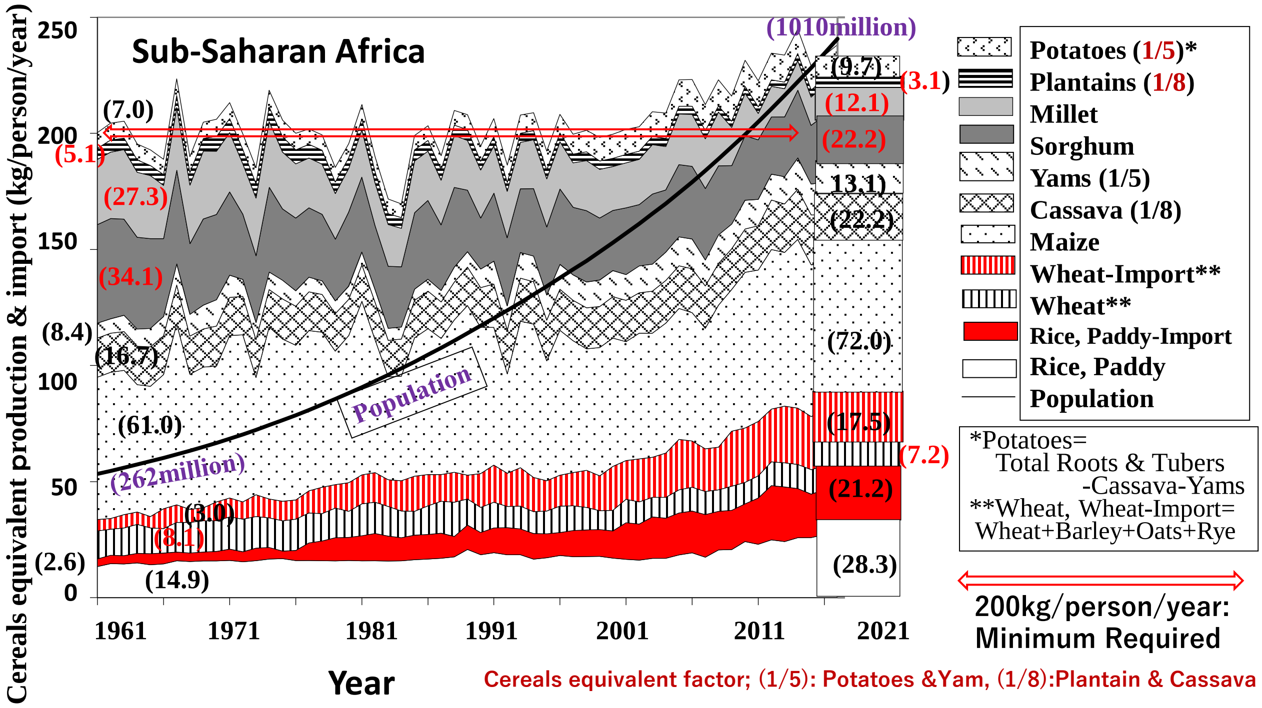

Fig. 2. Population growth curves and production (imports) in kg per capita per year for sub-Saharan Africa (SSA) from 1961-2020, illustrated for nine major crops: maize, rice, wheat, sorghum, cassava, yams, millets, potatoes, and plantain (edible banana). The values shown on the left side of the figure represent the average for the period 1961-70 (total 188.2), and the values on the right side represent the average for the period 2011-2020 (total 228.6 kg/year/person). Rice is shown in terms of paddy, hulled, rice (conversion rate: 0.65 paddy rice = milled rice).

As shown in Figures 1 and 2, in the 60 years after independence, the average 10-year population increased from 260 million to 1.01 billion, a 3.88-fold increase. The average food production (consumption) during the period 1961-70, immediately after independence, was 61.0 kg/year/person for Maize (No. 1), followed by Sorghum 34.1kg in No2, Millet 27.3 kg in No.3 , Rice (hulled or paddy base) 17.5 kg (production 14.9, import 2.6) in No. 4, Cassava 16.7kg in No 5, Wheat 11.1kg (production 8.1, import 3.0) in No. 6, Yam 8.4kg in No.7, Potato 7kg in No.8, and Plantain at 5.1 kg/year/person in No.9, showing a very diverse staple food composition. The total was 188.2 kg/year/person. Imported wheat and rice accounted for 5.6 kg/year/person, for a food self-sufficiency rate of 97%.

The average food production (consumption) for the 10-year period 2011-2020 was 72.0 kg/person/year for Maize in No. 1, 49.5 kg for rice (hull equivalent) (production 28.3, import 21.2) in No.2, and 24.7 kg for wheat (production 7.2, import 17.5) in No. 3, 22.2 kg for Sorghum in No. 4, 22.2 kg for Cassava in No. 5, 13.1 kg for Yam in No. 6, 12.1kg for Millet in No. 7, 9.7 kg for Potato in No.8, and 3.1kg for Plantain in No.9, totaling 228.6 kg/person/year. Imported wheat and rice accounted for 38.7 kg/person/year, for a food self-sufficiency ratio of 83.1%. The results in Figure 2 using the estimated approximations of grain equivalents were similar

to the results in Figure 1, and did not differ significantly in considering the changes in food crops in SSA over the past 60 years.
The No. 1 production growth rate per capita for the 10-year average between 1961-70 and 2011-2020 was Rice for 1.90 times (a production growth factor of 7.4x, taking into account a population growth rate of 3.88x); No. 2 was 1.56 times for Yam (6.1x); No. 3 was 1.39 times for potatoes (5.4x); No. 4 was 1.32 times for Cassava (5.1x); and No. 5 was 1.18 times for Maize (4.4x). Wheat, sorghum, millet and plantain decreased.
Among the nine staple crops mentioned above, imports of rice and wheat increased sharply, by a factor of 5.8 and 8.2, respectively. Wheat production has little room to increase given the ecological environment in SSA, and in fact, even in the past 60 years, production has increased by less than the population growth. On the other hand, the potential for sustainable rice production is extremely large in terms of climate, soils (wetlands), and hydrology. The potential area of irrigated sawah platform development for rice production is estimated to be at least 50 million ha/year, which is about 10 times the annual paddy production of 28 million tons as of 2020 (see Sawah Technology (4) and (5)). Figure 2 shows the annual production per capita including population growth rate, so the percentage increase is not very large visually, but rice production in SSA according to FAOSTAT (2024) averaged 3.9 Mt from 1961 to 1970, 7.8 Mt from 1981 to 1990, and the average for the period 2001-2010 was 14.8 Mt. This represents a nearly twofold increase over the past every 20 years. The most recent 2011-2020 average of 27.0 Mt represents a 1.8-fold jump between the 2001-10 average and the most recent decade of 2011-20 (FAOSTAT 2024). The most recent 2007-2011 and 2017-2021 five-year averages show a 1.7-fold increase from 18.4Mt to 31.9Mt, indicating an acceleration in rice production now in SSA.

In SSA, the slave trade and colonization by Western nations over the past 500 years have not only deprived SSA countries of the chance to develop independently and endogenously, but also of the opportunity to collaborate with non-Western countries, for example, Asian countries. Not only was the development of agriculture compatible with SSA's ecological environment stifled, but only agriculture that was convenient for the West had been promoted for 500 years. This did not promote "paddy", i.e, sawah based rice cultivation of Asian origins, and it also confused the basic concepts and techniques of sawah based rice cultivation. Namely, (1) confusion of technical terms between rice, un-hulled rice, paddy, and irrigated bunded and levelled farmland platform, and sawah platform, and (2) a narrow understanding of irrigation as only referring to water facilities such as dams, irrigation and drainage canals and channels, etc., (3) a lack of understanding that the levelled and bunded rice fields are the basic infrastructure (platform, foundation) for sustainable rice farming, etc. (4) Westerners seem to be unwilling to understand that upland agriculture and irrigated bunded levelled sawah based rice agriculture are fundamentally different. We therefore proposed the use of the Malay-Indonesian word sawah (bunded and leveled rice field) to at least distinguish between rice (paddy) and the paddy field infrastructure (paddy) (Wakatsuki 1998).

Asia has 94 million ha of irrigated sawah rice cultivation (60% of total rice production, AQUASTAT 2016) as of 2013; SSA has 240 million ha of wetland soils (FAO-unesco 1977, van Dam and van Diepen 1982, Andriesse 1986) and 3617 km^3 of annual water available for irrigated rice production, which is about 40% of Asia (Oki et al 2009). The irrigated rice potential area in Africa is estimated to be 9400 x 0.4 = 56 million ha, which is about 20% of the total wetland area. As of 2013, the irrigated rice area in SSA is 2 million ha (AQUASTAT 2016), only 1/30th of the potential area. However, as can be seen in Figures 1 and 2, there has been a sustained expansion of rice production in SSA over the past 60 years, far outpacing population growth. This may be important as Asian countries gained independence from Western colonial rule after the Second World War in the 1950s and African countries in the 1960s. This led to the expansion and evolution of cooperation between Asian and African countries away from the yoke of the West, and the formation of a new global society.

The foundation for this linkage can be attributed to the holding of the Asian-African Conference (Bandung Conference 1955, See Seng Tan et al 2009, Wikipedia 2024) in Bandung, Indonesia, in 1955, the middle year of the peak year of independence for Asian and African countries. The participating countries in the 1955 the first Bandung conference were Afghanistan, Burma, Cambodia, Ceylon, China, Cyprus, Egypt, Ethiopia, Ghana, India, Iran, Iraq, Japan, Jordan, Laos, Lebanon Liberia, Libya, Nepal, Pakistan, Philippines, Saudi Arabia, Syria, Sudan and Thailand. It was significant that Japan was the only major belligerent of the Second World War to be invited to this conference, where Asian and African countries that had just been liberated from colonial rule sang out the spirit of anti-imperialism, anti-colonialism and national self-determination in high spirits.

First, Taiwan pioneered the large-scale transfer of irrigated sawah based rice technology to 22 SSA countries, mainly from 1961 to 1975, and from 1970 onward, in addition to CG centers such as Afrirca Rice, IITA, IRRI, and other research institutions, the World Bank, the African Development Bank, Japan, China, South Korea, India, North Korea, and other countries, the Asia-Africa Cooperation has been developing from 1980 to 2000, Since 2007, international NGOs such as AGRA have been active. However, there are still many occasions when Western views of agriculture, particularly with regard to irrigated rice cultivation, have become an obstacle to smooth cooperation between Asia and Africa with regard to combating global warming and Africa's food crisis.

2. Nigeria contributed 40% of the total paddy production increase of 13.3 million tons between 2007 and 2021 for the 23 sub-Saharan African countries (SSAs) participating in the JICA (JICA, 2008, 2021) CARD (Coalition for African Rice Development) project (Table 1).

Table 1. Changes of paddy production of 23 SSA countries of CARD (Coalition of Africa Rice Development, JICA 2008, 2021) in 2007-2021. *Other SSA countries and **Egypt is included, too.

	Production (Million ton)					Increase(1)	Increae(2)	Contribution	Cultivated area(Mha)		Yield (t/ha)	
	Mean of 1961-1965	2008	Mean of 2007-2011	2018	Mean of 2017-2021	Δ(2018-2008)	Δ(2017-21)-(2007-11)	% of Paddy Increase**	Mean of 2007-2011	Mean of 2017-2021	Mean of 2007-	Mean of 2017-
Egypt	1.8	7.25	5.93	3.12	4.51	-4.13	-1.42	NA	0.62	0.49	9.62	10.20
Nigeria	0.21	4.18	4.00	10.86	9.34	6.68	5.34	40.27	2.27	4.23	1.77	2.21
Madagascar	1.6	3.91	4.22	4.03	4.03	0.12	-0.19	-1.43	1.27	1.52	3.33	2.66
UR Tanzania	0.12	1.42	1.80	3.42	3.01	2.00	1.21	9.13	0.90	1.04	2.00	2.92
Mali	0.17	1.62	1.46	3.17	2.90	1.55	1.44	10.86	0.52	0.89	2.86	3.27
Guinea	0.23	1.53	1.56	2.34	2.37	0.81	0.81	6.11	1.09	1.75	1.53	1.36
Côte d'Ivoire	0.22	0.68	0.81	2.01	1.83	1.33	1.02	7.69	0.38	0.66	2.15	2.77
DR Congo	0.06	0.32	0.48	1.29	1.39	0.97	0.91	6.68	0.64	1.41	0.76	0.986
Senegal	0.10	0.41	0.42	1.21	1.22	0.80	0.80	6.03	0.12	0.35	3.42	3.49
SierraLeone	0.34	0.68	0.86	0.92	1.16	0.24	0.30	2.26	0.51	0.82	1.66	1.47
Ghana	0.034	0.30	0.37	0.77	0.93	0.47	0.56	4.22	0.16	0.32	2.29	2.87
Benin	0.001	0.109	0.136	0.459	0.415	0.350	0.279	2.11	0.041	0.110	3.26	3.79
BurkinaFaso	0.032	0.195	0.198	0.350	0.391	0.155	0.193	1.43	0.097	0.183	2.05	2.13
Cameroon	0.010	0.073	0.120	0.334	0.326	0.261	0.206	1.58	0.092	0.268	1.44	1.22
Mauritania*	0.006	0.082	0.102	0.323	0.320	NA	0.218	NA	0.021	0.068	4.76	4.73
Chad*	0.029	0.174	0.154	0.260	0.267	NA	0.113	NA	0.116	0.188	1.33	1.42
Liberia	0.13	0.295	0.281	0.258	0.263	-0.037	-0.018	-0.15	0.219	0.239	1.31	1.10
Uganda	0.003	0.178	0.199	0.199	0.246	0.021	0.047	0.38	0.102	0.086	2.05	2.83
GuineaBissau*	0.048	0.149	0.168	0.176	0.188	NA	0.020	NA	0.087	0.117	1.92	1.60
Ethiopia	0	0.001	0.057	0.172	0.177	0.171	0.120	0.90	0.022	0.059	2.19	2.98
Mozambique	0.094	0.088	0.180	0.170	0.163	0.082	-0.017	-0.15	0.260	0.303	0.765	0.545
Togo	0.021	0.086	0.101	0.145	0.149	0.059	0.048	0.38	0.041	0.089	2.42	1.67
Kenya	0.014	0.022	0.062	0.113	0.144	0.091	0.082	0.60	0.021	0.027	2.86	5.42
Malawi*	0.058	0.115	0.118	0.112	0.132	NA	0.014	NA	0.061	0.070	1.93	1.88
Rwanda	0	0.082	0.075	0.114	0.121	0.032	0.046	0.38	0.015	0.032	4.98	3.80
Niger*	0.011	0.061	0.075	0.102	0.108	NA	0.033	NA	0.021	0.026	3.63	3.84
Burundi*	0.0027	0.071	0.079	0.089	0.138	NA	0.059	NA	0.026	0.052	3.07	2.61
CentralAfrica	0.0046	0.038	0.039	0.120	0.125	0.082	0.086	0.68	0.024	0.085	1.69	1.47
Zambia	0	0.024	0.037	0.043	0.042	0.019	0.005	0.08	0.023	0.031	1.60	1.36
Gambia	0.033	0.038	0.056	0.028	0.034	-0.010	-0.022	-0.15	0.050	0.055	1.054	0.555
Comoros*	0.01	0.020	0.022	0.031	0.031	NA	0.009	NA	0.018	0.024	1.23	1.31
Sudan*	0.012	NA	NA	0.030	0.034	NA	NA	NA	NA	0.011	NA	2.80
SouthSudan*	NA	NA	NA	0.013	0.021	NA	NA	NA	NA	0.024	NA	0.870
Total***	2.1	16.28	17.52	32.53	30.78	16.25	13.26	99.89	NA	NA	NA	NA
SSA Total	3.5	16.99	18.40	33.52	31.86	16.53	13.46	100.00%	9.25	15.07	1.99	2.11
WesternAfrica	1.6	10.40	10.58	23.11	21.61	12.71	11.03	81.90%	5.63	9.92	1.88	2.18
East&Others	2.0	6.60	7.83	10.41	10.24	3.81	2.41	17.90%	3.62	5.15	2.16	1.99

*****Contribution % are calculated based on 13.3Mt, ****Total is only for 23 CARD countries.**

Table 1 shows 23 major rice countries of CARD project in SSA near to doubled (1.8) the paddy production between each five years mean of 2007-2011 (17.52Mt) and 2017-2021(30.78Mt). As shown in Table 1, the increase was double if the single year comparison between 2008 (16.28 Mt) and 2018 (32.53 Mt) (CARD 2021, FAOSTAT 2023). As single year comparisons are subject to large variation errors, the trend of the increase was examined below using the five-year averages for 2007-2011 and 2017-2021.

The 10-years' increase of total paddy production (13.26Mt in 23 CARD countries) based on 5 years mean was accounted for by Nigeria as No. 1 by far, contributing about 5.34Mt or 40.3% (It is also important to note the prehistory of the 19-fold increase from the average of 0.21Mt in the period immediately after independence (1961-65) to the average of 4Mt in the period 2007-2011). The second was Mali with 1.44 Mt increase (10.86% contribution); No. 3 was UR Tanzania, with 1.21 Mt (9.13%); 4th was Côte d'Ivoire, with 1.02 Mt (7.69%); 5th was DR Congo with 0.91Mt (6.84%);6th was Guinea, 0.81 Mt (6117%);7th was Senegal, with 0.80Mt (6.03%); 8th was Ghana with 0.56Mt (3.8%); 9th was Sierra Leone 0.30Mt (2.26%);10th was Benin, with 0.28Mt (2.11%); 11th was Cameroun, with 0.21Mt (1.6%); 12th was Burkina Faso, with 0.19Mt (1.43%). These 12 countries contributed to 13.1 Mt increase in paddy production, which is 98.4% of the overall increase in 23CARD countries of SSA in the past 10 years. The West African countries contributed to 81.9% and only 17.9% was the contribution from Eastern and Middle African countries. The five years mean of 1966-1970, West Africa produced 2.04Mt of paddy (1.60Mha and 1.27t/ha) while Eastern and others Middle Africa produced 2.3Mt of paddy (1.51Mha and 1.52t/ha).

Madagascar had been the No. 1 paddy producer with the highest yield in SSA by around 2000s. But its yield dropped from 3.33 to 2.66t/ha during CARD project period of 2007-2021. In addition to political instability and social crises, and the effects of global warming such as drought and flooding, the mysterious post-2010 stagnation of rice cultivation in Madagascar, the leading Asian-type sawah based rice cultivation country in SSA in 1960s-2010s, should be noted in contrast to the development of rice cultivation in Nigeria (an emerging top rice cultivation country in SSA) and the majority of Asian countries that has been sustainable rice development since the Green Revolution in 1960-1970s.The following is a brief overview of the development of rice cultivation in SSA. Traditional African non-sawah based rice growing countries, Liberia, Mozambique and Gambia, became even lower yielding countries with an average of 0.765-1.31 t/ha in 2007-2011 to an average of 0.545-1.1 t/ha in 2017-2021. Yield declining is the main reason for the reduction of production. Apart from these four countries, production increased significantly in the 19 other CARD SSA countries due to a synergistic effect between the area under cultivation and increased yields.

3. Which states and regions contributed to the rapid increase in rice production in Nigeria in 2008-2021 (Tables 2 and 3)?

Table 2 shows the 2008-2021 changes in wet-season rice acreage and paddy production in all 37 states of Nigeria. The data are official government statistics reported by National Agricultural Extension and Research Liaison Services (NAERLS) affiliated to Ahmadu Bello University, Zaria, Kaduna State under the Federal Ministry of Agriculture and Rural Development (FMARD) in collaboration with the Federal Department of Agricultural Extension (FDAE) & Planning and Policy Coordination Department (P&PCD).The table also includes official Nigerian Government statistical data for 2000 (WARDA 2001, Project Synergy of the Nigerian Government 2004) and 2016 dry and rainy season crop data from GEMS4 (2017).

The reliability of the NAERLS wet season rice crop data in Table 2 appears to be problematic in view of the sampling survey methodology described below. The statistical survey covers not only rice production, but also millet, sorghum, wheat, maize, cassava, yams, cocoyam and other cereals, plantain/banana, cotton, ginger, cowpeas, groundnuts, soya beans, safflower seeds, tomatoes, onions, okra, cattle, sheep, goats, pigs, chickens and other livestock, catfish, tilapia, Clarias and other freshwater fish farming and other diverse agricultural and fisheries commodities together. No supporting basic panel data on survey methodology is presented, only final data. For example, Adamawa and Bauchi produced less than 100,000t of paddy until 2011-2014; after 2015, there was a discontinuous increase to 200,000-330,000t; In Ebonyi state, production halved from 0.3Mt until 2014 to less than 0.15Mt very strangely in 2015-2021. In Niger State, there was also a discontinuous sharp decline around 2009-2012. A sharp decline at this level would be comparable to a disaster outbreak in these states. However, there is no scientific discussion on the reasons for these abrupt changes. The reliability of these statistics is therefore questionable.

Table 2. Table 2. Changes in wet-season rice acreage and paddy production during 2000-2021 in 37 states of Nigeria (WARDA 2001, NAERLS 2008-2021). Dry-season data are limited for 2000 by WARDA, 2013 and 2014 by FMARD (Adesina 2014), and 2016 by GEMS4 (Aminu et al. 2017). The original GEMS4's data were divided by 1.65 using following two factors, i.e., (1) adjust the three yields data, i.e., 4.2t/ha of GEMS4, 2.56 t/ha of FAOSTAT, and 1.81 t/ha of USDA in 2016.The average is 2.1 t/ha. GEMS4's yield was 2 times higher than the mean. (2) In addition to the difference of yield data, the rice milling recovery rate for FAOSTAT was 0.65 while that for GEMS4 was 0.5, which make the adjustment factor of 1.3 (0.65/0.5). The average of the two adjustment coefficients, 1.65=(2+1.3)/2 to divide the original GEMS4 data and use the value of 60.6%.

		x(1000ton) x(1000ha)	2000 wet	2008 wet	2009 wet	2010 wet	2011 wet	2012 wet	2013 wet	2014 wet	2015 wet	2016 dry**	2016 wet**	2016 wet	2017 wet	2018 wet	2019 wet	2020 wet	2021 wet
Abia	South	Production	15	22	24	24	24	28	30	32	35		44	44	50	57	57	57	58
	East	Area	8	10	9	9	9	12	13	14	15		30	30	32	37	42	48	49
Adamawa	North	Production	128	24	35	41	42	57	60	268	354		266	266	279	281	281	275	276
	East	Area	65	121	22	35	35	37	39	99	99		156	156		162	163	164	172
AkwaIbom	South	Production	0.2	1.1	1.1	1.1	1.2	1.4	1.6	7.9	7.9		17	17	19	25	24	23	24
	South	Area	0.12	0.37	0.38	0.38	0.85	0.86	1.9	1.8	2		9.6	9.6	10	9.3	10	11	11
Anambra	South	Production	27	36	36	37	37	98	125	56	62		80	80	91	93	95	94	99
	East	Area	13	14	15	16	16	44	45	27	24		43	43	45	34	37	40	42
Bauchi	North	Production	41	50	70	66	67	78	82	88	298		238	203	216	247	246	232	250
	East	Area	22	30	36	38	37	36	38	41	96		111	119	122	137	141	146	153
Bayersa	South	Production	87	39	77	83	78	99	121	123	34		83	83	93	95	97	96	95
	South	Area	40	16	39	43	42	43	47	50	14		42	42	44	51	50	50	48
Benue	Central	Production	275	275	272	306	307	307	346	390	456		283	426	489	559	507	507	518
		Area	138	138	135	140	144	147	102	109	116		95	207	228	278	275	272	272
Borno	North	Production	125	127	145	146	146	146	144	144	48		178	178	181	187	190	186	190
	East	Area	92	110	129	136	134	129	138	125	47		112	112	113	115	116	117	120
CrossRiver	South	Production	0.15	46	46	179	197	187	100	52	53		102	102	116	145	155	158	163
	South	Area	0.1	20	20	69	91	90	94	25	27		57	57	60	63	67	70	73
Delta	South	Production	2	10	11	12	12	20	23	48	49		39	39	44	46	49	50	50
	South	Area	1.5	6	6	13	13	14	15	15	17		23	23	24	26	27	28	30
Ebonyi	South	Production	115	294	296	296	297	295	302	326	90		181	95	110	127	134	138	146
	East	Area	45	98	108	111	113	111	116	36	34		54	47	50	60	60	61	66
Edo	South	Production	8	no da	23	23	23	149	156	55	68		110	110	125	137	141	142	138
	South	Area	5	no da	13	13	13	84	85	25	27		57	57	61	67	66	64	62
Ekiti	South	Production	40	100	88	75	77	100	104	113	77		33	117	135	135	135	133	140
	WEst	Area	37	52	66	80	81	82	99	98	20		16	68	73	75	77	79	82
Enugu	South	Production	30	54	66	76	77	88	98	95	99		75	75	85	89	92	93	94
	East	Yield	10	20	23	41	42	35	36	35	36		36	36	40	42	46	50	52
FCT	Central	Production	14	40	42	57	57	163	173	287	384		32	353	408	417	415	404	415
		Area	6.4	20	21	26	26	125	126	130	133		10	189	196	201	201	291	207
Gombe	North	Production	69	90	93	92	93	111	120	236	284		166	166	174	209	211	210	215
	East	Area	38	42	44	46	49	51	56	84	89		100	100	102	125	136	147	157
Imo	South	Production	0.2	0.28	24	1.8	24	37	40	59	61		55	55	63	75	81	84	85
	East	Area	0.06	0.45	0.23	0.24	0.33	21	20	14	16		29	29	31	35	39	43	44
Jigawa	North	Production	19	57	63	14	14	110	121	210	235	64	757	187	212	246	203	203	215
	West	Area	21	64	70	40	41	103	105	59	67	21	310	97	100	109	113	118	122

Kaduna	North	Production	598	350	354	359	361	288	342	449	499	103	549	296	339	349	349	347	360
	West	Area	230	138	146	168	171	164	173	155	166	43	285	144	158	159	159	160	164
Kano	North	Production	120	207	257	268	269	248	275	348	398	584	1126	366	418	423	422	412	439
	West	Area	82	93	127	122	118	103	112	127	132	225	500	171	125	125	125	125	132
Katsina	North	Production	29	63	59	58	57	85	96	145	188		284	175	200	225	235	231	220
	West	Area	30	56	56	56	57	60	64	62	64		116	103	108	121	127	133	137
Kebbi	North	Production	68	53	55	63	59	164	179	287	319	917	1245	353	411	413	412	343	349
	West	Area	32	31	33	35	36	104	106	117	119	196	416	207	217	218	218	218	224
Kogi	Central	Production	103	125	131	135	190	492	513	510	525	57	262	447	513	564	548	522	535
		Area	37	53	56	60	61	172	187	169	193	19	147	216	236	275	272	269	292
Kwara	Central	Production	36	346	440	506	501	498	517	349	394		333	353	408	439	433	419	432
		Area	29	135	143	147	150	179	187	130	168		205	170	187	201	202	202	208
Lagos	South	Production	2.5	16	27	29	29	54	60	35	40		56	56	63	71	80	85	86
	West	Area	1.6	6.2	9.2	8.1	8.1	25	25	19	20		34	34	36	38	43	48	49
Nasarawa	Central	Production	106	91	138	183	184	185	196	399	497	83	502	355	411	414	413	404	417
		Area	45	41	54	78	80	103	102	135	143	36	241	170	178	181	181	181	190
Niger	Central	Production	473	506	532	139	141	163	263	295	325	216	622	471	545	617	626	623	630
		Area	206	163	165	156	157	157	107	128	138	59	191	208	229	262	260	258	256
Ogun	South	Production	12	21	26	31	35	46	50	61	68		22	61	69	77	85	89	94
	West	Area	10	17	20	24	12	22	23	21	23		12	42	45	52	53	54	58
Ondo	South	Production	45	54	60	61	106	108	159	79	89		104	104	117	119	120	118	120
	West	Area	22	29	29	30	51	53	57	30	34		54	54	35	37	42	48	48
Osun	South	Production	13	29	38	37	36	49	61	62	67		81	81	93	102	107	111	116
(South West	West	Area	9	16	21	22	22	22	22	24	28		39	39	42	45	50	57	61
Oyo	South	Production	0.9	no dɩ	no da	42	42	157	164	60	60		87	87	100	103	104	104	109
	West	Area	0.7	no dɩ	no da	24	24	92	94	18	20		51	51	55	56	59	61	63
Plateau	Central	Production	64	112	154	159	170	190	210	324	330		213	213	245	253	252	246	250
		Area	30	62	70	71	76	78	81	98	109		120	120	129	131	132	132	135
Rivers	South	Production	0	1.1	15	31	15	125	139	49	50		59	59	67	77	77	77	81
	South	Area	0	1	15	17	15	66	66	17	17		35	35	38	45	44	42	42
Sokoto	North	Production	14	79	52	54	59	87	91	103	123	157	436	145	162	165	165	162	163
	West	Area	20	31	43	44	46	58	59	58	60	39	129	79	80	81	82	83	84
Taraba	North	Production	200	260	276	294	294	289	309	328	390	173	665	324	366	417	407	387	388
	East	Area	200	169	174	204	204	157	161	122	127	67	260	161	174	189	191	192	201
Yobe	North	Production	37	25	27	34	33	98	97	197	238		157	157	169	156	163	159	160
	East	Area	30	21	21	21	42	42	42	88	92		102	102	103	100	99	98	98
Zamfara	North	Production	19	36	21	23	24	116	130	139	277	192	404	219	250	252	252	247	221
	West	Area	22	25	21	18	24	26	118	110	95	52	128	124	119	122	123	124	113
Total	**NAERLS**	**Production**	**2936**	**3926**	**4081**	**4538**	**4567**	**4527**	**4823**	**6690**	**7573**	**2581**	**9948**	**6916**	**7835**	**8403**	**8436**	**8172**	**8342**
	(GEMS4)	**Area**	**1587**	**1938**	**2013**	**2554**	**2571**	**2871**	**2982**	**2580**	**2626**	**757**	**4356**	**3651**	**3765**	**4065**	**4127**	**4195**	**4320**
Total	FAOSTAT	Production	3277	4179	3546	4473	4613	5433	4823	6618	7187			10517	10890	10859	8436	8172	8342
		Area	2199	2382	1837	2433	2269	2864	2931	3082	3122			4101	4447	4066	4127	4195	4320
		Production		5333	5667	4151	4567	3762	4400	4500	4300			5800	7400	7600	8000	8341	7937
Total	USDA	Milled rice		3200	3400	2615	2709	2370	2772	2772	2709			3654	4662	4788	5040	5255	5500
		Area		2300	2400	2150	2170	1575	2500	2700	2500			3200	3600	3600	3500	3650	3800
JICA total	FAOSTAT	Production		4179	3546	4473	4613	5433	4823	6003	6256			6071	N/A				
(CARD)	USDA	Production		4178	3546	4473	4567	3762	4400	4500	4300			4286	4400				
		x(1000ton) x(1000ha)	**2000 wet**	**2008 wet**	**2009 wet**	**2010 wet**	**2011 wet**	**2012 wet**	**2013 wet**	**2014 wet**	**2015 wet**	**2016 dry****	**2016 wet****	**2016 wet**	**2017 wet**	**2018 wet**	**2019 wet**	**2020 wet**	**2021 wet**

The NAERLS research methodology is outlined below. There are about 800 local government (LGAs) in the 37 states of Nigeria (an average of 20 LGAs per state), which are the basic units of the survey. Over a week at the beginning of September each year, 19 teams of about 60 field researchers, in groups of three, sampled four LGAs in each state (148 nationally), selected one community from each LGA, selected five respondents per community, and conducted interviews with 725 farmers across Nigeria. The basic problem lies in the sampling methodology of the four LGAs in each state. Particularly since 2013, rice cultivation in Nigeria has undergone a major shift from upland rice cultivation to lowland wetland rice cultivation, mainly due to the promotion of dry-season rice cultivation by the Minister of Agriculture, Adesina. The suitability of rice cultivation depends on the lowland topography and hydrological conditions, and the suitability of each LGA for rice cultivation varies greatly. The rice production clusters should be the basic focus of the survey, as in the GEMS4 study described below. Since the basic data on agricultural productions on farmers and rural communities do not exist, the NAERLS survey is a small sampling survey with a large margin of error. Even if conducted with the cooperation of ADPs in each state, the number and equipment of extension workers should be enhanced, and bottom-up statistical data should be accumulated from rural communities, especially rice production clusters. However, the size of the interviews, which would be conducted with 725 farmers across Nigeria, is too small. The main points of the GEMS4 research methodology are (1) 18 major rice-growing states covering 80% of national rice production were selected out of all 37 states in Nigeria. (2) A total of 96 major rice-crop LGAs and 165 clusters were selected from existing ADP and Fadama III data in each state. (3) From the selected clusters, 410,210 dry-season rice farmers and 1,426,505 rainy-season farmers were selected as basic data. On the other hand, NAERLS selected four LGAs annually from 37 states irrespective of rice farming clusters for a total of 148 LGAs, from which one community was selected and five respondents per community were selected and interviewed from 725 farmers across Nigeria for basic data. The NAERLS rice production statistics are less reliable than GEMS4 because they do not take into account rice production clusters and dry season production.

If you look at the national paddy production data shown at the bottom of Table 2, under Zamfara State, the FAOSTAT paddy production figures for 2016-2018 are 2.5-3.6 million tons (Mt) higher than those of NAEALS. The main reason for this large difference is that the only actual statistical data for dry-season rice production is from GEMS4. The total paddy production (12.53 Mt) for the dry season (2.58 Mt) and the wet season (9.95 Mt) in GEMS4 for 2016 is close to the 10.52 Mt in FAOSTAT. The FAOSTAT paddy production figures for all three years from 2016 to 2018 are over 10 Mt. The FAOSTAT data for this period may include data on the estimated production of dry season crops in Kebbi State and other northern states, as shown in Table 3. However, the data from NAEARL and FAOSTAT are completely consistent for 2019-2021, indicating that FAOSTAT used the wet season crop data from NAEARLS for this period. In any case, it can be seen that the reliability of the rice statistics from NAEARL, FAOSTAT, USDA and GEMS4 is not very high. Improving the reliability of statistical data in Nigeria is important for implementing appropriate rice promotion policies.

The data in the bottom two rows of Table 2 are FAOSTAT and USDA data used in the two final evaluation reports (JICA 2018, 2021) of JICA's CARD program implemented from 2008 to 2018. JICA's 2018 report uses FAOSTAT and USDA data, so the paddy production figures are 6 Mt in 2014, 6.26 Mt in 2015, 6.07 Mt in 2016, N/A (no data) in 2017, and 4.29 Mt in 2016 and 4.4 Mt in 2017 according to USDA data. However, the final report for 2021 uses data up to 2018, but strangely uses the 2018 data from NAERLS of 8.4Mt, rather than FAOSTAT. As can be seen in Table 1, the official FAOSTAT (2024) data was 6.6 Mt in 2014, 7.2 Mt in 2015, 10.52 Mt in 2016, and 10.89 Mt in 2017. The USDA data was 5.8 Mt in 2016 5.8 Mt in 2016 and 7.4 Mt in 2017. The JICA final evaluation report for 2021 missed the dramatic increase in paddy production due to the expansion of dry-season rice cultivation in Nigeria, particularly in Kebbi State, from 2014 to 2018 and beyond. Or, the final evaluation report does not place particular emphasis on the achievements of the CARD project in Nigeria. NAERLS, FAOSTAT, USDA, JICA and GEMS4 all have no reliable agricultural statistics, which may be the case.

4. Is it true that Kebbi State produced less than 100 000 ton of paddy per year before 2008, but achieved 1.85 million ton of paddy per year between 2015 and 2017, making it the No. 1 state in Nigeria?

Table 3. **Progress of Dry Season Rice Production: 2000 by WARDA, On-the job training in 2011-12 by Sawah and Fadama III, 2013 and 2014 by FMARD's estimation; 2016 by GEMS4's survey. *Estimation by 4xNumber of dry season farmers. **Field survey by using the method of Singh R (2013), Sapkota TB, ML Jat, RK Jat, P Kapoor and C. Stirling (2014). NA: no data available.**

	2000(WARDA)		2011(Sawah/FadamaIII)		2012(FadamaIII/Sawah)		2013 (FMARD)		2014(FMARD)		2016(GEMS4)		
	Cultivation area (ha)	Paddy production (ton)	Cultivation area (ha)	Paddy production(ton)	Cultivation area (ha)	Paddy production(ton)	Number of Farmers	Paddy production (ton)*	Number of Farmers	Paddy production (ton)*	Number of Farmers	Cultivation Area(ha)	Paddy production (ton)**
Abia	0	0	0	0	0	0	0	0	954	3,816	0	0	0
Adamawa	160	530	NA	NA	NA	NA	NA	NA	5,897	23,588	NA	NA	NA
Bauchi	0	0	0	0	0	0	5,822	23,285	7,219	28,876	0	0	0
Bayersa	0	0	0	0	0	0	0	0	2,301	9,204	0	0	0
Benue	412	1479	2	5	0	0	NA	NA	2,496	9,984	0	0	0
Borno	725	2400	0	0	0	0	NA	NA	NA	NA	NA	NA	NA
CrossRiver	0	0	0	0	0	0	0	0	1,306	5,224	0	0	0
Delta	0	0	2	10	NA	NA	0	0	0	0	0	0	0
Ebony	700	1800	2	10	NA	NA	NA	NA	NA	NA	0	0	0
Edo	300	141	0	0	0	0	0	0	2,154	8,616	NA	NA	NA
Ekiti	1250	710	2	10	NA	NA	NA	NA	439	1,756	0	0	0
Enugu	0	0	0	0	0	0	0	0	3,825	15,300	NA	Na	NA
FCT	0	0	4	20	NA	NA	0	0	607	2,428	0	0	0
Gombe	0	0	0	0	0	0	9,644	38	6,591	26,364	NA	NA	NA
Imo	290	550	0	0	0	0	0	0	1,009	4,036	NA	NA	NA
Jigawa	0	0	0	0	0	0	74,972	299,888	98,201	392,804	10,902	21,010	105,050
Kaduna	0	0	0	0	4	20	NA	NA	NA	NA	12,490	43,360	204,987
Kano	0	0	0	0	8	40	31,491	125,964	46,073	184,292	143,769	224,766	962,860
Katsina	0	0	0	0	0	0	3,334	13,336	34,027	136,108	0	0	0
Kebbi	195	340	18	128	199	1260	55,473	221,892	105,397	421,588	134,604	196,001	1,512,466
Kogi	0	0	4	16	NA	NA	7,355	29,420	9,852	39,408	5,940	19,200	94,520
Kwara	0	0	3	14	1	NA	0	0	2,831	11,324	0	0	0
Lagos	600	1440	6	27	NA	NA	NA	NA	NA	NA	NA	NA	NA
Nasarawa	0	0	2	10	NA	NA	0	0	3,080	12,320	7,280	35,884	137,164
Niger	0	0	50	175	100	350	1,002	4,008	31,845	127,380	29,950	59,470	383,455
Ogun	0	0	0	0	0	0	0	0	446	1,784	0	0	0
Ondo	49	120	5	20	NA	NA	0	0	NA	NA	NA	NA	NA
Osun	0	0	6	30	NA	NA	0	0	NA	NA	NA	NA	NA
Sokoto	0	0	0	0	0	0	46,087	184,348	58,433	233,732	33,638	39,480	259,018
Taraba	250	710	0	0	0	0	0	0	536	2,144	7,478	67,153	285,578
Zamfara	0	0	0	0	0	0	55,473	221,892	124,767	499,068	24,159	52,191	317,515
Total	4931	10220	106	475	312	1670	290,653	1,124,071	550,286	2,201,144	410,210	758,514	4,262,613

Table 2 above and particularly Table 3 below on dry-season rice production trends clearly show that rice production in Nigeria has developed rapidly after 2014. According to GEMS4 survey data in Table 3, this was driven mainly by the northern five states, namely Kebbi (21%), Kano (17%), Niger (8.3%), Taraba (8.2%) and Jigawa (8.0%). Kebbi State in particular made a significant contribution, due to both wet- and dry-season, especially dry season rice cultivation, which have expanded rapidly since 2014. It is unfortunate that the development of rice cultivation in Kebbi State, the driving force of rice cultivation in Nigeria in recent years, is not at all reflected in the NAERLS's official data in Table 2. FAOSTAT and USDA data, like NAERLS data, are not based on consistent scientific statistical studies that can cover the expansion of dry-season rice cultivation in Nigeria since 2013. Nigeria's agricultural statistics, including rice production, show that improvements are needed. As of October 2023, there are no official dry-season paddy production statistics from NAERLS of FMARD.

Dry-season crop paddy production compiled by WARDA, as shown in Table 3, was very low in 2000 in all states (WARDA 2001, Project Synergy of the Nigerian Government, 2004). The 2013 and 2014 dry-season crop data presented in Table 3 are estimates based on the dry-season rice promotion policy implemented by the Minister of Agriculture, Dr. Adesina, in 2013-2014 (Adesina 2014). The Federal Ministry of Agriculture and Rural Development (FMARD) distributed 50 kg qualified rice seed, 100 kg NPK (15-15-15) and 50 kg urea per capita to 290,653 farmers in 10 northern states from Bauchi to Zamfara in 2013 and to 550,286 farmers in 24 states in 2014. Data on paddy production and area in the dry season both in 2013-2014 are estimates based on the assumption that each farmer cultivated 1 ha of dry-season rice and obtained an average paddy yield of 4 t/ha (Table 3, Adesina 2014). These are not actual measured values. The only relatively reliable data based on field surveys and farmers' interviews of dry-season rice cultivation with a stated methodology is GEMS4 (2017), which surveyed both dry-season and wet-season rice cultivation in 18 major rice-producing states in 2016, and the data are included in Tables 2 and 3.

It should be noted that the data in Tables 3 of GEMS4 are taken directly from the original GEMS4 data, but as explained in Table 2, all GEMS4's paddy production data in 2016 were divided by 1.65 to allow comparison with NAERLS, FAOSTAT and USDA data. As a result, all paddy production and yields in Table 2 are 60.6% of the original GEMS4 data.

According to a 2017 Kebbi State ADP report (Shehu and Lolo 2017) and NAERLS and FDAE (2014), annual paddy production in 2011-2012 was only about 60,000 ton. However, from 2013 onwards, an incredibly significant increase in production began: in 2013, the wet season was 0.19Mt and the dry season 0.2Mt, in total 0.39Mt; in 2014, the dry season was 0.33Mt and the wet season 0.19Mt, in total 0.52Mt; in 2015, the total dry and wet season was 0.75Mt. As shown in Figure 3, in 2016, the total was 1.85 Mt (annual total of 1.79Mt in GEMS4 data in Table 2, adjusted with FAOSTAT and USDA, 1.03 Mt in the wet season and 0.76 Mt in the dry season; in GEMS4 crude data in Table 3, 1.51 Mt in dry season and 2.06 Mt in wet season, total 3.57 Mt), making it Nigeria's No. 1 paddy rice producing state (Shehu and Lolo 2017, Tene 2017, Essiet 2016, Yombe 2016, GEMS4 2017).

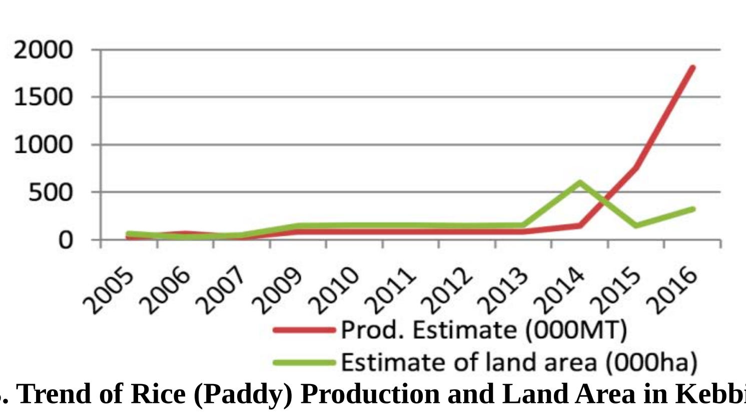

Fig. 3. Trend of Rice (Paddy) Production and Land Area in Kebbi State.
Cited from Kebbi State Agricultural Development Project (Shehu B and Lolo A 2017)

Paddy production in Kebbi state as a percentage of Nigeria's total production jumped from 1.3% in 2011, 8.1% in 2013, 6.7% in 2014 and 20.3% in 2016. This is a phenomenal increase in production. The reliability of the statistical data from 2016 onwards in the chart below will be verified in this paper. The realization of the rice revolution by Kebbi State was also being told in the neighboring state of Niger. On October 16, 2017, Niger State Deputy Governor's remarked 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, in accordance with FMARD's rice promotion strategy (Adesina 2014), the Niger state for the explanation of the sawah technology dissemination plan in Niger state.

Table 4 below presents data on the development of rice cultivation in Kebbi state, particularly dry-season rice cultivation, showing the volume and prices of paddy purchased and sold by traders and millers outside Kebbi state from May 2016 to June, the end of harvest. These data do not include the March-April harvest, as dry-season harvesting starts in March and ends in June. It also does not include sales and purchases in the other clusters in Suru LGA, paddy purchases by local traders and consumption by farmers. The total sales volume of 52 000 ton (692750 bags x 75 kg) shown at the end of the table represents 19.6% of the total dry season production of the Suru Local Government (LGA) of 266 000 ton in 2016. There are 23 LGAs in Kebbi LGA, of which 11 LGAs have rice clusters along the Rima, Niger and Zamfara river flood plains. These 11 clusters are estimated to account for more than 80% of the total paddy production in Kebbi state. Paddy production (milled rice ratio 0.5) No 1 in Kebbi State in the wet and dry seasons of 2016 was outstandingly high in Suru LGA at 870 000 tons (600 000 tons in the wet season and 266 000 tons in the dry season); No. 2 was Koko Besse with 440,000 tons (176,000 tons in the wet season and 266,000 tons in the dry season); No. 3 was Shanga with 360,000 tons, followed by Birinin Kebbi 369,000 tons, Ngaski 320 000 tons, Arugungu 274 000 tons, Jega 193 000 tons, Bagudo 169 000 tons, Dandi 150 000 tons, Augie 116 000 tons and Bunza 87 000 tons, respectively (GEMS4 2017). Locations of these 11 LGA rice clusters are shown in Figure 2.

Table 4: An Example of Paddy Purchased by Major buyers in Suru Market during the 2016 Dry Season Harvest Period (Total dry season paddy 266,000ton, March- June, 2016) (GEMS4 2017)

Buyer/Destination	Quantity of Paddy purchased (No. of Trailer)	Quantity of Paddy purchase in bags (75kg bag)	Unit Price (Naira/bag)	Value of Purchase
OLAM	69	31,050	10,000	310,500,000
WACOT	13.3	6,000	10,000	60,000,000
UMZA Rice Mill (Kano State)	157.1	70,700	10,000	707,000,000
Labana Rice Mill (Kebbi)	16	7,200	10,000	72,000,000
Goro Farm (Kebbi State)	26	11,700	10,000	117,000,000
Kano	200	90,000	10,000	900,000,000
Maiduguri	179	80,550	10,000	805,500,000
Katsina	110	49,500	10,000	495,000,000
Ogun	16	7,200	10,000	72,000,000
Kaduna	128	57,600	10,000	576,000,000
Sokoto	89	40,050	10,000	400,500,000
Zamfara	90	40,500	10,000	405,000,000
Bauchi	56	25,200	10,000	252,000,000
Gombe	64	28,800	10,000	288,000,000
Hadejia	49	22,050	10,000	220,500,000
Niger	38	17,100	10,000	171,000,000
Adamawa	67	30,150	10,000	301,500,000
Ilorin	42	18,900	10,000	189,000,000
Nasarawa	87	39,150	10,000	391,500,000
Kogi	39	17,550	10,000	175,500,000
Abuja	4	1,800	10,000	18,000,000
Total	**1539.4**	**692,750**	**-**	**6,927,500,000**

Data on dry-season paddy trade on behalf of Kebbi State was collected at Suru market, the central paddy collection center in Suru LGA, where market staff worked with rice farmers' associations to capture transactions through record keeping (GEMS4 2017). This represents 19.6% of the total dry-season production of 266 000 ton. The purchase price of 10 000 Naira for 75 kg paddy was based on the dollar exchange rate at the time of 300 Naira = USD 1. This translates to USD$ 440 per ton, and even during the high price period of the dry season, a milling rate of 50% would result in a milled rice price of USD 880 per ton of rice, which is a significant income for farmers. (Incidentally, as of January 2024, the price of paddy had risen even further to USD$ 700 per ton. The main reasons for this are said to be a decrease in smuggled rice due to border closures, flood damage, worsening security and a decrease in the area planted due to rising input material prices for production, but there is also a theory that hoarding by dealers, including paddy farmers, is the main cause, and the rapid increase in rice millers in last ten years due to the CARD project and government promotion policies is causing hardship).

The aim of this paper is to scientifically verify the endogenous development of irrigated sawah platform and rice cultivation in Kebbi state, i.e. the Kebbi rice revolution, by comparing and contrasting Google earth time series images and field survey results from 2011-2024 in Kebbi state. If the Kebbi rice revolution is a fact, the objective is also to clarify how it came about. The next challenge is to realize innovations that will enable the Kebbi rice revolution method, i.e. the Sawah platform at evolutionary stage 4 and above, to be spread across Nigeria in a farmer-led initiatives with the support of the states and Federal Government as well as Japan and other Asian countries. Given Nigeria's irrigated sawah platform potential for rice cultivation of about 5 million ha and an average paddy yield of 5 ton/ha, an annual paddy production of 25 million ton (about 10 million ton as of 2020) is the target for the next 10-20 years (Sawah Technology 5). At the same time, it is also a goal for the next 10-30 years to spread Sawah Eco-technology, which was born and evolved in Nigeria and Ghana, to neighboring countries such as Mali, Niger, Benin, Togo, Ghana, Burkina Faso, Corte d'Ivoire, Guinea, Gambia, Guinea Bissau, Senegal, Liberia, Sierra Leone, Chad, Cameroon, South Sudan, and Sudan to achieve the realization of Rice Innovation.

Dr Adesina, Minister of Agriculture and Rural Development (2011-2014), published the Agricultural Transformation Agenda (ATA) program as the title of “SCORE CARD” (Adesina 2014). Dr. Adesina implemented a policy to promote dry-season rice production from 2013 in order to facilitate the rice value chain. Based on this outcome, three main activity targets were set for 2014. Namely, (1) to promote dry-season rice cultivation of 0.6 million hectares in 24 states; (2) the names of rice farmers interested in receiving credit from the Nigeria Incentive Based Risk Sharing for Agricultural Lending (NIRSAL) list; and (3) establishing Sawah Eco-technology in 10 states to promote optimal use of water in the Fadama wetlands and promote the development of appropriate irrigated sawah platforms (proper bunding, puddling, levelling and transplant cultivation) using walking power tiller. However, following a change of government in April 2015, Minister of Agriculture Adesina stepped down, who is President of the African Development Bank as of 2015-2023+. The synergistic effect of the sawah eco-technology and the Anchor Borrowers Program (ABP) promoted by the new Buhari Government has accelerated the development of the sawah platform through farmers' self-help efforts in Kebbi state and is expected to increase to more than 100 000 ha by around 2013-2022. In floodplains with similar hydrological conditions in Sokoto, Niger and Adamawa States (whether undeveloped land or government-developed irrigated land without standard sawah platform of evolutional stage 4 or higher), the Sawah platform for mobile pump irrigation has expanded by several thousand ha each through technology transfer between farmers, as of 2023. This can be seen in the Google earth image as of 2023. In addition to Jigawa, Kebbi, Sokoto, Zamfara and Kano states, dry-season rice cultivation has expanded in Adamawa, Kogi, Bauchi and Gombe states since 2016. The new Tinubu Government is also trying to further promote dry-season rice cultivation.

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

Due to the construction of many dams on the upper reaches of the Rima (Sokoto) and Zamfara rivers in Sokoto, Zamfara and Katsina States, the flood plains of the Rima (Sokoto) and Zamfara rivers in Kebbi State suffer relatively little damage from flooding. However, flood damage has also occurred due to the destruction and release of water from poorly managed such dams. Furthermore, in recent years, the frequency of flood damage has increased due to the effects of global warming. However, there is less risk of destructive floods wiping out irrigated sawah systems, as is the case in many Asian countries. As in Egypt's Nile River Delta, flooding is gradual, so there are not many cases where large-scale rehabilitation works are required due to the destruction of bunds of sawah platform or the accumulation of sediments. This often contributes rather to fertility renewal through the deposition of fine-grained fertile top soils. In many cases, shallow groundwater is pumped directly from PVC pipes installed near individual sawah plots and irrigated with 10-50 m long hoses to surrounding 0.1-1 ha sawah plots, and irrigation drainage channels are either unnecessary or short (less than a few 10 m). However, due to frequent flooding of rice in recent years caused by relatively deep waterlogging during the rainy season, dry-season cultivation (December-May) has been expanded as shown in Table 3, with backing from FMARD (Adesina 2014) since 2013, as mentioned above. Dry-season cropping also has the advantage of easier weed and pest management, as well as high solar radiation, which enables high yields in Egyptian style rice cultivation (Table 2, GEMS4 2017).

Kebbi state is in the Sudan Savanna zone with an annual rainfall of 750-1000 mm (rainy season: June-October), making rainfed upland rice cultivation impossible and rice cultivation is limited to irrigated sawah platform developed on river flood plains and in inland deltas. Rice cultivation on flood plains and deltas depends on how to cope with the risk of inundation by floods. Based on the findings of Zwart et al. (2016) in Figure 3, the flood risk of a total of approximately 500 000 ha of flood plains across Kebbi state can be summarized as follows. (1) There are approximately 300 000 ha of flood plains in the Rima (Sokoto) River basin, of which approximately 200 000 ha between Augie-Arugungu-Birinin Kebbi and Bunza-Suru-Bagudo on the Sokoto State border are at relatively low flood risk for rice cultivation. (2) A floodplain of about 50 000 ha on the main stream of the Niger River between Bagudo-Koko Besse-Shanage-Mgaski is also at relatively low risk of flood damage. The flood plains shown in green color in Figure 2 have a low flood risk, while those in red and yellow colors have relatively high flood risk. These flood plains with low flood risk allow for two to three rice cultivation in wet and dry season of a year. Areas at high flood risk are approximately 50,000-100,000ha from Birinin Kebbi downstream to Bunza at the confluence of the Zamfara River and 50,000-100,000ha of the main stream floodplain of the Niger River from the Benin border city of Kamba (Dandi LGA) to Bagudo. Flood plains with high flood risk are areas where the river width is relatively narrow. Therefore, even these floodplains with high flood risk are also interspersed in places with floodplains with low flood risk (locally relatively wider flood plains), which are estimated about 50,000ha in total.

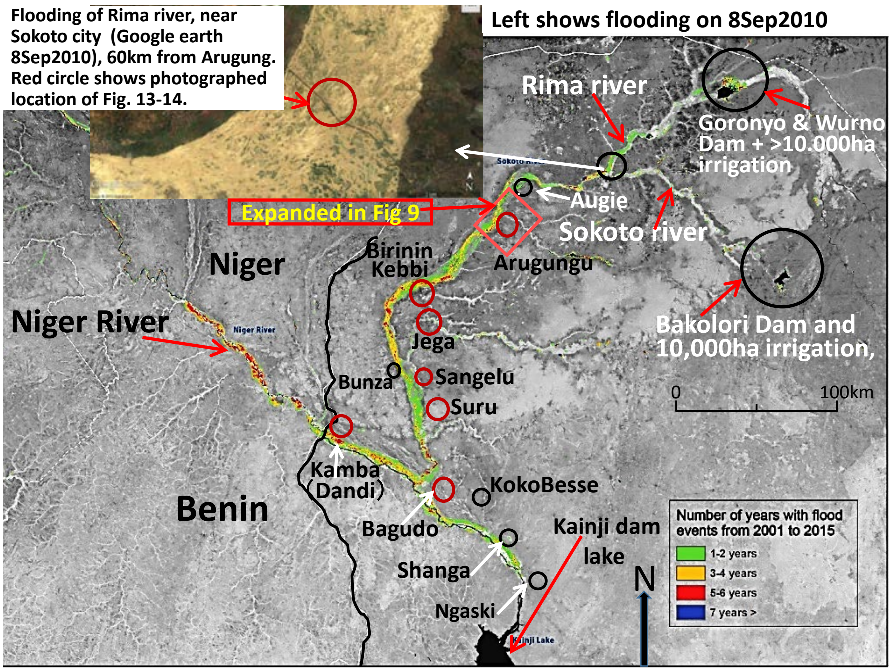

Fig 4. Sawah technology demonstration, on-the-job field training and dissemination sites (six sites (Arugungu, Birinin Kebbi, Jega, Sangelu, Suru and Bagudo, circled in red) were funded by the JSPS Grants-in-Aid for Scientific Research, Specially Promoted Research and Basic A in 2011-15 (Wakatsuki 2012, 2018); Kamba site dissemination was funded by NCAM under FMARD in 2017-18. (Flood frequency maps used in the original map are from Zwart et al 2016).

The World Bank
INTERNATIONAL BANK FOR RECONSTRUCTION AND DEVELOPMENT
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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. 5. MOU between Nigerian Sawah Team and Fadama III for the incorporation of Sawah Technology

Fig. 6. Powertillers supplied by JSPS fund (Wakatsuki 2007-12, and 2013- and 2018) for Sawah Technology training at Kebbi, Ebonyi, FCT, Benue, Delta and Lagos states during 2010-2015. ① 12 sets of Dong Feng powertiller ready to deploy to the six states at NCAM storage warehouse. ② Rotavators are suitable for puddling that have already been developed. As shown in Fig.21④, ploughs are more efficient for new sawah development. ③ Anti-skid wheels are suitable for upland and lowland areas with relatively firm ground. As shown in Figures 9③ and 21④, Cage-wheel is more suitable for wetlands with soft muddy soils. ④ Other power tillers used for other Sawah project Shakti from India and Kubota/Japan, at NCRI storage.

As shown in Figure 5, in June 2010, the Nigeria Lowland Agriculture Development Project (Fadama III) approved to incorporate Sawah technology as a project technology. With the approval of the funders of Fadama III, the World Bank, from March 2011 and December 2012, the National Centre for Agricultural Mechanization (NCAM) and the Kinki University/Shimane University team conducted the demonstrations and on-the-job trainings of the sawah eco-technology. Among the initial necessary costs for this action research, two sets of power-tillers (Fig. 4) and sawah technology experts cost for the on-the-job training were provided by the Grant-In-Aid of Japan Society for the Promotion of Science (JSPS), specially promoted research on "Materialization of West African rice green revolution through Sawah based eco-technology and the creation of African adaptive Satoyama watershed systems, 2007-2011" (Representative: Wakatsuki). All the other costs were provided by Fadama III/ADP through the World Bank and Nigerian Government. Sawah technology demonstrations and field training were conducted in six major rice growing areas in Kebbi State -i.e., Augungu, Birinin Kebbi, Jega, Sagelu, Suru and Bagudo (Figure 4). From March 2011 to April 2012, development of demonstration irrigated sawah plot construction and demonstration of sawah based rice cultivation were conducted by the Nigerian NCAM/Kinki University and Shimane University Sawah team in parallel with on-the-job training of farmers. Farmer groups at 18 sites in these six regions each developed 1 ha evolutionary stage 5 irrigated sawah platforms and managed sawah based rice cultivation using the transplanting method, producing a total of 127.5 tons of paddy (average 7.1 t/ha) on a total of 18 ha (Table 5-1). The results were confirmed by 16 farmer leaders from different parts of Kebbi State, who purchased at their own expense 1-5 power tillers each, for a total of 22 sets power tillers. They have thus developed an evolutionary stage 4-5 irrigation Sawah platform that also allows for dry-season rice cultivation. That is, during the rainy season from April 2012 to October 2013, as shown in Table 5-2, 131 ha of sawah platform were developed and 844 tons of paddy production was achieved; during the dry season from November 2013 to the end of May 2014, the area was expanded to 199 ha and 1260 tons (6.3 t/ha) of paddy production was achieved, as shown in Table 5-3. These were almost entirely due to the self-help efforts of farmer groups and Fadama III/ADP in Kebbi state.

The Governor of Kebbi State declared these results the '**Kebbi Rice Revolution**' at an economic summit in the capital Abuja in September 2013 (Figure 7, Dakingari 2013).

Table 5. Training, Demonstration and Extension of Sawah Technology in Major 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 1st Demonstration and Training , 2nd Extension and 3rd Dry season areas are shown in Figure 2.**
Yield data by Fadama III
****Mean**

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

Local Governm. Area (LGA)	Farmers	2. No. of powertiller bought	2. Sawah area developed (ha)	2. No. of 100kg paddy bag	2. Paddy yield (ton/ha)	3. No. of powertiller bought	3. sawah area developed (ha)	3. No. of 100kg Paddy bags	3. 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**

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. 7. 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.

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. 8. 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

The governor reported that Kebbi State cultivated 380,000 ha of wet-season rice in 2013-14, yielding 700,000 tons of paddy, and that dry-season rice (from around October 2012 to June 2013) produced 170,000 tons of paddy. In addition to including the two-year dry/rainy season from October 2012 to July 2013, the capital Abuja, the report is considered to include expected figures as it is a political announcement in Abuja. As such, the data differ slightly from those in Figure 5 and Table 3. However, as shown in Figure 3 and Tables 3 and 4., there has certainly been a breakthrough in rice cultivation in Kebbi State between 2013 and 2017. A shown in Figure 6 below, "Document of the world bank report No. ICR00003895, 2016)" described that Sawah Ecotechnology for Rice Farming (SERIF) was innovative, which can be 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 paddy yield and paddy production especially in Kebbi state.

As a result, as reported by the World Bank (2016), paddy yield increased 2-3 times from 1.5-2.5 t/ha to 5-7 t/ha with the introduction of Sawah technology. The increase in paddy production of about 1 ton per hectare can cover the cost of pump irrigation, allowing for investment in further expansion of irrigated farmland. As reported in the GEMS4 (2017) field survey in Table 3, Kebbi State has become the number one rice growing state in Nigeria. In Kebbi state as a whole, more than 100 000 ha of irrigated sawah platforms in evolution stage 4 and 5 were developed in about 10 years, 2011-2020. The Kebbi rice revolution has been achieved through an effective synergy between intrinsic farmer self-help efforts and the support of the World Bank and the Kebbi Government-supported Fadama III and ADP, and will continue to expand beyond 2020.

The National Centre for Agricultural Mechanization (NCAM) under the Ministry of Agriculture and Rural Development is trying to make nation-wide this success story in Kebbi State, based on Minister Adesina's policy in 2014 to establish the ESTRASERIF (Expansion Strategy for Sawah Eco-Technology and Rice Farming) as a regular operation, with the Ministry's budget, since 2015 (Adesina 2014). It has been implemented in Akwa Ibom, Ambra, Benue, Cross River, Delta, Ebonyi, Ekiti, Enugu, Kaduna, Kano, Katsina, Kogi, Kwara, Lagos, Nasarawa, Ogun, Ondo, Osun, Taraba and Zamfara states. Although small in scale, the project is implementing nationwide dissemination activities, while also obtaining budgets from the respective state governments. However, the explosive endogenous expansion seen in the 2011-2020 decade in Kebbi State has so far not been observed.

However, the authors observed recently in 2024 some new Google earth imagery of the Hadejia river flood plains in Jigawa state, the Komandugu river flood plains near Gashua, in Yobe state, various flood plains of the Gbako River, the Kaduna river and the Niger river near Bida in Niger State and the floodplains of the Benue River near Newman in Adamawa State, farmer-led small pump irrigated sawah platform for rice cultivation such as those seen in Kebbi State since 2016-2018. In Kebbi state, the expansion is sustained beyond 2020. Further surveys will be carried out within a few years using Google earth images etc.

6. Expansion and improved evolution of sawah platforms in the floodplains of Kebbi state before the introduction of sawah technology (1987 and 2011) and after from 2011 to 2024-present

Kebbi state as a whole has a total of 500,000 ha of flood plains and inland deltas (*Fadama*, meaning wet lowland or marshland in the local language), mainly along the Rima, Niger and Zamfara rivers. Before 2010, when Sawah Eco-technology extension activities launched, *Fadama* development projects I (1993-2002), II (2003-2010) and III (2010-2019) in Kebbi state have been supported by the World Bank. A distinctive feature of these *Fadama* projects in Kebbi state is that the style of on-site irrigation, i.e., individual farmland-based small pump irrigation, rather than large-scale government-led dam irrigation projects as in other states. Hundreds of thousands of farmers irrigate individual farmlands with small pumps (one or two per hectare, costing $250-500 per pump). Groundwater shallower than 8 m deep (including surface water from rivers, crescent lakes, swamps, etc.) in Fadama farmlands is pumped and irrigated using numerous PVC tube wells installed to a depth of shallower than 10 m of ground level. The rice irrigation system is based on sawah platform at the evolutionary stages 1 (non-sawah platform with no bunding and no leveling), 2 (bunded plots but no leveling with ridge planting) and 3 (poor bunding with small plots with poor leveling). Development had been carried out endogenously by the farmers themselves in a traditional manner. Such immature sawah infrastructures up to evolutionary stage 3 existed on about 30 000 ha in 2010. About 100,000 small pumps were implemented by farmers through subsidies and more than 100,000 farmers were irrigating a total of 30,000-50,000 ha in the dry and rainy seasons (Table 2). Each farmer has irrigated upland fields (mainly onion cultivation) and various sawah platforms of various acreages, ranging from less than 1 ha to more than 100 ha per farmer. If the flooding season (July-September) is avoided, shallow groundwater can be used for irrigation from October-July with small pumps, allowing for two or double cropping seasons in a year, and even three if rice cropping is included in the rainy season.

However, on the other hand, in northern states outside Kebbi, such as Borno, Gombe and Jigawa States, Sokoto, Zamfara and Kano States, government projects have developed large-scale irrigation facilities in the thousands to tens of thousands of hectares over the last few decades. Examples include the Wurno irrigation project in Sokoto State, the Bakolori irrigation project in Zamfara State, Hadeija irrigation in Jigawa State and the Kano River Basin Irrigation Site. In these irrigation projects, water storage and intake facilities, irrigation channels and drains are developed and managed by government agencies. Only the terminal irrigation drains are managed by farmers. Paddy production platforms, i.e. irrigated farmlands where rice is planted, i.e. irrigated paddy platforms, are undeveloped as in Kebbi Oblast before 2011 and are at sawah evolutional stage 1-3. It is left to the farmers to create a leak-free footpath between individual irrigated paddy plots, and to rake and level the soil surface, which is important for water management and weed control. Moreover, the government irrigation engineers do not understand the critical importance of such sawah platforms and are usually not informed or trained by farmers. Therefore, in addition to the water management of farmers' irrigated rice plots (i.e., sawah plots), irrigation system management as a whole is inadequate and inefficient, resulting in high maintenance costs. Thus, there are difficulties in expanding the area of irrigated sawah fields. This is a fundamental problem in Nigeria and SSA countries, where the concept and technology of irrigation and drainage systems exist, but the concept and technology of sawah platform systems are immature.

The recent emphasis in AfricaRice, IITA, IRRI and elsewhere on 'good agronomic practices'（GAP）as the key to increase productivity, but it is not understood that the existence of the Good Sawah Platform (GSP) is a prerequisite for the implementation of such GAPs. It is sufficient to emphasize the importance of GAP in Asian countries with a long history of sawah based rice cultivation. However, SSA countries have a history of irrigated sawah based rice cultivation shorter than 60 years, which started after their independence from the West in the 1960s. They also have an excessively long negative history of 500 years of slave trade and colonial rule by Western countries that have no understanding of irrigated sawah based rice cultivation. It cannot be over-emphasized that the existence of GSPs is a prerequisite for GAPs to function effectively.

6.1. **Observations of non-sawah rice cultivation, i.e., Evolutional stage 1 sawah platform for rice cultivation: Lowland without bunding and leveling (irrigation or rainfed), during survey of AR1-AR4 sites in the Sokoto (Rima) river floodplain, Arugungu in December 1987(Oyederan 1990).**

Fig. 9A is an enlarged view of the area around the main road crossing the floodplain near Arugungu in Fig. 4. First survey by Mr. Oyediran (currently Prof. Ladoke Akintola University of Science and Technology) and Wakatsuki was conducted on December 14-16, 1987, which was a joint PhD program under IITA and Obafemi Awolowo University, Ile-Ife, Nigeria (Oyediran 1990). The area around Arugungu city has been the center of rice cultivation in Kebbi state in1980s and still now. In addition, a fishing festival (participants compete for the size of the fish caught) is held in the floodplain crescent lakes in this vicinity, in which the president Buhari participated in March 2020.
Figure 9B(left) and 9B(right) were taken at approximately the same location with a time difference of 28 years (GPS position around 12.756N 4.512E). In 1987, African rice (Oryza *Glaberrima*) was being grown on a floodplain with no sawah platform, i.e., evolution stage 1, as shown in the December 1987 photo in Figure 9B (left). The photo in Figure 9B (right) was taken on July 2015 when Wakatsuki and Ademiluyi (NCAM) demonstrated advanced sawah platform development and puddling and leveling under waterlogged conditions by attaching cage-wheels to a power tiller manufactured by Quick Co. Ltd. in Indonesia. This site is where the

first sawah technology training and demonstration was conducted in March-June 2011, so as of 2015, most of the surrounding floodplain has already been developed by farmers' self-help efforts with evolutionary stage 4-5 sawah platforms, and farmers are standing on the sturdy bunds. In 2011, only Chinese-made power tillers

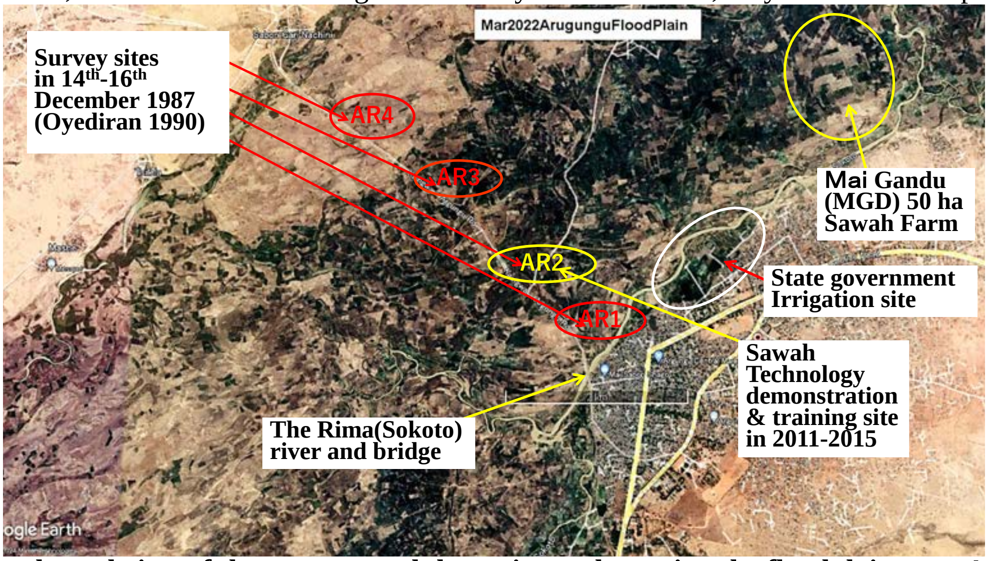

Fig. 9A: An enlarged view of the area around the main road crossing the floodplain near Arugungu city in Fig. 4. AR2 and Mai Gandu farm are the sites that the first on the job sawah technology trainings and demonstrations were done in 2011. In 2015 advanced training was done at AR2 site.

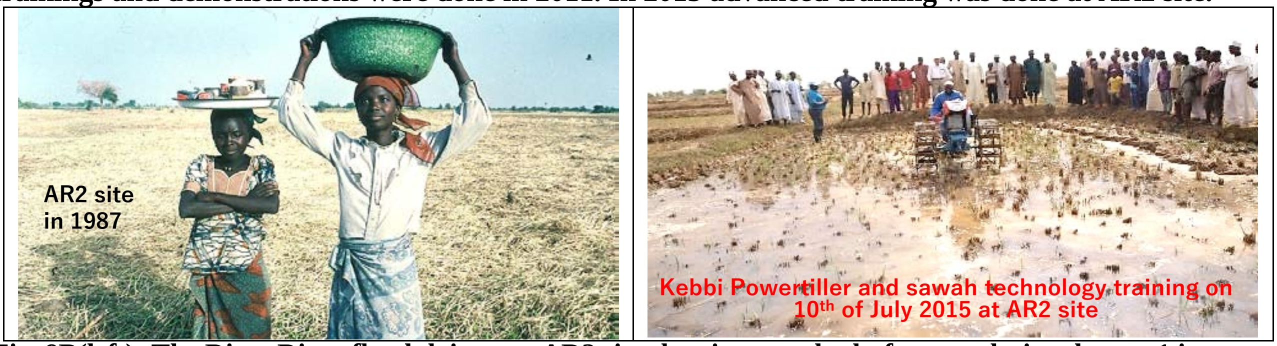

Fig. 9B(left): The Rima River floodplain near AR2 site showing sawah platform evolutional stage 1 in December 1987. Fig. 9B(right): The same AR2 site in July 2015 showing sawah platform evolutional stage 4 and 5. (GPS position is 12.756N 4.512E)

Fig. 10①-③: Sequential photographs taken the state government pump-irrigated rice land in Figure 9A. Fig. 10④ was taken toward the northeast on the upstream side of the bridge as shown in Fig. 9A.

equipped with anti-skid wheels and rotavators as shown in Fig. 6③ were available, which are suitable for dry rice fields and upland soils. Cage-wheels are for small soil bearing capacity of wet and soft soils, which are suitable for sawah platform development and rice cultivation in the rainy season.

As shown in Figure 10①-③ taken in 1987, which is sequential photographs taken around the 50 ha of the state government pump-irrigated rice land as shown in Figure 9A. Then Sokoto state, Kebbi state became a separate state in 1991. Rice in harvest season can be seen in the distance of the photos. Onions were irrigated with a small portable pump from a shallow 3-5 m well dug by hand from November to May during the dry season. Although salt precipitation is observed on the soil surface due to strong evapotranspiration during the dry season, the salt damage to crops is not so serious because the surface salts are washed away by flooding during the rainy season. Rice cultivation was done in non-flooded topographical position from June to December with deepwater tolerant African rice (Oryza *Glaberrima*), taking advantage of the 1-3 m topographic elevation difference of the floodplain, where water management is not possible, and direct seeding rice cultivation was done considering the timing of flooding and the flood water level and timing. Figure 10④ was taken towards the north-east on the upstream side of the bridge crossing the Rima (then Sokoto) River, which flows bordering the western edge of Arugungu City. The location is estimated to be about 2 km upstream northeast of the bridge**.**

Fig. 11①: The photo was taken from inside the car showing the overview of Arugungu flood plain. Photos of ② and ③ were taken near AR 3 site, location is shown in Fig. 9A, in December 1987

Fig. 11 ① photo shows overview of Arugungu flood plain from the bridge of Arugungu town heading toward the AR1-AR4 sites (See Fig. 9A). The road traversing the flood plain was nearly the same position to the current road in Fig. 9A. The Rima (Sokoto) river in the dry season can see on the right side of the ① photo, which was taken from inside the car. The lower two photos were taken near AR 3 site. African rice (Oryza *Glaberrima*) and wild rice had been widely grown. Mr. GB Oyediran (Currently Prof. LAUTEC University, Nigeria) investigated wild rice in 14-16 of December 1987. All these rice-crop areas were non Sawah platform and had a sawah platform evolutional stage of 1. According to Oyediran's (1990) soil description, AR2 was mostly flat, located 1.8 km from the Arugungu bridge, between a natural levee and a swampy area where short-stalked African rice (*Oryza glaberrima*) and grassy weeds were cultivated or growing. AR3 is a swampy area 1 km away from AR2, and there was little cultivated or barren rice growing in the vicinity of the soil profile. However, as shown in the ② and ③ photos in Figure 11, African rice and wild rice were grown extensively in the surrounding area.

Fig.12 (Left side): Cultivation deepwater African Rice (*Oryza Glaberrima*) and Duku hill near Birinin Kebbi. Fig.12 (Right side): Two soil profiles at AR2 site (Fluvaquent) and at AR3 site (Tropaquent).

Fig. 12(Right side) shows two photographs of soil profiles, AR2 is Fluvaquent formed on proximal natural levee position and AR3 is Tropaquent forms on backswamp position, both of which are typical flood plain soils. Calculations based on the data reported in Oyediran's PhD thesis (1990) shows that the organic carbon accumulation in the AR2 soil profile was 33.4 ton in Carbon/ha (0.34% C content) from 0-50 cm and in the AR3 from 0-85 cm to 76.9 ton Carbon/ha (0.45%). Asian paddy(sawah) soils from the 1960s, the same soil profile was studied in the 2010s after a half-century of rice-green revolution farming, and found that organic carbon accumulated at an average rate of 1 ton C/ha/year for 50 years (Yanai et al 2021 and 22, Sawah Technology(4)). This study was the result of country-level surveys in Thailand, Indonesia, Bangladesh and other countries. Therefore, if sawah (paddy) rice cultivation in SSA can be realized on a scale of 40% of Asia (50 million ha) by around 2050, the amount of carbon sequestration due to sawah based rice cultivation in SSA altogether will be $1x(CO_2/C)$ x5 $x10^7x=1.8x10^8$ tonCO_2/year. This is a significant contribution from SSA not only to increased food production, but also to the prevention of global warming. It is a promising contribution to the i.e., "4 per 1000" (Poulton 2018) initiative, a movement to store carbon in soil to prevent global warming.

6-2. Pump-irrigated micro rudimentary sawah platform (Evolution Stage 3) and irrigated ridged rice cultivation (Evolution Stage 2) in Kebbi and Sokoto states just before the sawah technology dissemination in 2011. Google earth imagery observation of sawah platform evolution and expansion by 2011-2023 due to the dissemination of Sawah technology.

Figures 13-19 show the rice farming in the Rima (Sokoto) River floodplain from Sokoto to Birinin Kebbi and in the Zamfara River floodplain near Jega. These surveys were conducted in May 2011 (24 years after the 1987 survey), just before the start of extension activities through on-the-job training and field demonstration of rice farming based on sawah platform evolutional stages 4 (oxen plowing) and 5 (power-tiller use) using sawah technology. The progress of sawah technology expansion near the cities of Arugungu and Jega, Kebbi State, approximately 10 years after the start of extension activities, is presented for comparison. It also outlines the relative stagnation of sawah based rice cultivation in the neighboring state of Sokoto, where no Sawah Technology extension activities were implemented, for comparison.

When Wakatsuki re-examined with Admilyui in May 2011, as shown in Fig. 13 and 16, rice and onions were cultivated in micro rudimentary sawah plots using small pumps which lifted shallow ground water shallower than 8 m. Irrigated sawah rice cultivation (evolutionary stages 2 and 3) was an extension of onion cultivation of upland field crops. Figures 13①-② show micro (small) rudimentary sawah fields (platforms) along the road crossing the Sokoto (Rima) river floodplain (evolutionary stage 3) and Figures 13③-④ show irrigated ridged rice platfrom (cultivation) (evolutionary stage 2) (see Figure 4, whose GPS location is 13.1136°N, 5.2565°E). Figure 13③ photo was taken in early May 2011 at the central red circle of the road and small bridge crossing the floodplain near Sokoto (the point indicated by the red circle in the photograph pasted above Figure 4). The photograph in Figure 13① is an enlargement of the red circle in Figure 13②. Irrigation water is pumped and supplied via a hose to the central canal of the micro (small) rudimentary sawah fields (platforms) in Fig. 13①

. All photographs were taken in May 2011. Shallow groundwater is sucked up by a small pump through pre-installed PVC pipes to irrigate small parcel semi-paddy fields, where rice, tomatoes and onions are grown. As this is an extension of field irrigation for onions and other crops, the beds and irrigation channels were poor. Neither leakage nor water storage can be managed due to inadequate furrowing and levelling. Therefore, the depth of waterlogging cannot be controlled on this irrigation platform, making weed control and nutrient management difficult. Inevitably, water use efficiency is very low. Average yields were less than 2.5 t/ha (Figure 8, World bank 2016).

Fig. 13①-②:Micro rudimentary sawah plots (evolutional stage 3) and Fig.13③-④: Ridge rice cultivation with shallow tube well and small pump irrigation along the road crossing the Rima River floodplains (see Fig. 4). GPS position is approximately 13.1136N 5.2565E. The left photo ① is the expansion of the red circled area of ②. Irrigation water is pumping up and supplying using hose to the central canal of the ① micro rudimentary sawah (evolutional stage 3). All photos taken on May 2011.

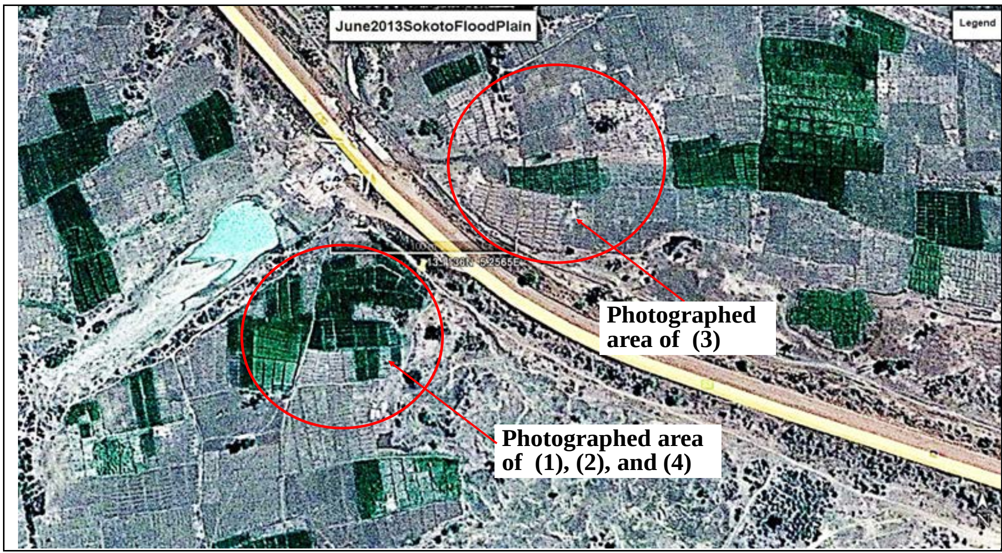

Fig.14A.Google earth image near the location 13.1136N 5.2565E in June 2013 (beginning of the rainy season).

Note: The 2 years of time difference from the time of the photographs of Fig.13①-④. Dark green areas show sawah platform which evolutionary stage is estimated to be 3, while the other sawah platform is evolutional stage 2 (ridge rice cultivation)

Fig. 14B. Google earth image of the same location as Fig. 14A but in April 2023 (late dry season).

The dark green area is mainly sawah platform evolution stage 3, which has somewhat expanded since 2013. The others are evolutional stage 2 (ridge rice cultivation). The improvement and the evolution of sawah platform are not well recognized.

Figures 15A, 15B, and 15C below show Google earth images of the center of the Takakume irrigation site under Goronyo dam in Sokoyto state. The photo was taken October 2010 with GPS location information around 13.51N 5.813E.

Fig. 15A: Google earth of Takakume irrigation site under Goronyo dam, Sokoyto state, taken October 2010. The photo shows that the irrigation and drainage canals and major farm land boundaryies about 200m intervals were constructed by contractor, while sawah platform was left to the farmers.(Marker length:100 m)

Fig. 15B. The image taken at the same site on June 2018. As can be seen from the photo, the sawah plots left to the farmers have been completed, but they are micro sawah plots of 20-30 m^2 each (evolutional stage 3), thus water management is difficult and paddy yield is less than 3t/ha. (Marker length: 100 m). The total irrigated area is estimated to be about 5000 ha.

Fig. 15C. The image taken at the same site on April 2022.

No standard sawah platforms are developed. About 10% of the irrigated fields are at evolutionary stage 3. Most of the fields are at evolutionary stage 1-2. Thus, water control is not feasible.

The total irrigated area including Takakume, Maiyali and Falalia sectors, is estimated to be about 5,000 ha, but the farmers are left to develop the farmland infrastructure of the sawah platform including tertiary irrigation/drainage canals and inflow and drainage gates, and leveling of individual sawah plots. Farmers (including the contractor engineers) have neither experience nor knowledge of basic water management platforms such as sawah in rice cultivation, nor do they have basic farm equipment. Therefore, standard water management for transplant rice cultivation are not possible, and paddy yields are less than 3 t/ha. Paddy yield would be better served by an irrigation rice platform such as the one shown in Figures 13①-④ (Figures 14 and 15), where individual farmers can manage water through personal mobile pump operation management. Hence, the paddy yield would be rather lower in official irrigated areas such as Goronyo, where there is no such freedom to control water. Apart from irrigated 5000ha farmlands, a number of technical problems have been identified, including structural safety of the Goronyo dam, difficulties in flood control, and management of irrigation and drainage canals (World bank 2020).

Fig. 16. Rice and onion cultivation by pump irrigation at the vicinity of AR3 site in Fig.9A, Arugungu. Photographs were taken on May 2011.

Figure 16 photos were taken in May 2011 (end of the dry season) near the AR3 location in the Google Earth image of the Arugungu floodplain shown in Figure 9A, at approximately the same location as the photos taken in December 1987 near Figure 11 ② and ③. In May 2011, dry season rice and onion cultivation with shallow tube well pump irrigation was extensively implemented under the long-term World Bank-supported Fadama I-III project in 1992-2019. The irrigated sawah rice platforms were either row cultivation (evolutional stage 2), similar to Figure 13①-④, or small plotted sawah platform (evolutional stage 3). Although the land is divided by relatively strong bunds used for farmers land demarcation and for walking, but bunds of internal small plots were poor. As with the onion field seen in the foreground, leveling was either absent or inadequate, each plot surface was not or insufficiently leveled, which are important for water management.

Figure 17A shows a Google earth satellite image taken in 2009 before the introduction of sawah technology near AR3, and Figure 17B shows a satellite image taken 10 years later. The position of both images is the same, and the length of the marker line in the middle of Fig. 17A and 17B is 200 m. The GPS position information is around 12.767N 4.507E. In the November 2009 image (rainy harvest season), sawah plots are generally unclear and cover less than 50% of the total area in this image. The area of individual sawah plots is small (20-100^2 m), and the sawah plots are indistinct and the leveling of the sawah plots' surface is unclear (sawah platform evolutional stage 3 or lower). In contrast, in January 2019 (at the start of the dry season), more than 90% of the total area is in clear sawah plots. The area of one sawah plots is more than 100^2 m, with clear bunds and black-green sawah plots' surfaces levelled to a 'smooth texture' like a glass surface. The transplanted seedlings are protected from weed growth by controlling adequate water depth (sawah platform evolution stage 4 or 5). An example of a photo similar to this sawah platform is shown on the right-hand side photo of Figure 9B, taken on 10 July 2015. However, the photo was taken at the AR2 site, not AR3. High paddy yields of 5-7 t/ha have been achieved (Table 5, World Bank 2016, GEMS4 2017). Dry season rice cultivation has expanded rapidly since 2013, and the area under dry season rice cultivation, which was almost non-existent before 2013, reached 50% in the Google Earth image of May 2013 and over 80% in the June 2016 image during the dry season rice harvest season (not shown in figure).

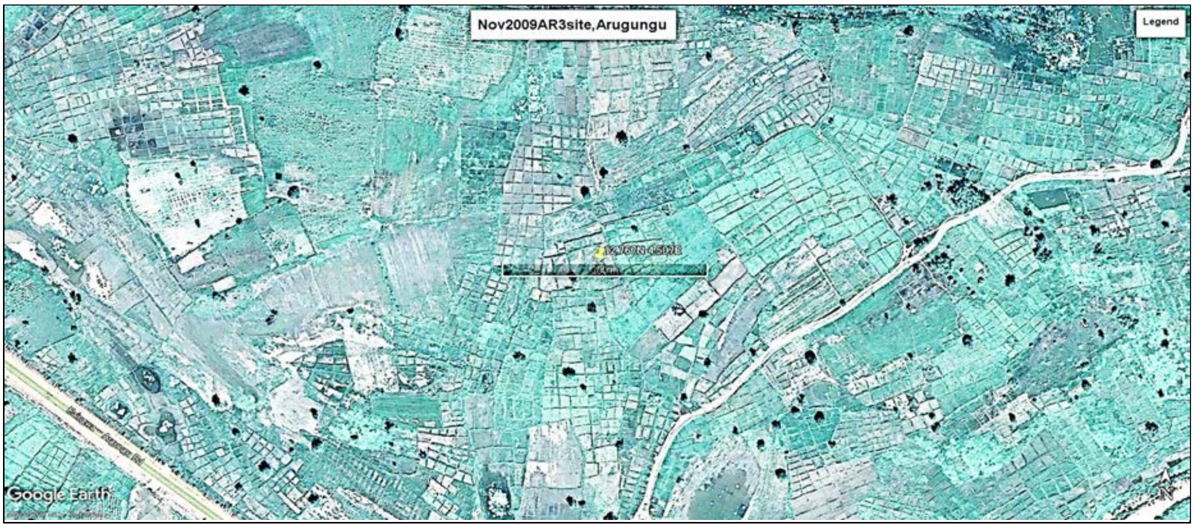

Fig. 17A. Google Earth Satellite image near AR3 in November 2009 (just after the end of the rainy season) before the introduction of Sawah technology.

Fig. 17B. Google Earth Image taken in January 2019 (start of dry season rice cultivation) at the same location as Figure 14A, 8 years after the introduction of Sawah technology. Central marker length is 200m.

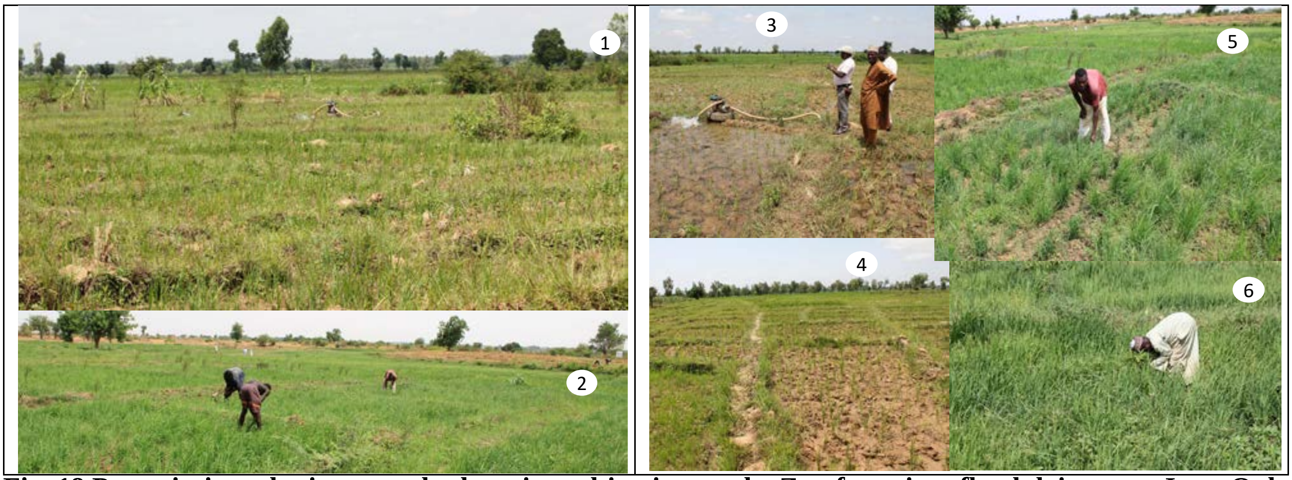

Fig. 18 Pump irrigated micro sawah plots rice cultivation on the Zamfara river floodplains near Jega. Only ⑥photo was taken from the Official irrigation site in flood plain at Birinin Kebbi (taken on May or Sep 2011)

Photos ①-⑤ of Figure 18 show pump-irrigated rice cultivation before the introduction of sawah technology in the floodplain of the Zamfara River, which flows south of Jega City (see Figure 2 for location). The Zamfara River joins the Rima River 40 km south-west of Jega. Photo ⑥ was taken from an official pump irrigation project site of about 100 ha developed on the floodplain of the Rima (Sokoto) River, which flows north of Birinin Kebbi City. The photographs were taken in May or September 2011. All these irrigated sawah platforms, both public and farmer systems, are at sawah platform evolution stage 3 (small sawah plots with poor bunding and no leveling, thus poor water management and therefore weed management is difficult), so farmers cannot control weeds and paddy yields of more than 2.5 t/ha are difficult to achieve.

Figure 19① below is a Google Earth image of the Zamfara River floodplain south of Jega, taken in October 2007; Although not shown in this Google earth image, the town of Jega lies 2-5 km just north of the floodplain, the town of Jega is 2-5 km north of the floodplain, and Lake Crescent can be seen in the upper right of the image. The length of scale marker is 200m. As shown in Figure 19①, size of each sawah plots in 2007 (before sawah technology training) was 20-40m^2. Bunds are not clear and no clear leveling in each sawah plot (Evolutional stage 2 or 3). Please compare with Figure 19③, which is showing evolutional stage 5 sawah platform.

Fig. 19①. Google image of the Zamfara River floodplain south of Jega, taken in October 2007. Size of each sawah plots was 20-40m^2. (Evolutional stage 2 or 3). Two red circles indicate the location of the sawah technology demonstration plots (1 ha each) implemented in March-October 2011. Fig. 18 ①-⑤ were taken in May and September 2011 in this area.

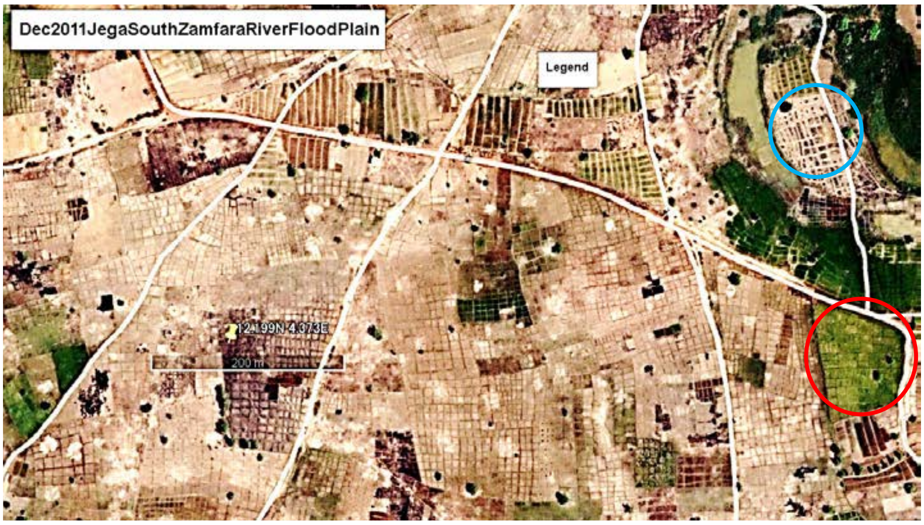

Fig. 19②. Google image of the same site in December 2011. The blue and yellow circles are sawah technology training and demonstration site in 2011. The blue circle site was damaged by flood in July 2011. The red circle site shows that dry season rice cultivation has just started.

On the job sawah technology training and demonstration sawah based rice farming was done in the area of the two red circles area during March to December 2011. One power tiller was supplied by JSPS project (Fig. 6③). By April 2012, 8 ha of standard sawah plots were developed by farmers, the farmers bought two sets of additional power tillers by their own budget and developed 28ha of standard sawah platform by May 2014 endogenously (Table 5).

Figure 19② is the same location as Figure 19① but is a Google earth image taken in December 2011 showing farmers' rice plots, including the first 2 ha of exhibition plots from March-December 2011. One red circles show Sawah Technology training and exhibition plots conducted in March-September 2011. The site in the light blue circle next to Lake Crescent was damaged by flooding in July 2011.

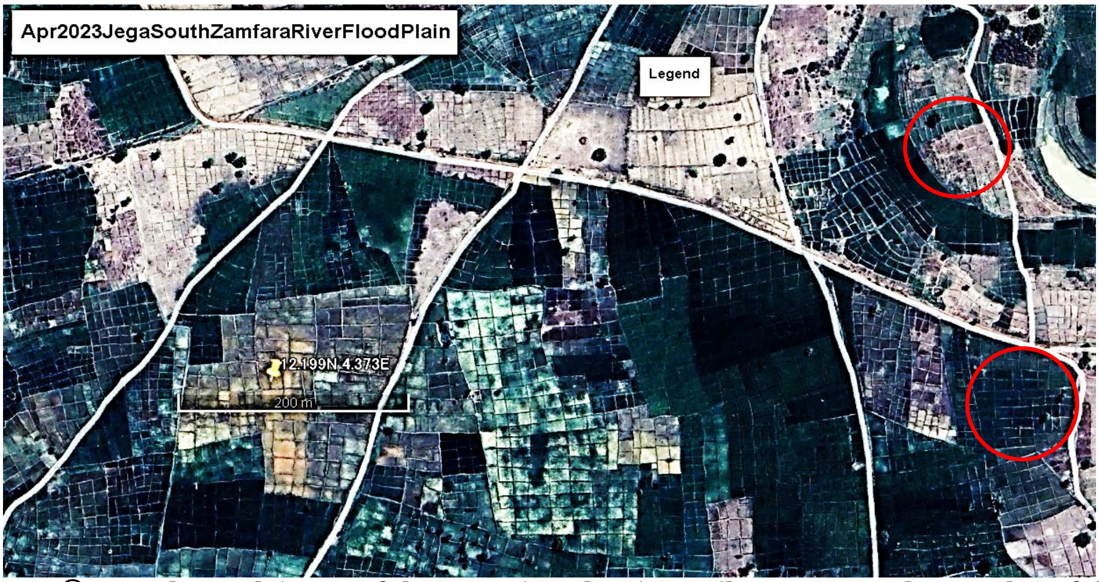

Fig. 19③. Google Earth image of the same site taken in April 2023. 80% (about 70 ha) of the approximately 90 ha shown in the image were self-developed by farmers with evolutionary stage 4 or 5 sawah platforms. Standard transplanted rice cultivation was used for dry season farming.

Figure 19③ shows the Google Earth image in April 2023. Ninety percent of the entire image has been developed into standard irrigated sawah platforms. Each sawah plot has leveled well, enlarged to 100-300m^2, and enclosed by reinforced bunds. The thick, well-defined plots of individual sawah plots and the white, blue, and greenish black mirror-like shine of individual plots seen in the image indicate that individual sawah plot soil surfaces have been leveled to within ±5 cm accuracy and that standard transplanted rice cultivation is in place. The data in Table 5 and the report by GEMS4 (2017) that the paddy yield in Kebbi State is 5-7 t/ha, the highest in Nigeria, support the reliability of the report. The figure only shows Google Earth images from 2011 (at the beginning of the spread of the dissemination of sawah technology) and 12 years later, but Google Earth images from 2014 and 2019 can also be verified. It is observable to all that the sawah platforms have expanded steadily over 2014-19 with the continuation of farmers' self-help efforts; it is estimated that the irrigated sawah platform above evolution stage 4 in the Zamfara River floodplain near Jega City reached more than 2000 ha by farmers' own efforts.

6-3. Definitions and photographic summative examples of rice farming platforms in evolutionary stages 1-5.

Evolutional stage 1（lowland non-sawah platform）: This platform is defined as lowland rice fields, with or without irrigation, no bunding, and no leveling. It is a platform where little or no artificial water control or nutrient management is possible in the cropland where rice is grown. Figure 20(1) shows a spring-fed irrigated non-sawah field in Gadza village, Bida, taken in 1987 (area indicated by A) and an evolutionary stage 3 micro-rudimentary-sawah platform (area C: mid-season weeding and construction of bunds are the creation of micro-rudimentary-sawah fields).

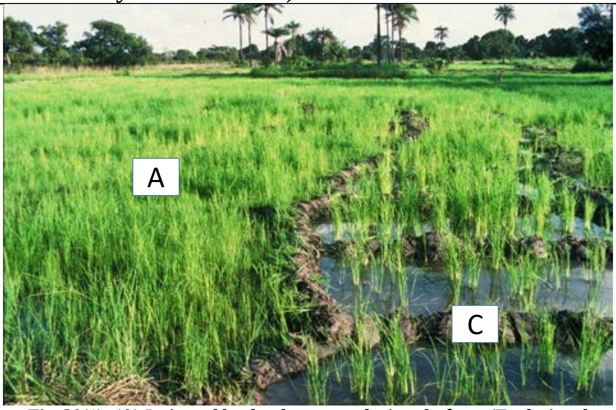

Fig. 20(1): (A) Irrigated lowland non sawah rice platform (Evolutional stage 1), (C) Irrigated micro rudimentary sawah platform (Evolutional stage 3). Gadza village, Bida, 1987, GPS 8.978N 6.0073E

Fig. 20(2): Irrigated micro rudimentary sawah platform (Evolutional stage 3, Sokoto, 2011, GPS 13.1136N 5.2565E)

Fig. 20(3): Ridge rice planting, upland and lowland topo-sequescne Nyankpala-Tamale area, Northern Ghana (September 1995).

Fig.20(4): Irrigated ridge rice cultivation, inland valley of the Emikpata river near Gadza village, GPS: GPS 8.9825N 6.005E

Evolutionary Stage 2 (lowland ridge rice platform): Lowland rice fields with or without irrigation systems, and with or without with or without bunding where individual sawah plots are not leveled and ridged rice is grown like upland crops are defined as Evolutionary Stage 2. It is difficult to artificially control water in rice fields, and neither weed control nor nutrient management is feasible. Figure 20(3) shows a non-irrigated ridge rice cultivation platform created on a gently sloping terrain surface from plateau to lowland near the cities of Tamale to Nyankpala in central Ghana. Sudden heavy rains cause surface runoff that destroys the ridges and erodes the topsoils, resulting in partial waterlogging. Figure 20(4) shows a rice ridge platform in an inland small lowland irrigated rice field near Gadza village, near Bida, Niger State, central Nigeria, where water management is not available and weed control is difficult. Farmers then cut the ridge soils with weeds using their African hoe, and the ridges disappear at harvest time.

Fig. 20(5). B/C area: Micro Rudimentary Sawah (Stage 2 or 3). D/E area: Standard Sawah(Stage 4 or 5), Nassarafu village, Bida, Nigeria, September 2004

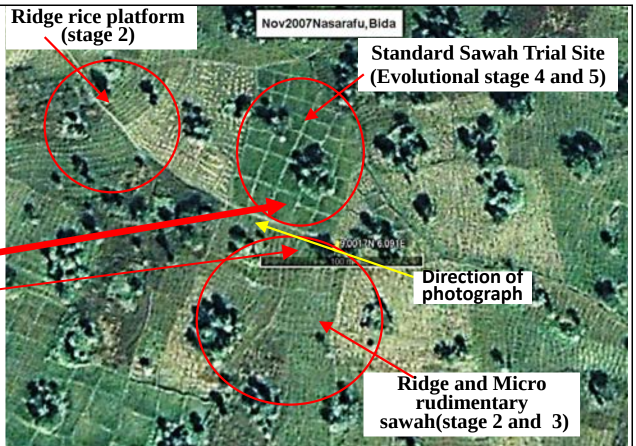

Fig. 20(6). Google Earth, November 2007. GPS 9.0017N 6.091E

Fig. 20(7). Irrigation canal and micro rudimentary sawah platform (Stage 3), Shaba Maliki, Bida. September 2010, GPS 9.01715N 6.0785E

Fig.20(8). Nupe's spring irrigated micro rudimentary sawah (evolutional stage 3), August 1995. No integration of Fulbe grazing with Nupes' rice farming. Gadza, Bida, GPS 8.9825N 6.005E

Evolutional stage 3 (rudimentary micro or small sawah platform): Lowland rice field platform with or without irrigation systems and with bunded sawah plots with 20-50 m^2 size sawah plots. The soil surface in each sawah plot is not leveled and bunds are so small and weak that it is impossible for humans to walk on them. Weed control and nutrient management are difficult due to poor artificial water control. Figure 20(2) above is an example of a groundwater-irrigated rudimentary micro sawah platform (evolutionary stage 3) on the Sokoto River floodplain, taken in May 2011. Figure 20(5) above shows a spring-irrigated ridge rice platform and a micro rudimentary sawah platform (evolution stage 2 or 3, photo of area B/C) and a spring-irrigated standard sawah platform developed using power-tiller (evolution stage 4 or 5, photo of area D/E) in Nasarafu village, Bida District, taken in August 2004. In the center is Mr. Joshua Aliyu, and the two on either side are a farmer and a village chief; the three persons are standing on a farm road. Figure 20(6) is a Google Earth satellite image of the area in Figure 20(5), GPS 9.0017N 6.091E, taken in November 2007. Figure 20(7) is a photo of a traditional irrigation canal and micro rudimentary sawah platform in ShabaMaliki, a neighboring village to Nasarafu village, taken in September 2010, GPS 9.01715N 6.0785E. Figure 20(8) is a photo of a spring-fed irrigated micro rudimentary sawah plot in Gadza and Fulani nomadic cattle herds. GPS is 8.9825N 6.005E. The destruction of the irrigation canals and bunds of Nupe farmers by Fulani cattle makes damage rice fields, but the dung from the cattle herds is fertilizing the farmland.

Evolutional Stage 4 (sawah platform corresponding to human-powered hoe cultivation or livestock cultivation using ploughs, on which the Green Revolution technology works effectively): Standard lowland irrigated sawah platform, with each plot larger than about 100 m^2, with stable, walkable, and leak-free bunds; Leveling quality is better than ±5 cm per each sawah plot; Weed control and nutrient management are possible through artificial water control, and the generation of greenhouse gases such as methane can be controlled. Figure 20(9) below shows a groundwater-irrigated micro sawah platform in the Zamfara River floodplain, taken in September 2011 (near the yellow circle in Figures 19(1) and (2)). The plots sizes are less than 30 m^2 and not leveled, but the bunds are strong and walkable, so they are considered small sawah platform rather than micro rudimentary sawah platform. The evolutionary stage seems to be between 3 and 4.

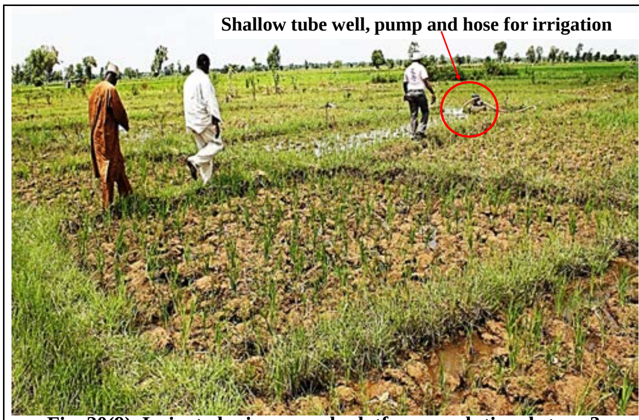

Fig. 20(9). Irrigated micro sawah platform, evolutional stage 3 Zamfara river flood plain, Jega, Nigeria, May 2011, Before Sawah Technology training at the red circled area of Figure 19 (1) and (2).

Fig.20 (10). Standard sawah platform stage 4 or 5 irrigated by small pump, Zamfara river flood plain, Jega, Nigeria, May 2011, Sawah Technology on-the job-training site and the demonstration site at the blue circled area of the Figures 19(1) and (2). Pump irrigation hose

Evolutional Stage 5 (platform co-evolving with early stage of agricultural mechanization): A lowland irrigated sawah platform with each plot size larger than about 1000 m^2, which has strong bunds that do not leak water, and water can be easily controlled by controlling the opening and closing of the water intake and drainage gates. The leveling quality is better than ±5 cm in height difference. Good water control enables basic weed management, nutrient management, and greenhouse gas generation control. Efficient cultivation with a power tiller and/or small tractor; 15 ha of rice paddy can be cultivated per year with a single 10 hp power tiller. Figure 20(10) is a demonstration and field training site of a standard sawah platform with groundwater irrigation (evolution stage 5, using power-tiller) and weed-efficient straight-row transplanted rice cultivation, taken in May 2011 (the site is blue circles area in Figures 19(1) and (2)).

Fig. 21 (1): Power tiller stuck and overturning in hole under muddy water. Is risk avoidable with sturdy cage-whale attachment?

Fig. 21 (2): Power tiller stuck and overturning risk on liquefied ground. High risk even with cage-whale attachment.

If sawah platform farmland development progresses further and a 30-50 horsepower(hp) tractor becomes available, it is possible to cultivate more than 30 ha of sawah rice platform per year. However, the maximum area that can develop new irrigated sawah platform with a single power tiller of 8-10hp in inland valley bottoms, flood plains and inland deltas where conditions are favorable for new rice cultivation is likely to be 10 ha. It is better to introduce a tractor after the new development of sawah platform is completed, so that there is less risk of damage due to overturning of the tractor by ditches or holes, etc. Even 8-10 hp power tiller weighing 300-500 kg are at risk of overturning or sinking in water-hidden holes or liquefied ground in newly opened fields, and are difficult to pull up, even with many human helps. The risk is there, and even the best efforts will struggle to pull it up; a 30-50 hp tractor cannot be rescued by human power (see Figures 21(1) and 21(2)). This platform evolutional stage 5 allows for more efficient implementation of water control, weed and nutrient management, and greenhouse gas emission control than in Evolutional Stage 4.

7. 2011-2015 Demonstration and on-the-job training by a Kinki University/Shimane University JSPS's KAKENHI team and National Centre for Agricultural Mechanization (NCAM) team on the efficient development of an evolutionary stage 5 sawah platform by improving sawah technology.

Based on the June 2010 agreement (Figures 5, 6, 7, 8) between the World Bank-supported Fadama III project and the National Center for Agricultural Mechanization (NCAM) and JSPS's Kinki University and Shimane University Grant-in-Aid research projects (Wakatsuki 2012, 2017, 2018), sawah technology transfer activities were initiated in Kebbi, Ebonyi, and Benue states between February and March 2011. The other three states, FCT (Federal Capital Territory), Lagos, and Delta, started their activities one year earlier, in 2010. The Nigeria Sawah team was divided into four groups and conducted hands-on training and development of 1-2 ha demonstration plots in each of these six states at sites selected from the main rice-growing areas (LGA, Local Government Area) of each state as basic extension parcels. These demonstrations were conducted in collaboration with the state Agricultural Development Project (ADP), Fadama III extension staffs, and the Rice Farmers Association of Nigeria (RIFAN). However, only 1-2 sites in the four states other than Kebbi State and the FCT were able to implement the basic package.

In Kebbi State, there was a voluntary and intrinsic effort beyond the special support of the state government and traditional chiefs and the active participation of farmers associations in sawah technology extension activities. As shown in Table 5, in one year from March 2011, 18 ha of demonstration plots were developed in three LGAs (6.5 ha in Arugungu LGA, 3.5 ha in Birinin Kebbi LGA, and 8 ha in Jega LGA) with an average rice yield of 7.1 t/ha. Farmer leaders confirmed the results of this extension. During the next two years from April 2012 to April 2014, 16 advanced farmers in 5 LGAs (many of them alumni of state government officials, 2 of them PhD holders) purchased 22 sets of tillers at their own expense and developed 199 ha of evolutional stage 5 irrigated sawah platforms, producing 1260 tons of paddy. (yield 6.3 t/ha). In Arugungu LGA, 9 farmers purchased 11 sets of power tillers and developed 74 ha of sawah platforms; in Birinin Kebbi LGA, 3 farmers purchased 3 sets of power tillers and developed 21 ha; in Bagudo LGA, 1 farmer purchased 5 sets of power tillers and developed 50 ha; in Jega LGA, 2 farmers purchased 2 sets of power tillers and developed 54 ha, In Suru LGA, one farmer purchased one unit and cultivated 5 ha.

The person in charge of sawah technology extension in Kebbi State was Mr. J Aliyu for the NCAM/JSPS team and Mr. HM Yeldu for Fadama III in Kebbi State (both are co-authors of this paper; data in Table 5 were collected by Mr. Yeldu). Mr. Aliyu is a Nupe from Bida, Niger State, and has been a member of the JSPS project since 2000, providing technical training and extension activities to farmers in the villages of Ejeti (GPS: 8.922N 6.026E) and Sheshi Bikun (GPS: 8.914N 6.094E) around Bida, as a base for the Niger State. These two sites had served as bases for Sawah Technology's Action Research Site in Niger State, where technical training and extension activities have been conducted among farmers. Mr. Sleiman, son of the village head of Ejeti village, was employed by Aliyu to work in Kebbi State, training farmers how to maintain and manage power tillers, how to develop standards sawah platforms using power tiller, and how to prepare and level soil surface of sawah plots within ±5cm height difference to control weeds for transplant rice cultivation. Mr. Sleiman was employed by the JSPS sawah team for a year in 2011-12, and then he was employed by the Kebbi State rice farmers' association until 2019. He stayed in villages in the main rice farming areas of Kebbi State and contributed to the dissemination of Sawah technology using power tillers.
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. 22-28 below. Details are shown in Sawah Technology (5): Practices and Potential of Irrigated Sawah System Development and Sawah Based Rice Farming by Farmers’ Self-help Efforts.

First, from March to December 2011, NCAM/JSPS and Fadama III/Kebbi farmer teams selected three major rice-producing local government area (LGA), i.e., Arugungu, Birinin Kebbi, and Jega, as shown in Table 5. Twenty irrigated sawah platform sites of 0.5 to 1 hectare each, for a total of 18 hectares, were developed in the rice production centers of these three LGAs. The NCAM/Kinki University sawah team led by Wakatsuki (Kinki/Shimane Univ.), Ademiluyi (national sawah ecotechnology coordinator, Nigeria), Aliyu (Kebbi State representative of NCAM sawah team), and staffs of Kebbi state ADP and Fadama III as well as farmers’ group worked together. The development of these new irrigated sawah platforms using sawah technology and sawah based rice cultivation in the developed sawah platforms were all conducted through on-the-job training. The technology was transferred to ADP, Fadama III, and farmers' cooperatives in Kebbi State.

The photo in the upper part of Figure 22 ① was taken in May 2011 at the demonstration plot indicated by the blue circle in Jega shown in Figure 19②. A sturdy bunded sawah plots were constructed. It is important that the bunds of sawah plots do not break even at a waterlogging depth of 15 cm and do not break or leak when farmers walked on it for water, rice growth, and pest management purposes. The individual sawah plots enclosed by bunds were filled with the appropriate amount of water, and the soil surface of the sawah was puddled and levelled to within ±5 cm using power tiller. Wooden rake boards were used to finish leveling. The degree of this leveling is extremely important in planting to improve the quality of the sawah platform. In a standard evolutionary stage 4 or 5 sawah platform, it is important to be able to transplant seedlings with a rice seedling height of 15 cm or less and manage the water depth between 0 cm and -10 cm after transplanting. This makes possible control weed growth in the early transplanting stage. The straight-row transplanting shown in the photo allows for efficient weeding from the mid-planting stage onward. Figure 22② shows a shallow well, pump, and hose for irrigation taken near the demonstration plots in Figure 22①, photographed in May 2011. The same ③ and ④ in Figure 22 were taken in July 2015 at the AR2 site in Arugungu (Figures 9A, 9B(Right side)). The Chinese-made power tillers used during the technology transfer in 2011 were not the most suitable machines for the implementation of new sawah platform development, as shown in Fig. 6①-③. Sawah platforms have been developed by farmers in Asia over a long period of years. In recent years, sawah platforms have been constructed (developed) by civil engineering contractors using heavy machinery such as bulldozers with laser levelers. Power tillers are agricultural machinery for sawah platform cultivation, and currently power tillers are not commercially available with specifications for new development of sawah platform for rice cultivation. Sawah (eco-) technology is integrated skills in which SSA farmers themselves implement irrigated sawah platform and rice cultivation as integral parts of civil engineering works.

Fig. 22. 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 G1000Bower power tillers (11 Hp equipped with Kubota engine) attached a mould board plough, puddler, leveler and cage wheel, at AR2 site, Arugungu, in July 2015.

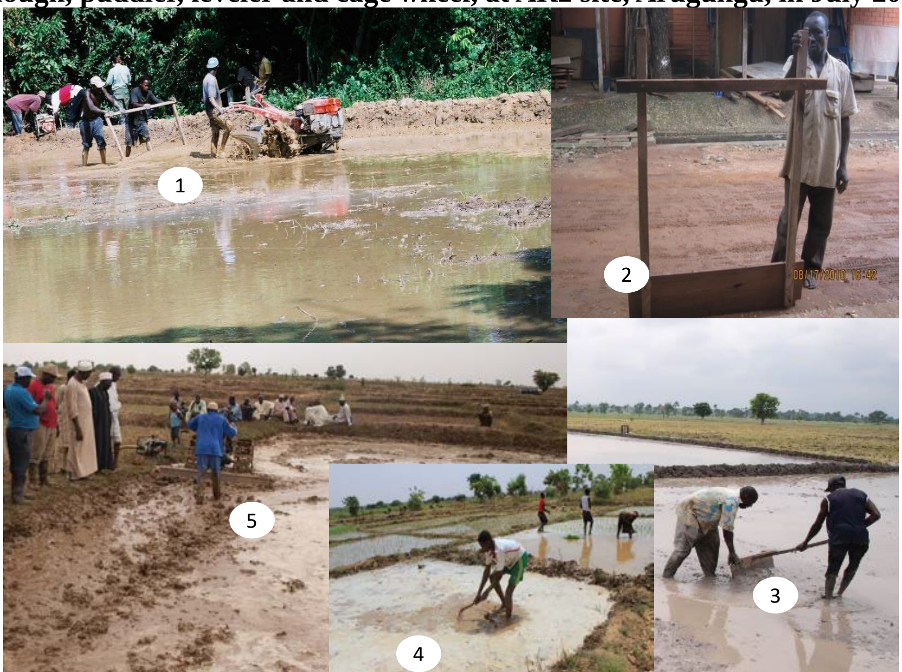

Fig. 23. Leveling operations to height difference, i.e., <±5cm in a plot of sawah. ①&②powertiller & wooden board (①taken in 2002 in Biemso No.1 village of Ghana. Manual leveling by wooden leveler(③ at Bida) and iron rake(④ at Jega). Powertiller attached leveler operation at Arugungu (June 2015).

Figure 23① shows some leveling operations to get standard height difference, i.e., <±5cm in one plot of sawah. If the height difference of one sawah plot is within 10 cm, rice seedlings with standard grass height of about 15 cm, which is normally about three weeks after germination, can be transplanted to the whole one section of sawah plot. In the case of System Rice Intensification (SRI) (J-SRI 2011, Toriyama 2012, Mizoguchi 2012) practice and direct seeding method, in order to realize high yield through proper weed management, it is necessary to further increase the degree of leveling to within ±2.5 cm height difference in one sawah plot. Otherwise, weeding operations will be tedious and increases the use of herbicides.

Fig. 24 ① and ④: A plow and wetland cage wheels can be attached to power tiller to work in conjunction with the farmer's hoeing operation to streamline the work of creating larger bunds for flood control and cutting waterways. Farmer can use it in place of a backhoe. Fig.24②: A leveler and plow are attached to the power tiller to fluidize (so called thixotropy) and level the soil and efficiently cut drainage channels as shown in ③. The soil can be moved 10-30 m, replacing a bulldozer. Photo taken near Gbajigi village, Edozhigi irrigation scheme, Bida, Niger state, 2015-2017.

Figure 24 above shows the new training content of Sawah technology with plow and leveler attached to a power tiller, which was implemented from 2015 to 2017. As a result, sawah technology was upgraded with improved operational efficiency in land leveling, bunding, and irrigation and drainage channel construction. The accuracy of leveling individual sawah plots is very important, but manual leveling is hard work. Leveling work with a power tiller has a work efficiency equivalent to that of 30-40 people; the labor cost per day is about $3-5 (500-1500 Nigerian naira in 2013-2017), so the labor cost for 30-40 people is about $100-200, and the rental cost of a power tiller is about $50/day, Mechanization such as a power tiller is advantageous and feasible in the current economic situation in Nigeria.

Figure 25 below shows an Indonesian KHS Quick G 1000Bower tiller with Mould Board Plough, Puddler, Leveller, and Cage Wheels installed at AR2 site, Arugungu, in July 2015 (8.5 and 8.5 HP with Kubota engines horsepower and 11 horsepower) to demonstrate the upgraded Sawah technology and show the location of the training, which was conducted in the vicinity of Figure 25② in the Google satellite image taken in June 2016. Photo 25① was taken from direction red arrow ①. Photo 25② was taken from direction red arrow ②. The location of the AR2 site is shown in Figures 9A-9B(right side).

Fig. 25. The site of advanced sawah technology training on July 2015 at the AR2 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. 26. Google's satellite images of GPS15.756N4.511E near AR2 in November 2009 (pre-Sawah technology) and February 2024.

Figure 26 shows Google satellite images of the AR2 site taken in November 2009, before the introduction of Sawah technology, and in February 2024. The quality of the rice fields has continued to improve in February

2024. In 2024, rice fields have been developed over most of the floodplain, each rice field has been enlarged, and a well-defined footpath has been created between rice fields. The improvement of the rice farmers' rice cultivation skills can be seen from the fineness of the "Texture" in the picture.

Figure 27 shows version up skills of sawah technology practiced at the AR2 site in the Arugungu floodplain. The goal was to open efficiently a new sawah platform, using a power tiller with a standard cage-wheeler for wet, deep, and very soft soils. However, at the time of the demonstration, the rice fields were dry, because of just after the dry-season rice harvest, so groundwater was pumped up with portable pumps through PVC (vinyl chloride pipes) already installed next to each sawah plots to create waterlogged conditions for the technical training and demonstration. The Chinese-made power tillers used in 2011-12 could not use the cage whales, puddlers, levelers, and ploughs as attachments, and only rotary blade assembly attachments were available. Therefore, such Chinese made power tillers, which were useful mainly for rice cultivation of already developed sawah platform, were inadequate for the development of new sawah platform.

Compare Figure 9B (left side in 1987) with Figure 25/26/27 (photos in 2015 and Google earth image in 2016). These are the same AR2 sites. In 1987, there were no irrigated bunded and leveled sawah platform around the AR2 sites. Between 1987 and 2011, Fadama I and II project developed evolutional stage 3 sawah platform as shows in Fig. 26, Google earth on November 2009 (and Photos of Fig. 16 and Fig.18). Between 2011 and 2015, standard irrigated sawah platforms developed by farmers' self-help efforts were everywhere in these flood plains, and after 2016, Kebbi state became Nigeria's No .1 rice growing state in the country.

Fig. 27. Advanced sawah technology training on 8^{th}-12^{th} of July 2015 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. 28 below show the continuation of pictures in training in 2015. ①: Transporting the power tiller on the pickup truck bed. The tooth like equipment of the comb of the loading platform is a leveler, the equipment with a large number of steel plates rotate is a puddler. This power tiller, G1000 boxer, was bought from KHS company in Indonesia using KUBOTA’s engine. ② and ③: A heavy (over 500 kg) power tiller made by Dong Feng of China is transported by motorbike and cart dolly under the project of Kebbi state’s SURE project (Subsidy Re-investment and Empowerment Programme) (Federal Republic of Nigeria 2013). The power tiller can be dismantled into parts and transported by motorbike on narrow footpaths on flood plains or by small boat on meandering waterways. ③: Rotavator, not plough, of Dong Feng power tiller. ④ Plowing operation by mould board plough by Indonesian KHS G1000 boxer at AR2 site. Before 2015, Nigerian sawah team had been used rotavator like ③ in Fig. 28 (also see the Fig.6② and ③). Rotavator was good for cultivation of the sawah plots that was already developed, but it was found that Mould board plough (please see Fig.22 ④ and Fig. 27①) is more suitable for new sawah platform development. The operation performance of Indonesia's 8.5 Hp power tiller, G1000Boxwer of 297kg weight, with a cage wheel was better than the heavy Chinese 15 Hp power tiller, Dong Feng of 570kg weight. The G1000Boxer did not sink even in deep soft 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 are very important new skills for Sawah platform development.

Fig. 28: Sawah Technology's upgraded technical training on July 8-12, 2015. ①: KHS G1000boxer power tiller to Kebbi state on a pickup truck along with puddler, leveler, and cage wheels. ② and ③: A heavy Chinese-made Dong Feng (570 kg, 15 HP) power tiller can be transported to any small village in Kebbi state by towing a cart on a motorcycle. ④: Mould board ploughing operation by KHS G1000boxer power tiller.

8. Innovative characteristics of on-site pump irrigated sawah based rice cultivation by farmers in Kebbi State using Sawah Technology

As discussed later in Sawah Technology (6-2): Kebbi rice revolution 6-2, in 2014-15, 1000 sets of power tillers were distributed by the Kebbi State Government to farmers across the state on a subsidized basis and packaged with sawah technology and disseminated throughout the state. Figure 29 quotes photos uploaded to social networking medias such as Google's Instagram showing farmers in Kebbi State developing self-funded irrigated sawah platforms and implementing irrigated sawah based rice cultivation with portable pumps from groundwater in flood plains. The photo was taken around 2015-16 and appears to have been taken in Suru LGA, one of the rice cultivation centers in Kebbi State (see Figure 4). Photographs of Fig. 29 shows on-site pump irrigated sawah rice fields in flood plains in Kebbi State. On the left, the bunded and leveled sawah field immediately after transplanting. On the right, sawah plots are irrigated by direct groundwater suction from a PVC pipe installed on-site of the sawah plots. (Quotes via Google instagram).

It is characterized by the use of appropriate machinery such as small power-tiller instead of bulldozers for the development of small weir irrigation or on-site small pump irrigated sawah fields, which can be implemented at the individual farmer level. The technology of opening new sawah platform evolutionary stage 5 (capable of transplant rice cultivation with a leveling quality of ±5 cm) and at the same time allowing farmers to cultivate sawah based rice on their own is the basic technology of sawah technology. As the majority of SSA is on gentle slopes and hydrological conditions with low disruptive force. Heavy machinery is not feasible in low marshy areas such as flood plains and inland deltas in the early development stage, as shown in Figure 30 below, where numerous watercourses and crescent lakes are intermingled.

https://agronaturenigeria.com/kebbi-rice farmers-emerging-millionaires-achieving-rice-sufficiency-target/

https://www.google.com/search?sa=N&rlz=1C1SQJL_jaNG833NG834&q=Kebbi+Rice+revolution&tbm=isch&source=univ&ved=2ahUKEwj1yMK7l9PkAhWsQEEAHYIjBOw4ChDsCXoECAkQJA&biw=869&bih=442#imgrc=C87rJctEUH560M:

Figure 29: Photographs of on-site pump irrigated sawah rice fields in flood plains in Kebbi State. On the left, the bunded and leveled sawah field immediately after transplanting. On the right, sawah plots are irrigated by direct groundwater suction from a PVC pipe installed on-site of the sawah plots.(Quotes via Google instagram).

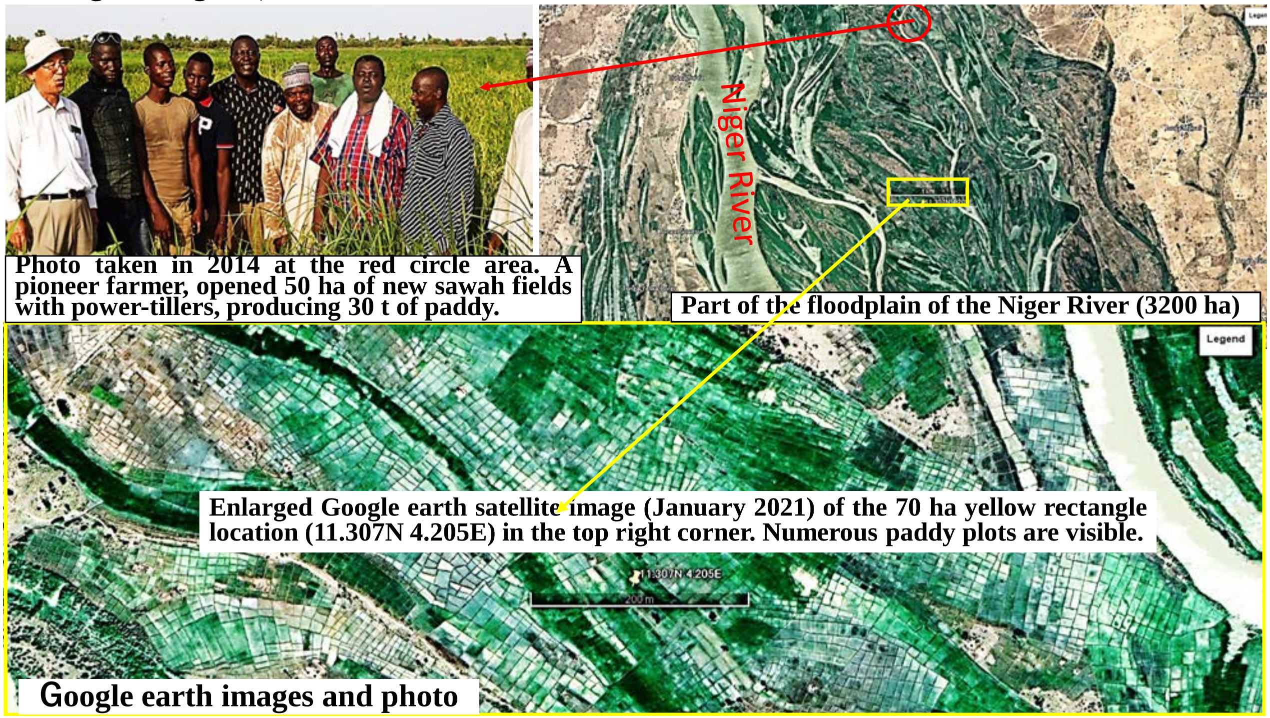

Fig. 30. Bagudo LGA in Kebbi State is in the floodplain of the Niger River, where the risk of inundation is relatively high but not very destructive, so on-site pump irrigated sawah based rice cultivation is expanding, mainly during the dry season, December -May.

The power tiller can be fitted with a plough and a wetland cage whaler and linked to the farmer's hoeing operation to streamline the creation of large footbridges (dyke, embankments) for flood prevention and the opening of water channels. Farmers can use it as a substitute for a backhoe. A steel levelling fence, a rotary tiller and a plough can be fitted to the cultivator to fluidize (so-called thixotropy) and level the soil. Drainage and irrigation channels can be cut efficiently by combining a plough on a power-tiller with a human-powered hoe. According to a report in the Nigerian Guardian newspaper dated 19 January 2024 (Alabi 2024), Kebbi

State has purchased 6 000 sets of solar pumps and 300 cultivators and started distributing them to farmers at subsidized rate. This is expected to be the next phase of the Kebbi rice revolution, which will contribute to the prevention of global warming.

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