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Sawah **Technology「アフリカ水田農法」(5): Practices and Potential of Irrigated *Sawah* System Development and *Sawah* Based Rice Farming by Farmers' Self-help Efforts**

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Contents

1. Potential of Irrigated sawah system development in Sub Saharan Africa (SSA)

As we described in a separate companion paper on ***Sawah*** **technology (4) Principle and Theory** and others published in Sawah technology home page (http://www.kinki-ecotech.jp/, Wakatsuki et al. 1998, Hirose and Wakatsuki 2002, Wakatsuki and Masunaga 2005), irrigated *Sawah* system platform, infrastructure, and Sawah eco-technology (hereinafter *sawah* technology) have been lacked in majority of Sub-Saharan Africa (SSA). Among the 240 million hectares (ha) of wetlands in SSA (Van Dam and Van Diepen 1982, Andriesse 1986, Windmeijer and Andriesse 1993), about 20%, i.e, 50 million ha (56 million ha for annual harvest and 40million ha equipped for irrigation) are estimated to be appropriate sites for sustainable irrigated *sawah* platform development, of which 9–21 million ha are in small inland valleys, 8–23 million ha in floodplains, 4–9 million ha in coastal deltas, and 5–20 million ha in inland basins/deltas, as shown in Table 1 (Wakatsuki et al. 1998, Hirose and Wakatsuki 2002, Abe and Wakatsuki 2011).

Table 1. Distribution of wetlands and potential irrigated sawah area in Sub Saharan Africa (SSA) (Andriesse 1985, Windmeijer & Andriesse 1993, Potential Sawah area estimate by Wakatsuki 2002 and 2015)

Classification	Area (million ha)	Area for potential irrigated sawah development
Coastal swamps	17	4-9 million ha (25-50%)
Inland basins(deltas)	108	5-20 million ha (5-20%)
Flood plains	30	8-23 million ha (25-75%)
Inland valleys	85	9-21 million ha (10-25%)

Note 1. Although initial priority was small inland valleys because of easier water control, flood plains and inland basins (delta) in Sudan and Guinea Savanna zones should be given priority, such as Kebbi, Jigawa, and Borno in Nigeria and Chad, where wide distribution of shallow ground water (Gleeson et al. 2012, Fan et al. 2013) makes small pump irrigated sawah efficient and soil fertility is high.

Note 2. Estimated potential sawah area and paddy production are 0.5-1 million ha and 2-4 million tons of paddy in Ghana, 3-5 million ha and 12-20 million tons in Nigeria, and 26-73 million ha and 104-292 million tons in SSA. Estimations in Table 1 can be supported by following data, i.e. Asia has 140million ha of potential (94 million ha of sawah rice harvest in 2013) with 9485 km^3 of available water, whereas SSA has 3617 km^3 of water availability (40% of Asia) gives 56 million ha potential harvest area (only 2 million ha sawah rice harvest in 2013) (Oki et al 2009, AQUASTAT 2016, FAOSTAT 2016)

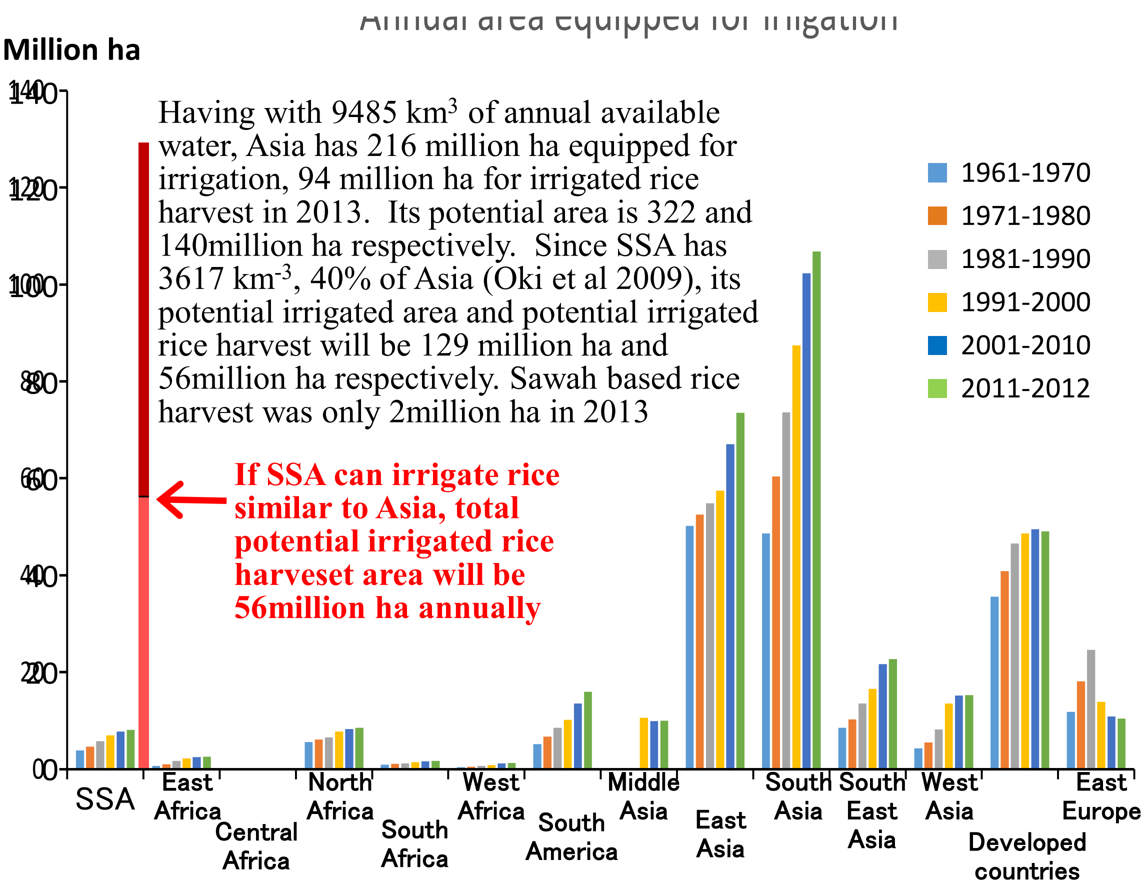


Figure 1. Area Equipped for Irrigation and Potential of SSA (Aquastat 2016)

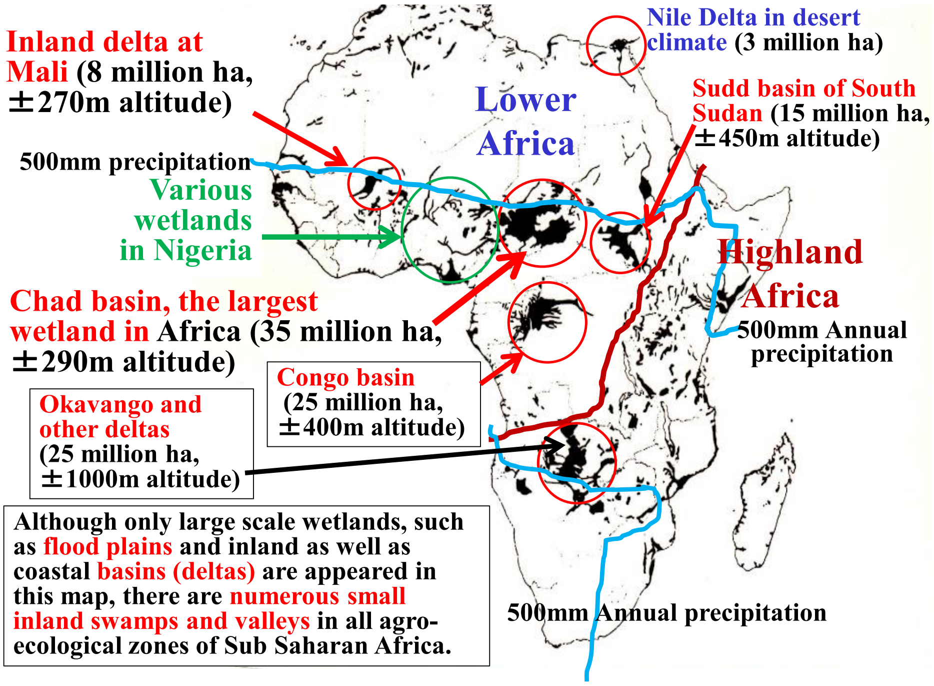


Fig. 2. Distribution of flat wetland soils in Africa (Van Dam and Van Diepen 1982)

The potential area on inland basins (deltas) is revised considerably in the Table 1, because of recent findings of huge areas with shallow and moderate depth (< 10-20m) of groundwater in savannah zones, stretching from Sudan and Chad basins to Senegal and Mauritania along the annual precipitation of 500mm (Sahel zone border) on various altitudes as shown in Fig 1, 2 and 14 (Gleeson et all 2012, MacDonald et al 2012, Fan et al 2013, and Xie et al 2014). Total range of total area for sawah system development is 26-73 (mean 50) million ha. This estimation of 50 million ha is also supported by the comparison of annual water availability between Asia and Africa, i.e., 9485 km^{-3} water is supporting 146 (97 million ha for irrigated and 49 million for rain-fed) sawah based annual rice cultivation area in Asia (mean paddy yield 4.76 t/ha in 2017), thus 3617 km^{-3} of water may support about 50 million ha of both irrigated and rain-fed sawah area in Africa (Oki et al 2009, FAOSTAT 2015). If mean paddy yield 5t/ha and this area potential is realized, more than 250 million tons of annual paddy production will be possible in near future by 2050 for one billion people, which give us time before to stabilize population explosion.

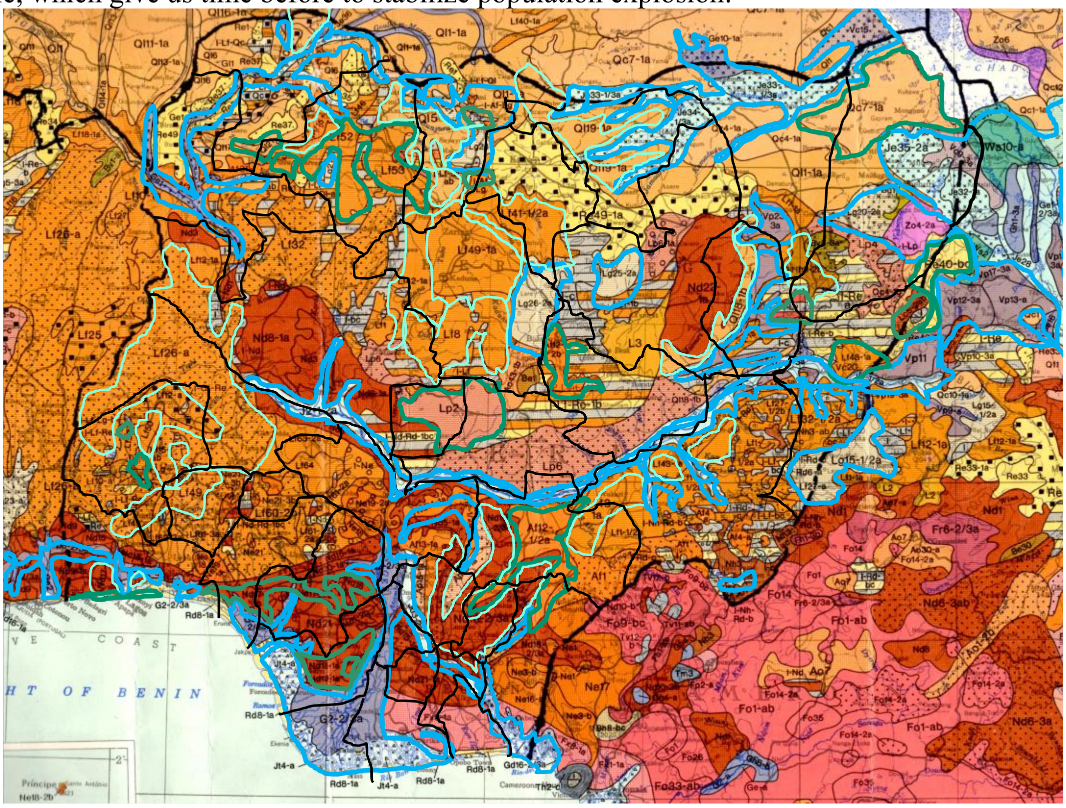


Figure 3. Soil map of Nigeria for the estimation of irrigated sawah platform potential area.

Major wetland soils are distributed in blue lined area, which have >50% of Fluvisols, Gleysols, and Vertisols in flood plain and delta. Green lined areas have soils which associate (>20%) Fluvisols, Gleysols, and Vertisols. Light green area have soils which include (20-5%) Fluvisols, Gleysols and Vertisols. Apart from these major wetlands, almost all soils have numerous small inland valleys (Windmeijer and Andriesse 1993)

Table 2. Estimation of wetlands area in Nigeria based on the FAO-Unesco soil map of the world(1977)

Major Wetland	x1000ha	Soil units	Associati	Inculsio	Soil units	Assciatio	Inclusion	Soil units	Assciati	Inclusion	Soil units	Associa	Inclusi
Jd1-a	42	Rd16-1a	27	15	Rd8-1a	578	77	Lf1-1/2a	1488	0	Ne19-1a	115	0
Je32-1a	305	Nd15	108	0	Re49	378	0	Lf1-1a	630	0	Ne19-2a	340	0
G2-2/3a	2349	Nd15-1a	809	0	Re37(combine)	612	0	I-Q1-Re	14	0	Ne-21	21	0
Gd16-2/8	319	Nd16-2/3	1617	343	Af13-1a	501	0	Lf10-a	49	0	Ne21-3b	119	0
Jd3-2a	322	Nd17-1a	410	115	Ap15-1a	483	0	Lf46	21	0	Ne1	28	0
Jt4a	1225	Nd1-2b	17	0	Af1	924	0	Lf15-ab	55	29	Nd8-1a	1740	0
J2-1/2a	2408	Nd17-1ab	346	50	Af4-a	189	0	Lf62-3a	404	0	I-Lf-12b	17	0
Je36	210	Nd18	153	22	Af15	267	38	Lf63-2a	417	0	Fx8-1a	965	64
Je33-1/3a	1075	Nd18-1a	264	142	Af31	301	0	Lf64	476	0	Lp4	613	0
Je34-1/3a	921	Nd19-1a	40	9	Af12-1/2a	959	203	Lf49	676	45	Lp2	669	360
Je35-2a	742	Nd22-1a	1575	0	Af2	77	0	Lf50	118	25	Lp6	2422	0
Lg20	49	Nd1	84	0	Re40-bc	50	27	I-Rd-c(combi)	497	0	I-Lp	73	0
Lg21	112	Nd9	38	0	Lc5-2ab	32	17	Lf12-1a	213	0	Lf32-1/2a	473	0
Lg24	206	Nd9-1a	213	0	Q118-1b	572	76	Lf52	685	481	Lf42-1a	814	173
Lg27	49	Nd20-1a	143	77	QI5	1041	149	Lf-61-2a(2ケ)	784	0	I-Lf-bc	994	0
Zo4-2a	455	Nd21	795	0	Q121	69	29	Lf61-3a	536	0	I-Lf	651	0
Lg20-2a	480	Nd21-1a	532	0	Qc7-1a	1410	760	Lf26-a	4705	316	I-Lf-1b	501	0
Ws10-a	161	Nd3	980	0	Qc4-1a	1113	0	Nd5-1a	973	0	Lf27-1/2b	189	0
G3	17	Nd14-1a	52	0	Qc1	28	0	I-Re-a	623	0	I-Lf-Q1	80	0
Ge1	417	Nd1	84	0	Q11-1a	2205	0	Lf49-1a	1369	91	I-Lf-Q1-ab	1414	0
Ge5-1a	49	Ne16-a	364	0	Q117	455	0	Lf43-1a	853	365	I-Lf-Re	248	0
Ge10-1a	150	Ne17	245	0	QI16	203	0	Lf53	394	212	I-c	1040	0
Vc9-3a	357	Bf6	105	0	Q116-1a	252	0	Lf1	318	0	I-Lf-Qc	420	0
Bg1	73	Nh3-ab	38	0	Lf12-a	375	0	Lf48-1a	223	71	I-bc	455	0
I-Af-Lg(1/3)	43	Nh3	326	0	Q112-1a	92	13	Lf32	2209	0	I-Re-b	655	0
Vc20	133	Hh9-2b	283	60	Q119-1a	1556	222	Lf41-1/2a	797	169	I-Nh-Rd-b(	112	0
I-Lf-Lg-b(1/4	6	L3	686	0	Q16	788	0	Lf8	1165	78	I-Nd	150	0
Lg15-1/2a	157	Ne3-b	171	0	Qc14	354	0	Lf27-a	231	0	I-Nd-Rd-1b	985	0
I-Lv(50%)	70	Fo9-bc	45	0	Qc4-1b	182	0	Lf10-1a	347	0	I-Ne	10	0
Bv8-3a	203	Re50	35	0	Be1	98	0	I-Af-Lg(2/3)	86	0	I	298	0
Vp23-3a	865	Re35	192	0	Ao43-1b	301	0	Lf60-2b	1001	0	I-Rd	35	0
Vp19-3a	140	Re1	210	0	Af12-2b	269	57	I-Lf-Lg-b(3/4)	11	6	I-Lf-Re-1b	1554	0
Je21	91	Re49-1a	2489	0	Lf25	28	0	I-Lv(50%)	20	0			
Lg26-2a	704	Lp6-1a	441	0									
Lg25-2a	319												
Vp8-2/3	70												

Nigeria total: 5.53 million ha

Total area of **flood plains and deltas (F &D):** 20.3 million ha. The 1st estimation is that 20% can develope the irrigated sawah platform: **4.06 million ha**

Total area of **inland valleys (IV):** 7.35 million ha, of which tentatively 20% can develop the irrigated sawah platform: **1.47 million ha**

Table 3. Similar calculations on some West African countries give following estimation (in million ha)

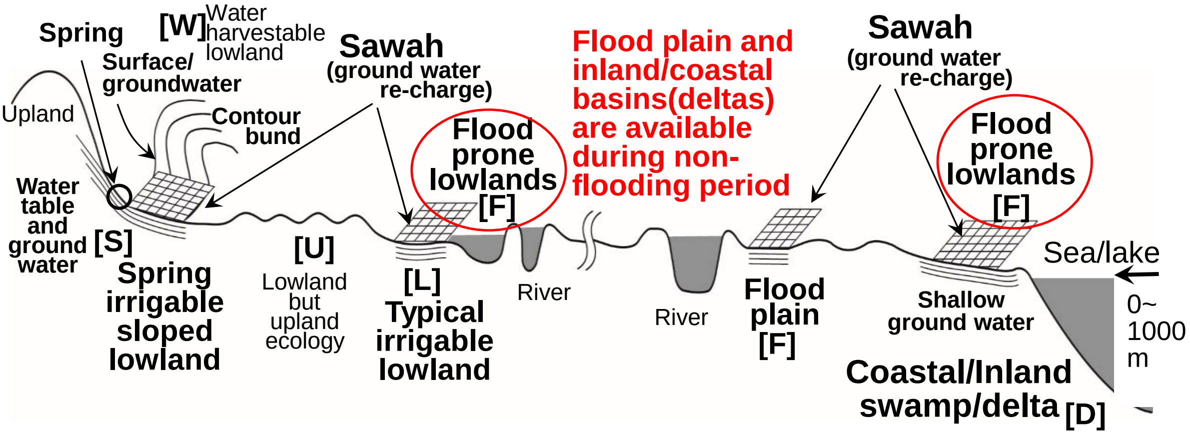
Country	Floodplains/Deltas	Inland Valleys	Sawah in F&D	Sawah in IV	Total in million ha
Nigeria	20.3	7.35	4.06	1.47	5.53
Core d'Ivoire	2.4	3.3	0.48	0.66	1.14
Ghana	2.8	2.3	0.56	0.46	1.02
Togo	1.05	0.55	0.21	0.11	0.32
Benin	1.50	1.15	0.30	0.23	0.53
Cameroon	7.20	4.45	1.44	0.89	2.33

2. Characteristics of various wetlands of SSA compared to Asia in relation to irrigated sawah system development

2-1. Characteristics of African wetlands

As shown in Figure 4, appropriateness for *sawah* system development is affected mainly by hydrological and topographical conditions (Hirose and Wakatsuki 2002). Extreme sandy soils (>95% of sand and <3% of clay) are not appropriate because of too rapid water permeability to control water in *sawah* plots. Initially small inland valleys in Guinea savannah zone and tropical forest zones, the annual rainfall is higher than such as Ashanti in Ghana and Niger state as well as BRACED (Bayelsa, Rivers, Akwa Ibom, Cross river, Edo and Delta) states in case of Nigeria, were given the highest priority for development to apply the *sawah* technology, because controlling small gravitational water is easily done by farmers' own efforts. One of the reasons why the ecology of lowlands in West Africa is so diverse (Jamin and Windmeijer 1995) can be explained partly from Fig. 4-6. Inland valleys and flood plains as well as deltas have various micro-topographies as shown in Fig. 4, of which spring irrigable sloped land and typical irrigable lowland can be developed easily to irrigated *sawah* systems using simple weir and dyke. Many areas of inland valleys that have upland ecology have the lowest priority for sawah development. Water harvestable lowland along the foot slopes (Fig. 4) can be developed as contour bunded sawah systems.

Because of diversity in hydrology, topography, soils, climate, vegetation, and geology as well as socio-economic, cultural and historical conditions, the *sawah* technology must fit into such diverse conditions. As shown in Table 1, the lowland area of SSA is enormous, 240 million ha (Andiresse 1985), because of characteristics of natural environment, particularly scarce water resources (Fig. 2, also please see **Figure 28 of Sawah Technology (2): Background**), the potential area for sustainable *sawah* development cannot cover all the lowlands of SSA (Table 1). Lowland soil formation by sedimentation of eroded topsoils in SSA is much smaller than in tropical Asia (Fig. 5). This will be a basic ecological limiting factor to develop *sawah* systems in SSA (Table 1).



Diverse irrigation options: Rainfed sawah, sawah to sawah/contour bund water harvesting, spring, dyke, river, pump and shallow tube well, peripheral canal, interceptor canal, tank

Wetland sawah development priority: [S] [L] [F]* [D]* > [W] > [U]
*Even large flood plain and deltas, farmers can practice sawah based rice farming using small water pump and shallow tube wells, except for 2-3 months flood period. Since flood water power of majority of African big rivers are not so destructive, sawah systems developed by farmers can survive under flooded water. Bunded sawah systems can not only recharge ground water, but also contribute to trap eroded fertile topsoil particles in flood water to sustain fertility.

Fig.4. Diverse wetlands/lowlands and targeted sites of sawah technology along topsequence of inland valley, flood plain, and costal/inland delta in SSA.

Can watersheds of SSA sustain sawah system? High rate of soil erosion and lowland soil formation can be compensated by high rate of soil formation in Asia. However soil formation, soil erosion and hence lowland soil formation are appeared to low in comparison with Asian watersheds. This is because of many huge inland basins/deltas are trapping sediments, such as Mali, Chad, Sudd, Congo and Okavango (see Fig. 2)

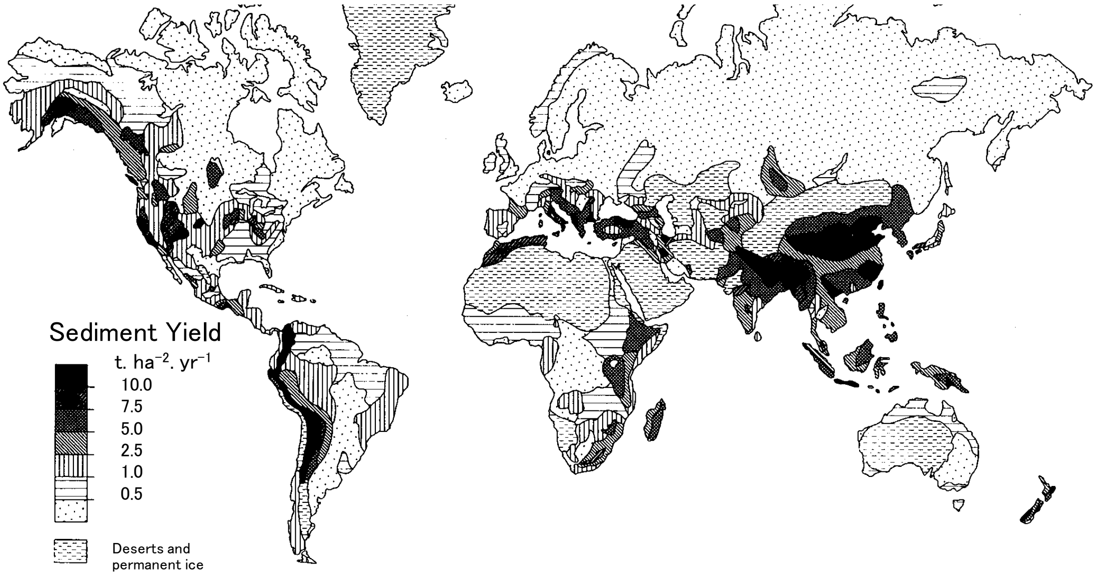


Fig.5. Rate of soil erosion in the world (Walling1983)

2-2.Kebbi Rice Revolution by Promotion of Dry season Sawah Based Farming on the Flood plains and Inland Deltas

However, since both wet and dry season trials during 2011-2014 on flood plains and inland basin (delta) of Sokoto and Niger river at Kebbi state of Sudan savanna zone at northern Nigeria, it became clear that some large flood plains as well as inland basins (deltas) in the Sudan savanna zone, such as Kebbi, Sokoto, Jigawa, Yobe and Borno states in Nigeria, can also be given higher priority if an appropriate cropping season can be selected to avoid flooding season during August to October and using shallow groundwater by tube wells, less than 10-20m depth.

During 2011-12, two power tillers supplied by Sawah team of Kinki University/NCAM for demonstration resulted in 18 ha of *sawah* development by farmers' self-support efforts who were trained by *Sawah* experts of Nigeria and Japan. Kebbi farmers bought additional 22 sets of power tillers to develop more than 200 ha of *sawah* by the end of 2013. As shown in Fig. 6 and Table 4, during dry season of October 2013- May 2014, half year, the cultivated sawah area reached to 199 ha and produced 12596.5 tons of paddy(mean yield 6.3 t/ha) (Yeldu HH 2014). This high yield was realized even under the standard quality sawah plots. This may be benefited by the strong radiation similar to the Egyptian stile ultra-high yield, because of dry season. Then 1000 sets of power tillers were bought by Kebbi state government, which distribution to farmers had started in April 2015 to boost *sawah* technology dissemination. This will increase the total area covered by sawah technology in the state more 10,000 ha within a few years. It seems Kebbi state could produce annual paddy production 1 million tons in 2014 -15.

Kebbi Rice Revolution through Sawah System Development and Evolution

Fig.7 shows soil and landuse survey route and soil sampling points of AR1-AR4 in 14th -16th of December, 1987 (Oyediran 1990). The trip was supervised by Wakatsuki who took photographs in Fig. 7 and 8. The two photographs in Fig. 7 show rice fields at almost same location but in 1987 and 2015. Fig.8. shows farming systems in 1987 at Sokoto river flood plain at Arugung and Birinin Kebbi area. Non sawah rice cultivations were common practice at that time. National Cereals Research Institutes had stations deep water rice research at that time. But nowadays deep water rice has no more importance. Onion cultivations using shallow borehole by both hand and pump irrigation were observed at that time, although minor portion. However as seen in Fig. 9, by 2011, all over the flood plains have shallow tube well and small pump irrigated micro sawah plots for onion and rice cultivation. These irrigation systems were evaluated as successful results under Fadama 1- III project assisted by World bank (2002) and Nigerian and

Kebbi state Government (Dakingari 2013). This program constructed and trained 50,000 tubewell and small pump irrigation for about 30,000ha micro sawah plots for both onion and rice cultivation by 2011. Rice yield, however remain 2-3t/ha before introducing sawah technology.

Table 4. Extension of Sawah Rice Production Technology in Kebbi State during March 2011 to April 2014

1. Kinki University/NCAM Demonstration and Training, March 2011–April 2012

Local Government	Farmers	No.of powertiller supplied/ bought	Total sawah developed(ha)	Total No. of 100kg bag	Paddy yield in 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(mean)

* Demonstration and dissemination sites sites are shownin Google erath maps of Fig. 6

2. Sawah Technology extension, April 2012-October 2013

Local Government	Farmers	No.of powertiller supplied/ bought	Total sawah developed (ha)	Total No. of 100kg bag	Paddy yield in ton/ha
Arugungu*	MGD farm*	2	15	975	6.5
	JUM farm	1	10	650	6.5
	ABK farm	1	4	260	6.5
	AK farm	1	3	180	6
	AMB farm	1	4	240	6
	Dr YA farm	1	4	240	6
	ANL farm	1	3	180	6
	AMI farm	1	6	390	6
	ASD farm	1	5	300	6
Birnin Kebbi	ABA farm	1	4	260	6.5
	BB farm	1	3	180	6
	AS farm	1	3	180	6
Bagudo	ABB farm	5	35	2450	7
Jega	HHJ farm	1	7	455	6.5
	AUA farm	1	20	1200	6
Suru	Dr.UD farm	1	5	300	6
	Total	22	131	8440	6.4(mean)

3. 2014 Dry season rice in November 2013 to May 2014

Local Government	Farmers	No.of powertiller supplied/ bought	Total sawah developed (ha)	Total No. of 100kg bag	Paddy yield in ton/ha
Arugungu*	MGD farm*	2	20	1400	7
	JUM farm	1	10	650	6.5
	ABK farm	1	8	480	6
	AK farm	1	6	360	6
	AMB farm	1	5	300	6
	Dr YA farm	1	5	300	6
	ANL farm	1	5	325	6.5
	AMI farm	1	10	650	6.5
	ASD farm	1	5	300	6
Birnin Kebbi	AAA farm	1	4	no data	no data
	BB farm	1	6	360	6
	AS farm	1	6	360	6
Bagudo	ABB farm	5	50	3500	7
Jega	HHJ farm	1	14	910	6.5
	AUA farm	1	40	2400	6
Suru	Dr.UD farm	1	5	300	6
	Total	22	199	12595	6.3(mean)

The sawah technology demonstration and training were operated by Nigerian sawah team during 2010-2012 at 6 states, i.e., Kebbi, FCT, Benue, Ebony, Delta, and Lagos, under the agreement between NCAM/Kinki University and Fadama III/World bank in 2010. Although majority of demonstration and training were successful, endogenous sawah technology development is still not so clearly visible at the moment except for Kebbi state. As shown in Table 4 and Fig. 10-13, Kebbi rice revolution has started (Dakingari 2013). Major reasons of success are good rice ecology, success prehistory of Fadama projects, excellent collaboration and field oriented working style in all stake holders from governor to farmers in Kebbi state. Thanks to the Kebbi rice revolution, Nigerian sawah teams could evolved their sawah technology for not only inland valleys but also flood plains and inland basin/delta areas.

2-3. Potential of Flood plains and Inland Basins (Inland Deltas) as new target of Sawah Technology

Fig. 14 shows characteristics of topography (left by Araki 2008) and groundwater of Africa (Fan et al 2013). Africa is stable continent, which has about 10 steps of flat peneplains of various altitudes, which are shown as C, D, E, F, and G in Fig. 15-17. The D flat land has 300m altitude. This wetlands correspond to Chad and Mali basins. The E has 400 m altitude. These wetlands correspond to Sudd and Congo basins. The flat land of F has about 600m altitude. This is tableland/plateau surrounding wetlands of Chad, Congo and Sudd basins. The G basin has about 1000m altitude. This is highland basin in East and South Africa, typically Okavango basin/deltas and surrounding areas. These basins are not good sites for rice cultivation, because of cold climate and game reserves for ecological importance. The percentage of area between 200-500 m altitude is 38.9% (1.2 billion ha) and 28.2% (0.86 billion ha) between 500-1000m in Africa, both of which contains vast inland wetlands, such as flood plains and inland basins. But in Africa, the percentage of area less than 200m (A < 50m, and B about 80m altitude in Fig. 17, mainly coastal plains and inland valleys) is only 9.7% (0.3 billion ha) including coastal lowland/wetlands. Whereas Asia has vast lowlands less than 200m, which is shown as in Fig. 17, 24.6% (1.1 billion ha), which become major wetlands for rice in Asia.

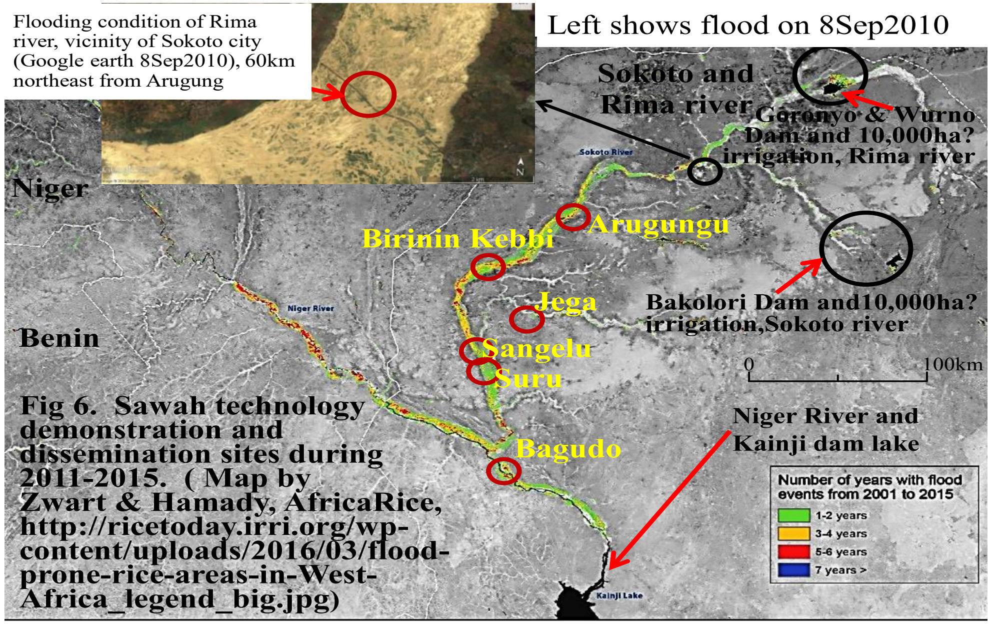


Fig 6. Sawah technology demonstration and dissemination sites during 2011-2015. (Map by Zwart & Hamady, AfricaRice, http://ricetoday.irri.org/wp-content/uploads/2016/03/flood-prone-rice-areas-in-West-Africa_legend_big.jpg)

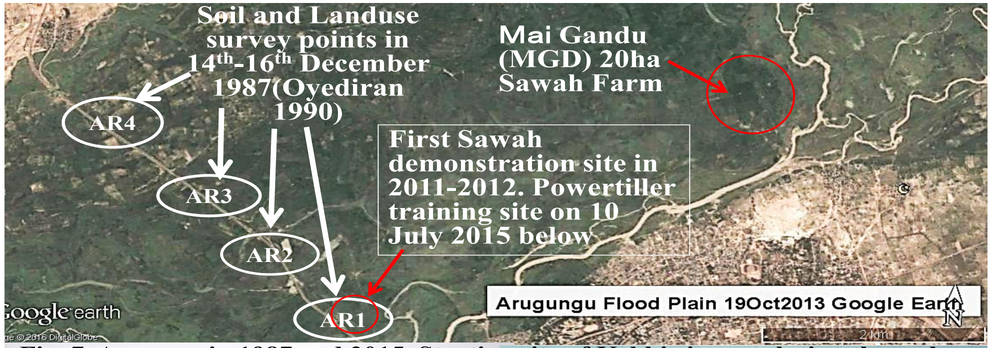
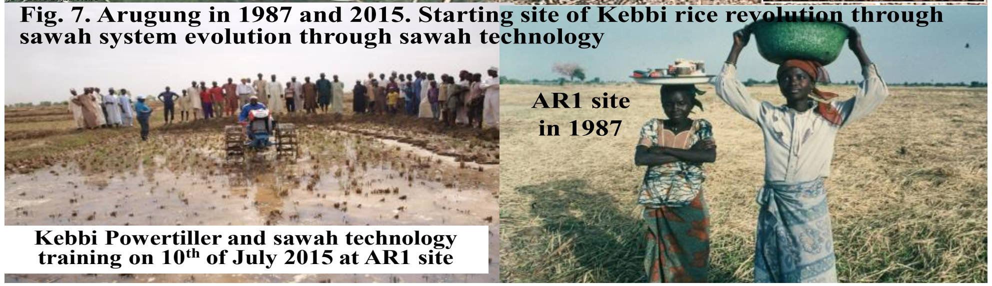


Fig. 7. Arugung in 1987 and 2015. Starting site of Kebbi rice revolution through sawah system evolution through sawah technology



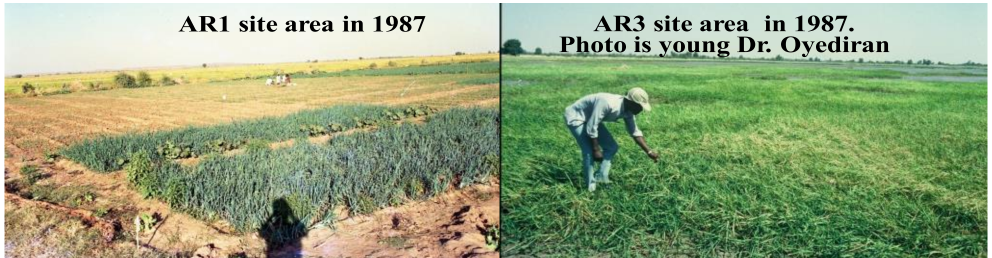
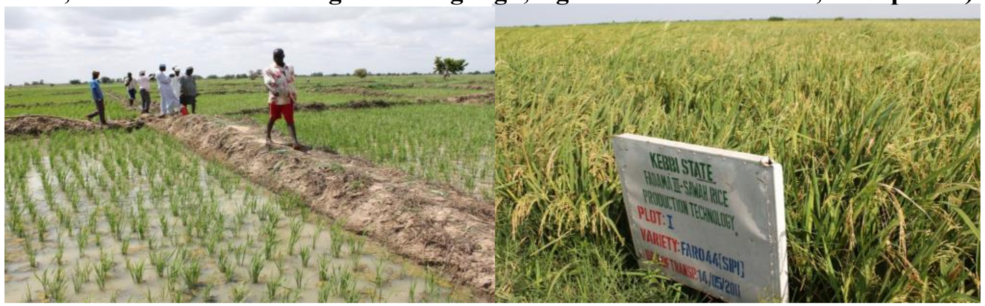


Fig. 8. Arugung in 1987. Starting site of Kebbi rice revolution through sawah system evolution through sawah etchnology. Position of AR1, AR2, and AR3 are shown in Fig.8 of Google earth in 19th of October 2013

Fig. 9. Micro Irrigated micro sawah rice and vegetable fields. Poor water use efficiency and weedy rice field before Sawah technology applied at Kebbi, Nigeria

Fig. 10. Demonstration & training of sawah technology(upper two are Jega on April, 2011, lower left is AR1 in Fig. 7 at Arugungu, right is at Birinin Kebbi, on Sep 2011)



20 ha of sawah developed by Mr. Abdullahi Maigandu Arugungu

June 2014

35 ha of sawah developed by Alh. Bello Baidu at Bagudo, Niger river floodplain

Fig. 11. Sawah development and evolution at Arugungu and Bagudo in Kebbi rice revolution sites (Photographed locations are shown Fig. 6,7, 12b and 13)

Fig.12a Stage 0-3 Sawah

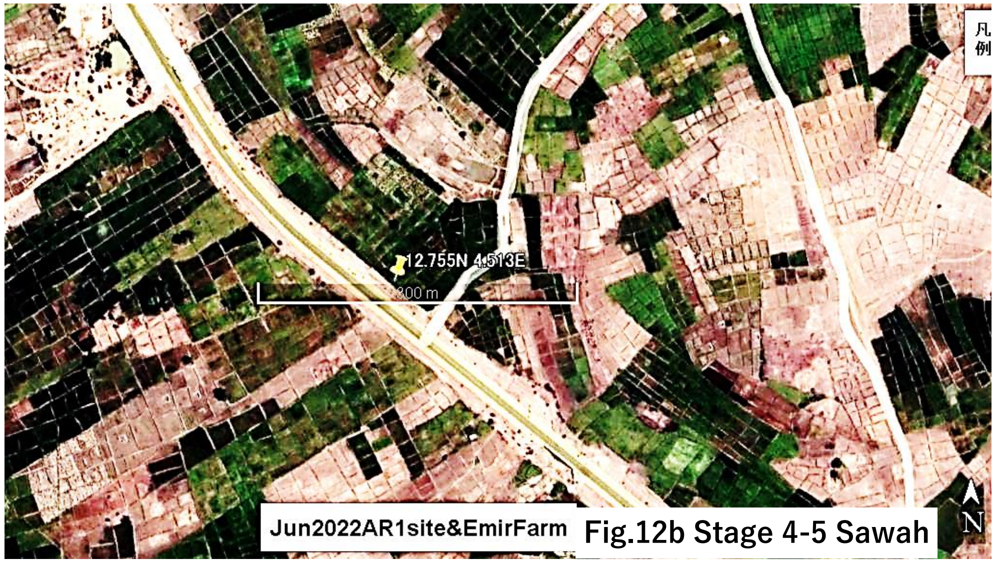


Fig.12b Stage 4-5 Sawah

Fig 12b. Evolution of Maigandu Sawah system (Fig 6&7 shows the position)is on-going after Sawah technology training in 2011-2015 using power tiller by NCAM sawah team (both are Google earth). Each Two red tetragram area has 12ha, in which about 2200 micro sawah plots exist, mean area is 55m^2 in 2009, while total sawah plots reduced to about 450, mean area expand to 270m^2 in 2016. Red circles show the position of photograps in Fig 11. Expansion of sawah plots resulted through improvement of bunds' quality for both water control and operations. Leveling quality of sawah soil surface was improved. These sawah evolutions improved intermittent irrigation efficiency and gave paddy yield, double 2-3 to 5-7t/ha.

Fig. 13. Sawah development by farmers. (11.329N 4.205E)

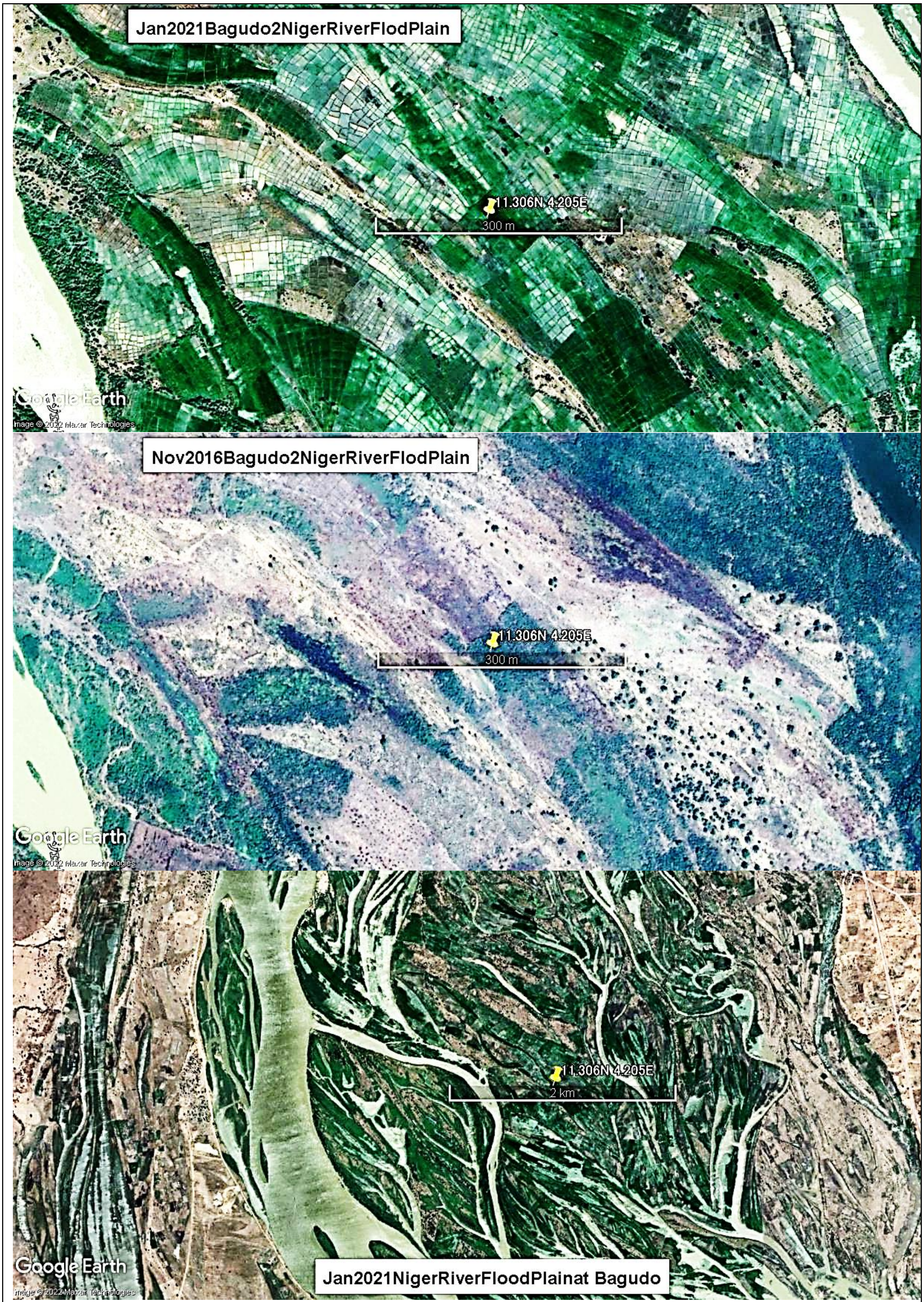
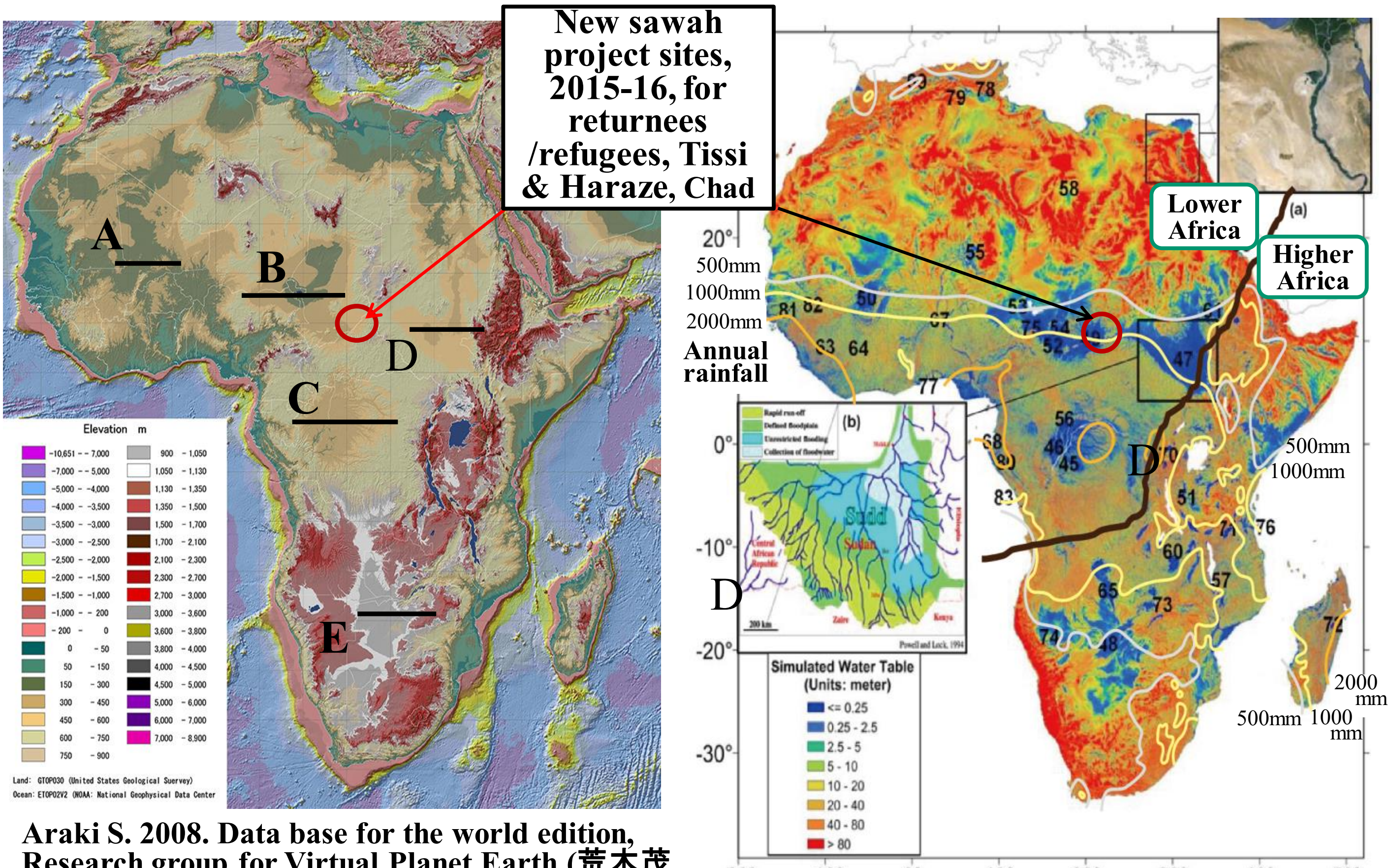


Figure 13(Supplement): Progress of Endogenous Sawah Developemnt at Bagudo area of Nigeri River Flood Plains in 2014-2021. GPS locatiopn is 11.306N 4.205E, the marker position just 2.5Km south of Figure 13 's marker position of 11.329N 4.205E.



Araki S. 2008. Data base for the world edition, Research group for Virtual Planet Earth (荒木茂, 2008. データベース世界版, 仮想地球研究会); http://virtual-earth.asafas.kyoto-u.ac.jp/ve-world/datac.cgi

Fan, Y *et al.* 2013. Global patterns of groundwater table depth. *Science*, vol. 339, p. 940-943

Fig.14. Distribution of inland basins in various altitudes with shallow groundwater for possible future application of sawah technology in Sub Saharan Africa

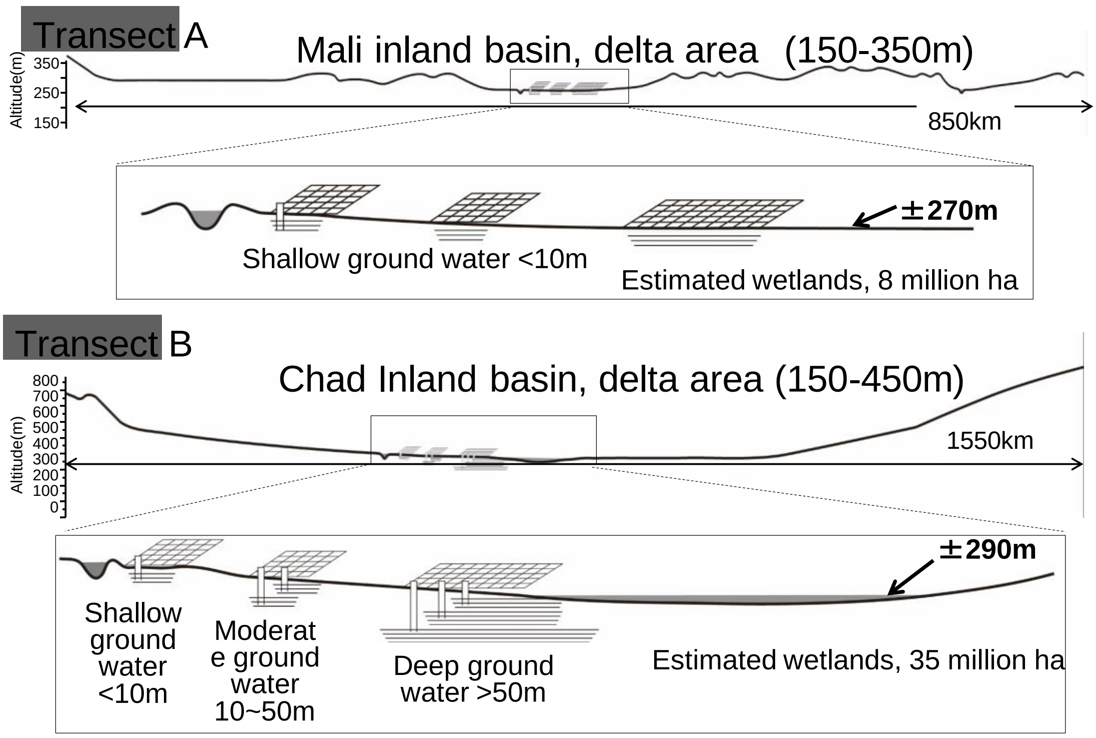


Fig 15. Topographical cross section of the transect lines of A and B in Fig. 14. The two basins have shallow groundwater good for pump irrigated sawah system

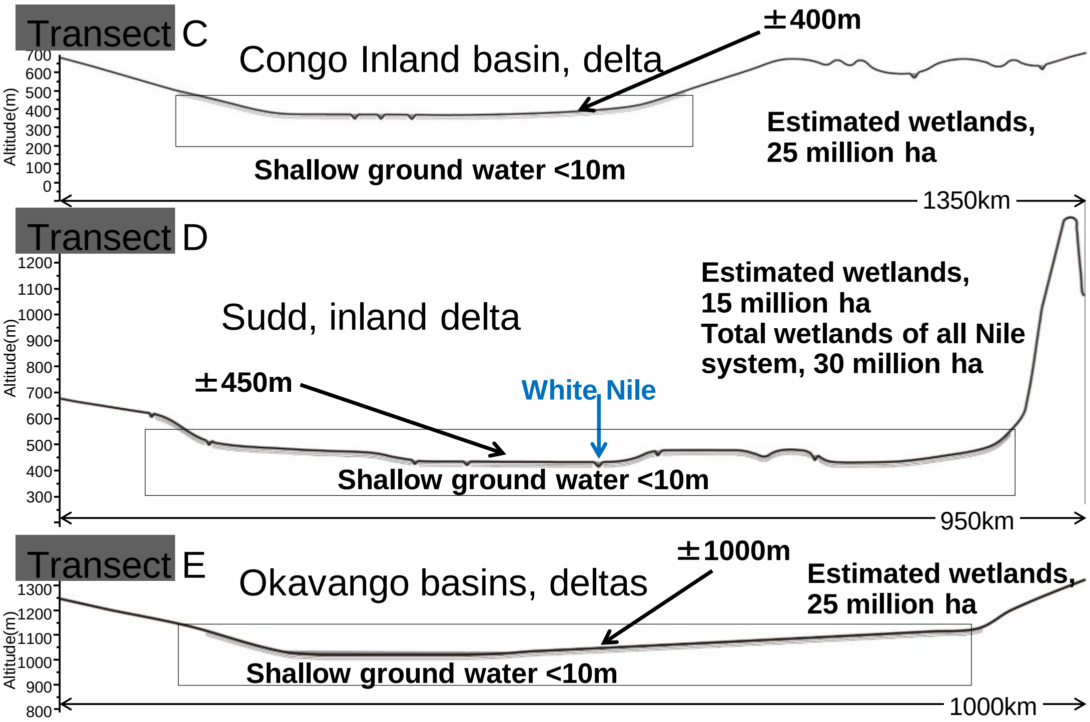


Fig 16. Topographical cross section of the transect lines of C, D and E in Fig. 14. Congo and Sudd basins have shallow groundwater good for pump irrigated sawah system. However, Okavango basins need careful environmental examinations

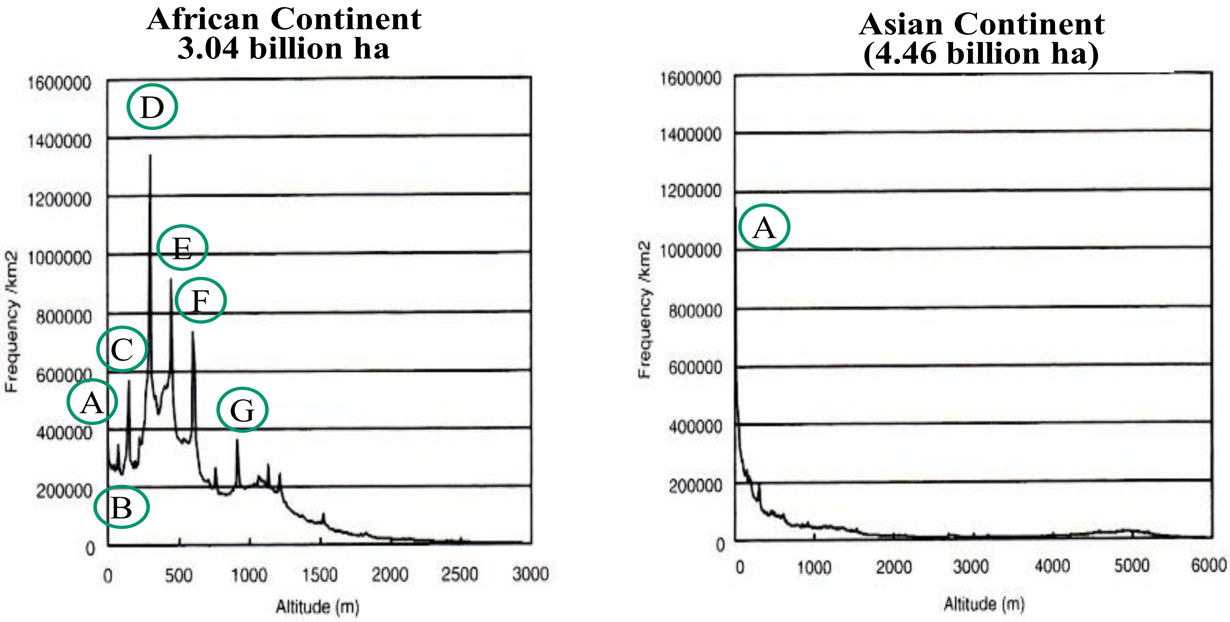


Fig. 17. Frequency distribution of area in each altitude in African and Asian continent by Araki (2008). Africa is stable continent, thus has about 10 steps of flat peneplains of various altitudes between 200-1000m, such as C, D, E, F, and G, which have vast inland basins/wetlands/deltas, except for F (plateau) as see in Fig. 14. Whereas Asia has vast lowlands, mainly coastal areas, lower than 200m, A, which are major wetlands for sawah based rice cultivation in Asia.

As shown in Table 1, Fig. 14- 17, various flood plains and even inland basins/deltas have huge potential for irrigated sawah development using small water pump with shallow tube wells installed in <10-20m groundwater aquifer. The savannah zones of Africa have huge potential to apply sawah technology using shallow groundwater resources, if appropriate sites are selected in good timing of the season. All these lowlands have the highest priority for *sawah* development in SSA. Flood prone areas need the control measures or select no flooding season. Sawah system developed on flood plains and inland basins can survive under flooded water in Africa because of destructive power of flood water is not so strong. Bunded sawah system can rather contribute to trap eroded fertile topsoil particles in flooded water suspension to sustain soil fertility, which is similar mechanism operating traditional basin irrigation farming systems on Nile river flood plains and deltas.

3. ***Four Basic Skills of Sawah*** **Technology: Site-specific Farmers' personal irrigated *sawah* system development and *sawah* based rice farming technology to realize green revolution in Africa**

The *sawah* technology consists of four important skills and technologies, as described in Table 2: (1) site and right season selection and site-specific *sawah* system design, (2) skills for efficient and cost-effective *sawah* system development using appropriate agricultural machineries, such as high performance power tiller, (3) rice farmers' socio-economic empowerment for the successful development and management of *sawah* systems, and (4) *sawah*-based rice agronomy, including variety selection and soil and water management to realize at least the sustainable paddy yield of more than 4t/ha. The establishment of institutional training and dissemination systems for *sawah* eco-technology transfer (Sawah Technology home page 2016, Wakatsuki et al 2001, Buri et al. 2009, 2012) is necessary. The coordination of farmers' group formation and land-tenure arrangements at least 10 years secured rent (Oladele 2010) to sustain *sawah* development are also important. Training of lead *sawah* farmers is the key factor. The lead *sawah* farmers can train other farmers and farmers' groups to develop *sawah* and manage *sawah*-based rice farming by themselves. This is the final goal of our *sawah* technology implementation and endogenous development.

In 2011-2012, the *sawah* technology reached the stage to make strong impact to farmers to realize Green Revolution in Kebbi state, Nigeria. If farmers master the four components of the *sawah* technology, they can develop their personal irrigated *sawah* systems and realize 20–50 tons of paddy production per season, which is equivalent to \$10,000 to \$25,000 of gross selling, using one power tiller, which costs \$3,000–\$4,000 per set, within three years after the initiation of new *sawah* development activity. The technology can be transferred from farmers to farmers. If 500 lead farmers can be trained, this will result in new irrigated rice fields of 2,500–5,000 ha within 5 years at inland valleys, flood plains and inland deltas as well as various coastal swamps. Thus the technology can spread like wild fire to realize the long-waited Green Revolution in Africa.

Traditional ODA-based development of 2,500–5,000 ha irrigation systems for rice cultivation requires more than 5 years period and \$100–200 million for development alone, without any training for the systems management. In addition, the development is done by outside experts. Therefore, the systems cannot be expanded if the ODA stops. This *sawah* technology, however, can realize the same scale of development shorter than 5 years period and with just one tenth of the ODA cost, i.e., \$7.5–15 million in demonstration stage and \$ 3-5 million in farmers' to farmers technology transfer stage (as described below) with sustainable development, because of the on-the-job training of 250-500 qualified lead *sawah* farmers at the same time. These farmers will then be able to develop new *sawah* fields endogenously. This is the most innovative characteristics of *Sawah* technology. For example as described above, Kebbi rice revolution (The Executive governor of the Kebbi state, Dakingari 2013, Yeldu HH 2014) is close to this situation in Nigeria in 2011-2015 and beyond. Some Nigerian newspapers described one of our Sawah farmers, Mr. Abdullahi Maigandu's as Bumper Harvest at Kebbi (All Africa 2014, Independent, Nigeria 2014).

Thus, what is needed now is nation-wide full dissemination/implementation at inland valleys, flood plains and other lowlands in all agro-ecological zones in all 10 states in Ghana and 37 states in Nigeria. Fortunately in 2014, Nigerian government approved the *Sawah* technology as an official technology to promote Rice value chain of Agricultural Transformation Agenda (FMARD 2014). If we can continues such efforts, we will be able to achieve an adaptive evolution and endogenous development of s*awah* technology set (Table 2) to scale up the successful results obtained by long continued *sawah* project (Wakatsuki et al 1998 and 2001, Hirose and Wakatsuki 2002, Wakatsuki et al 2009, Sawah Technology Home Page 2016) for all states of Ghana and Nigeria — as primary targets — as well as Togo, Benin, Liberia and Sierra Leone under *Sawah*, Market access and rice technology, project of Africa rice (SMART 2015, AfricaRice 2013 and 2014, Mohapatra 2016), then finally all West & Sub-Saharan African countries.

Table 5. Four Skills of Sawah Technology for Farmers Personnel Irrigated Sawah Systems Development <Sawah Platform> and Sawah based Rice Farming

(1) Site & Right Season Selection & *Sawah* system design

(a)Rice cultivation >15ha
Farmers strong will to improve technology
(b)Hydrology & quality
Gravitational water use:
>30 L/s, >5 months/year.
To control Flood:
Maximum flow <10ton/s
Note: Good community cooperation, if >50ha
Shallow Groundwater
Shallower <10-20m, small pumps make possible double cropping
(c)Topography and soil
Slope <1-3%
Sand+Silt <90-95%
(d)Privately own the land or at least Secured rent longer than 5-10 years
(e) *Sawah* system design
Sawah layout
Leveling quality
Bunding quality & Mgt.
Drought and Flood control measures
(f) Powertiller and trailer traffic road
(g) Water intake, storage, distribution, & drainage
Simple sand bag & wooden dam/Weir dam, barrage
Canal system
Interceptor canal
Pond and fish pond
Small pump & shallow tubewell
Central drainage

On-the-job training on site-specific *sawah* development & management

Collaboration between farmers & scientists, engineers, and extension office is very important

Farmers know site specific hydrological conditions which are the most important for site election

The successful example of *Sawah* ecotechnology innovations:
(1) Mobile pump irrigation in floodplain/Delta (Sudan and Sahel savanna zone, Kebbi state, Chad)
(2) Spring or small weir based irrigation system (all climatic zones)
(3) Grade up the micro sawah/ridge planted sawah platforms in Official irrigation schemes

(2) Efficient & Low cost Sawah Development: Skill & Technology

(a)Skills for bush clearing, de-stumping & support smooth powertiller operation
(b)Skills for bunding, canal construction and levelling ±5cm in a sawah plot
©Cost for hired labors, tools, pump and powertiller
>10ha of development/3 years using one powertiller
Purchasing $3000-4000/10ha
Running $2000-3000/10ha
Pump&Tubewell $1500/10ha
Tools & materials $1000/10ha
(d)On-the-job training cost
Scientist & engineers $1000/ha, Extension officer $500/ha, Leading Farmer $250/ha

Sawah development: at least 10ha by one Power-tiller

Target cost: <$1000-3000 /ha

Target speed of develop-ment: >3-10ha/year /powertiller

(3) Socio-Economic Skills for Rice farmers empowerment

(a) Group organization & leading farmers training
(b)Training of powertillers assisted sawah development & sawah based rice farming
(c)Post harvest technology using small harvesters of $10,000 per set if sawah area >25ha & paddy production >100ton per year
(d)Loan system to buy agric. Machines and sawah lands
(e)Land tenure arrangement for secured rent >10 years

(4) Sawah based rice farming

(a)Management of water intake, storage, distribution, & drainage systems
(b)Management of bunding & leveling
(c)Water Managt. of sawah
depth of water
irrigation timing
(d)Puddling skills
(e)Skills of Nursery & trans-planting
(f)Weed, pests, and birds Managt.
(g)Managnt. of Fertilizers, nutrient & organic matters
(h) Variety selection & Managnt
(i)Achievement of targeted yield

(1)Immediate target: Paddy yield >4t/ha, >20ton paddy /powertiller

(2)>50t paddy /year /power tiller will accelerate *sawah* Development

(3) Basic research on sustainable paddy yield >10t/ha is important

(1) To train qualified sawah farmers and or groups who could develop sawah >5ha and get annual paddy production >20ton using one powertiller within three years after the initiation of sawah development.
(2) To train the leading *Sawah* farmers is the key for sustainable and endogenous sawah development. The leading farmers can train farmers and farmers groups to achieve the target as qualified *Sawah farmers*.
(3) If site selection is suitable, sawah can be developed in Africa easier than Asia.

Sawah technology can reform ODA and contractor based development : Endogenous development will be, farmers to farmers >> extension officers > researchers >> ODA style technology transfer

4. Sawah Technology as an integrated skills in four fields: Basic and photographic illustrated manuals as well as general time schedule to establish a demonstration *Sawah* System of 2 ha and then >10-20ha of new sawah dissemination surrounding the demonstration site using 2-3 sets of powertillers by one family or group.

4-1. Site and Right Season Selection and Appropriate Sawah System Design

4-1 A: Site selection: 2–5 days per potential area

(1) The priority site is the on-going major rice growing area of Fadama and lowlands; the potential area should be larger than 15 ha (if >25ha is the best) for the sustainability and endogenous dissemination of *sawah* technology. Although site selection can be done any time in the year by experienced sawah expert, the best season for the site selection will be between September/October (just before harvesting) to January/February (just after harvest). Intensive interviews of rice farmers on the local hydrological conditions and extreme drought and flooding events for the past 10–15 years are important.

(2) Secured continuous river water flow: > 5 months, base surface water discharge: > 30 l/sec, i.e., > 2600 m^3/day, potential irrigated *sawah* area: >15 ha. Although if daily water requirement is 20 mm per day, surface water discharge >35 l/sec, i.e. >3000 m^3/day, is necessary, assuming direct supply from rainfall 3-5 mm per day (300-500 mm per 100 days for core rice growing period) and ground water supply is more than 10% of the surface water discharge in majority of Africa lowlands (although data collection is difficult). During puddling and levelling stage, water requirement is >100mm (i.e., 100 ton/ha) per day. However these practices are only necessary to continue less than a few days in each sawah plot. Therefore appropriate water distribution is possible even after the completion of potential of 15ha of sawah. Details water requirements and appropriate water distribution have to be adjusted after some years of trials and errors experiences.

(3) Majority of flood plains such as Kebbi, Sokoto, Niger, Kwara and other states along Niger river systems in Nigeria which have shallow ground water level of less than 10m can supply enough water using small water pump connected with shallow tube wells less than 20 m depth (see photograph at page 18). As shown in Fig. 3-5, savanna zones of inland basins from Mauritania, Senegal, and Mali to Chad and Sudan have huge areas of lowlands with shallow groundwater (Fig.14). If ground water flow is smooth, one or two pumps of the capacity of 600-1000 litre per minute can manage one ha of irrigated sawah development and sawah based rice farming.

(4) No strong flood attack: Flood depth will be < 50 cm, and continuation of the flood will be < 3–4 days. Flood water discharge should be < 10 ton/sec in case of inland valleys. However even the flood continue >3-4 days and deeper than 50cm and discharge is >10 ton/sec, Sawah development is possible such as large flood plains in Niger river systems in Nigeria and inland basins in West and Central Africa as described above (Fig. 3-5). Since flood water power of majority of African big rivers and inland basins are not so destructive, *sawah* systems developed by farmers can survive under flooded water. Tamale area at Ghana may be also possible. Since the flood season is normally during August/September to October/November, sawah technology can be practiced during December to August, about 8 months (good for double rice cultivation), if appropriate pump irrigations are available. Appropriate time selection for Sawah technology operations will be adjusted after some years of trials and errors experiences.

(5) Flat and very gentle slope: < 2%, if slope is < 0%–1%, the levelling operation to develop high quality *sawah* is easy. If sand content is higher than 90-95% and ground water level is deeper than one meter, *sawah* developed will be leaking and thus difficult to control water. If farmers continue intensive puddling, clay particles can ceils in the long run. If irrigated water contains clay particles, levelled *sawah* plot can accumulate clay particle in the long run. Some Asian rice farmers carry and deposit clay particles in *sawah* plots using irrigated running water to ceil and level *sawah* plots.

(6) Strong will of rice farmers to master *sawah* technology skills and *sawah* development by farmers' self-support efforts. This is the most important point for site selection. Even if the site has ideal ecology, if farmers have no strong will, the *sawah* technology is useless.

(7) Privately own the land or at least the rent contract longer than 5-10 years (secured rent) are desirable.

(8) Good access road for the demonstration site

<u>**Note:**</u> The most important factor in the site selection and appropriate *sawah* system design, development and management is collaboration between farmers, extension officers, engineers and scientists. Although local

farmers do not know *sawah* technology (before the project starts), they are familiar with the site-specific seasonal and decades-wide hydrological conditions that are critical for *sawah* system design and development.

4-1B. Sawah system design: one to two weeks. The design, however, have to always ready to modify based on the trial and error process through the observation of seasonal draught and or sudden strong flood water flows

(1) *Sawah* system design include *sawah* layout based on ①the observation of water flows and topographical survey of the watershed. Detailed topo-survey based on *sawah* layout will minimize the cost and effectiveness of *sawah* development to achieve high quality leveling. However ②since the efficiency of power tiller operation is the higher in the bigger sized *sawah* basin with straight lined bund, one plot of *sawah* should be bigger than 500-1000 m^2. Water control of rudimentary sawahs smaller than 10-100m^2 is practically difficult if farmers total cultivation area is larger than 1ha. Majority of lowlands in SSA are bushy and many unseen sinkholes, small power tillers are better option. However if lowland *sawah* development will be progress rapidly, we will be able to use more powerful wetland tractors in near future. In that case, *sawah* plots bigger than 5000$m^2$are preferable. However since lowland *sawah* development is just beginning in SSA at the moment, thus the *sawah* layout has to compromise between "bigger quadri-lateral shape" and "contour line based natural shape and smaller size". *Sawah* system layout determines the easiness of the *sawah* system development, especially leveling operation and *sawah* based water management

(2) Major function of bund is to retain appropriate water depth. Therefore no leakages with proper compaction, no crab holes and no cracks are necessary. Bund is also useful to monitor water, weed, and rice in *sawah* plots, thus should be durable for farmers to easy walk on. Some bunds can be used for boundary demarcation of land owners, which should be more durable than water control bunds in each *sawah* plot. Flood control bund and traffic road for power tiller and trailer need bigger and durable bund, which can serve as road. Since weedy bund hides holes and cracks, weeds on bund have to manage and control. Compaction of bund and polish of bund surface soil are also important.

(3) Appropriate Irrigation facilities for water intake, storage, distribution and drainage have to be designed based on each site specific conditions. Possible options are ①simples sand bag and wooden dam, weir, and barrage, ② canal system, ③interceptor canal, ④ pond and fish pond, ⑤ pump irrigation, small and middle capacity with shallow(<20m depth) and middle(<50m depth) tube wells, ⑥central or peripheral drainage, small, middle and big.

(4) Note 1: On-the job and site specific training is necessary. Trial and error process to reach appropriate *sawah* system are necessary through the observation of variability of water flows. Therefore *sawah* system design have to ready to modify to fit local site specific conditions.

(5) Note 2: Paradoxically, if site selection is appropriate, new *sawah* development is far easier in SSA than in tropical Asia, because of generally very gentle slope are available in SSA. Therefore leveling operation is easy.

4-2. New *Sawah* Development for Demonstration and On-the-Job training: One to Six Months for 2-4 ha sawah development using one set of power tiller depending on the skills, water availability, and site topography, soils and vegetation.

Two to four extension officers from the state Agricultural Development Project (ADP) or Fadama III offices in Nigeria and ministry of food and agriculture in case of Ghana are needed, as well as 3–10 active farmers, who will be trained through intensive OJT by one or two *sawah* experts (*Sawah* experts from NCAM *sawah* team in Nigeria, SRI-CSIR and CRI-CSIR as well as qualified Fadama III and ADP and MOFA extension officers in Ghana).

(1) Skills for bush clearing, de-stumping, and delineation of possible *sawah* area: 10–20 work-days/ha

(2) Site survey and mapping: 1–3 work-days/ha, if scientific report is necessary in demonstration site.
This requires 1–3 approximately 100-m *x*- and *y*-axis lines using survey tools, such as the laser-assisted Total Station (Cannon Co. Ltd.) if available. If not available, 90 degree crossed lines can be made on the sites using simple measuring tools, then sketch the crossed lined field site in sketch note book including upland and lowland border and river/canal lines, and landowner/tenure lines.

Note: Since the farmers cannot use such tools, *sawah* technology uses water as a topography guide. Therefore, *sawah* system development must be done using water. Without the availability of appropriate water, no sawah technology can operate. Laser assisted heavy machines or tractors are necessary if the water guidance skills are not available in dry season development. But those machine based operation is out of scope of our Sawah technology at the moment. If sawah development is rapidly progressive, laser assisted wetland tractors may be required in near future.

Water shows height differences, and skilled *sawah* personnel can make good canal line slopes (not too steep to avoid canal erosion cutting). *Sawah* plot leveling can also be done using water and soil as a marker within ±5 cm height differences, without using any sophisticated laser apparatus. Water can also tell us all what is needed if the *sawah* personnel use their skills. The quality of sawah can be determined by the quality of leveling. If height difference in a plot of Sawah is within ±2.5cm (<5cm), excellent, ±5cm (<10cm), good, ±10cm (<20cm) marginal to get the targeted yield of 4t/ha, if ±15cm or more (>30cm), paddy yield will be less than 3t/ha becuae of difficult water cntrol, thus difficult weed control.

(3) Skills for bunding, canal construction, and land surface treatment for easy power tiller operation

(3)-①:*Sawah* delineation based on contour lines with 30-cm height differences and based on the consideration of efficient use of power tiller operation as described **I-2(1):** 5 work-days

(a) The site delineation using tapes, ropes and pegs should start from the lowest valley bottom at each land owner/tenure line, and (b) should be straight lines and as large a size as possible, in light of the efficient use of a power tiller, and (c) pegs and rope can be used to delineate and guide line for bund, borders of the land, canal and drainage lines.

(3)-②: Bunding: 15–30 workdays/ha

Standard size is as follows: height 50 cm± 25 cmx width 100 cm ± 20 cm

A: Big bund: For power tiller traffic > Flood-control > land tenure delineation

B: Standard bund: Major *sawah* delineation

C: Small bund: Sub-*sawah* delineation in case of not enough levelling in a poor *sawah* plot.

(3)-③: Canal and drainage lines: 10–60 workdays/ha

Appropriate slope of the canal must be less than 1%, preferably 0.1%–0.5%; if too steep, bottom soil will erode.

(3)-④:Dyke, weir, and dam: 30–50 workdays/ha. About 500 sand bags (20 kg each) reinforced with wooden piles and planks can be used to lift the central river water surface 1–1.5 m higher to irrigate *sawah* plots. River will be 10–15 m width in 5,000–10,000 ha size of watershed under 1,500 mm annual rainfall. If the watershed size is 2,500–5,000, about 300 sand bags may be enough.

(4) Nursery preparation: Three workdays/ha in three phases at about 3-week intervals, one day for each phase: the nursery must be prepared 15 to 21 days before transplanting.

(5) *Sawah* ploughing, puddling, leveling and smoothening: 50–80 workdays/ha. The standard sawah plot development should start from the nearest point of available water source

(6) Cost for hired labors, tools, powertiller purchasing and operation/management: Basic target is to achieve new *sawah* development larger than 10 ha using one powertiller within 3 years, if this target is realized the targeted cost <$1000-3000/ha is realized, including the training cost below.

Powertiller purchasing US$2500-4000/10ha, Running cost $2000-3000/10ha, Tools and materials $1000/10ha

(7) Cost for on-the-job training

Scientists & engineers at the stage of demonstration: $1000/ha

Extension officers at the stage of official extension: $500/ha

Lead farmers: $250/ha at the stage of farmers to farmers technology transfer

4-3. Socio-economic skills for rice farmers' empowerment

(1) Apart from the first demonstration, because of sustainability, pump and power tiller should be supplied to farmers as subsidized loan, 30 to 50% discount or less/more?. Payment will be done by paddy and repayment should be between 3-5 years.

(2) *Sawah* rice farmers' organization. To train lead farmers is the key for sustainable and endogenous *sawah* development. The lead farmers can train farmers and farmers' groups to achieve the target as qualified *sawah* farmers.

(3) Training the qualified *sawah* farmers and groups who can develop sawah >5ha and get annual paddy production >20 tons using one powertiller within three years after the initiation of new *sawah* development activity and training.

(4) Training of power tillers assisted new *sawah* development and *sawah* based rice farming

(5) Post harvest technology using small harvesters of $15,000 per set, if *sawah* area reach to >25 ha and annual paddy production >100 ton. This empowers market competitiveness not only domestic but also international.

(6) Establish loan systems to buy agricultural machines and other input as well as *sawah* land acquisition

(7) Land tenure arrangement for secured rent longer than 5-10 years.

(8) *Sawah* technology can transform traditional ODA based to sustainable development. Sustainability and endogenous development will be ①Farmers to farmers technology transfer >② Extension officers based >③ Researchers and engineers based >④ Traditional ODA based technology transfer.

4-4: Sawah –based rice farming

4-4A. *Sawah*-based rice farming in the first year of new *Sawah* development

Since *sawah* development and rice planting will run one after another by one continuously in the first year, the targeted area may be divided three phase, i.e., one ha each in 1 month and total 3 ha in three months, for example. One ha can be further divided about 0.2-0.4 ha each in 1-2 weeks. Since 15-21 days rice nursery should be prepared transplant immediately after leveling and puddling, nursery should prepare and sow 2-3 weeks before the estimated day of the completion. About 30kg of selected seed are necessary for one ha of transplanting. However, because of unforeseen events, the completion of *sawah* plot development may be delayed. In that case, some percentages of nurseries have to be abandoned. Thus we are estimating 60-90 kg per ha for the amount of seed necessary. However, the next season after completion of the *sawah* development, about 30 kg of seed selected, will be enough.

(1) Management and fine tuning of water intake, storage, distribution and drainage systems for optimum *Sawah* water control: 20–50 workdays/ha
(2) *Sawah* systems fine tuning and maintenance: 10–30 workdays/ha
(3) Transplanting: 30–40 workdays/ha
(4) Fertilization: 6 workdays/ha
(5) Weeding: 10–14 workdays/ha
(6) Bird-scaring: 30–40 workdays/ha
(7) Harvesting: 30-40 workdays/ha
(8) Threshing: 20-25 workdays/ha

4-4B. *Sawah*-based rice farming in the subsequent year

These operations are the same at the standard irrigated *sawah* rice farming. In details, please refer to the books such as **IRRI's publication "A Farmer's Primer on Growing Rice (Vergara 1992).**
(1) Water management operations through the daily management of *sawah* inlet and outlet, including water storage, intake, distribution and drainage systems, such as pump, maintenance of canals, dykes, etc.
(2) Power tiller assisted plowing, puddling and leveling
(3) Seed selection, nursery preparation, transplanting: 30-40 works days/ha
(4) Fertilization: 6 workdays/ha
(5) Weeding: 10–14 workdays/ha
(6) Bird-scaring: 30–40 workdays/ha
(7) Harvest: 30-40 workdays/ha
(8) Threshing: 20-25 workdays/ha

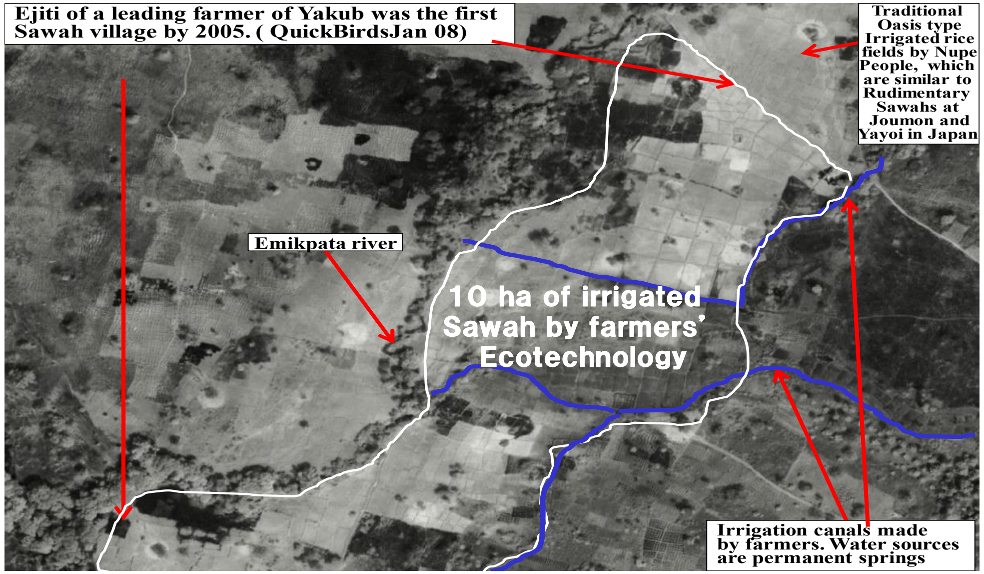
5. Overall Target for Sustainable *Sawah* Development and *Sawah* technology Dissemination

The overall target is to realize 20–50tons of paddy production, which is equivalent to the total paddy sales of $10,000–25,000 per year using one power tiller, which costs $2,500–$4,000 per set, within three years after the initiation of new *sawah* development. If the paddy yield is 4t/ha and only mono-cropping is practiced, at least 5 ha of *sawah* must be developed using one power tiller to guarantee economy of power tiller use.

6. Continuous improvement, "KAIZEN", of the *sawah* system and sawah ecotechnology

KAIZEN is Japanese, which philosophy is common in vehicle production in TOYOTA Co. Ltd. These scale-up and implementation activities will also give opportunity to improve continuously, i.e., "Kaizen or small improvement to reach innovations finally" of *sawah* system and *sawah* technology continuously, i.e., ①land tenure system to secure sustainable development, ②more cost reduction of development <$1500/ha, ③speed up the development to >10ha/power tiller/3years, ④increase paddy yield >5t/ha, ⑤marketable paddy production by small harvester, and ⑥empowerment of lead farmers & farmers association. These activities will also contribute to capacity buildings of African rice researchers through publication of ⑦ academic papers by African scientists including their PhD training, ⑧manual for *sawah* technology to secure yield of 4-8t/ha, and ⑨policy establishment of the *sawah* technology for rice development in Nigeria and Ghana, SSA

(Photographic explanation) Examples of endogenous expansion of *Sawah* systems in inland valley and flood plain at Bida and Zaria, UN-Village, Arugung and Jega in Kebbi state, Nigeria, and Adugyama, Biemso No. 1, and Afari in Ashanti, Ghana.



Nupe village of Sheshi Bikum: 3 ha of sawah was developed in three months in 2010 using one powertiller of sawah project. Paddy production was about 13 ton, which is equivalent to $5000. Sawah farmers group bought additional powertiller of $3000. Sawah area expanded to 40ha by January 2012.


Training on topo-survey NCAM

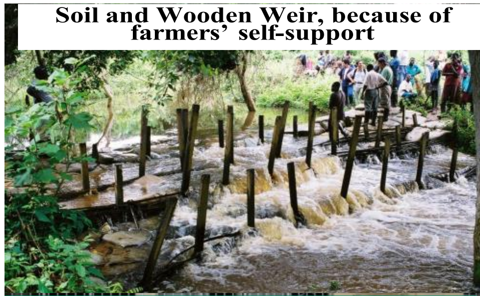

Bida, Shabamaliki

On the job training


Powertiller sinking


Bida, Shabamaliki

Soil and Wooden Weir, because of farmers' self-support

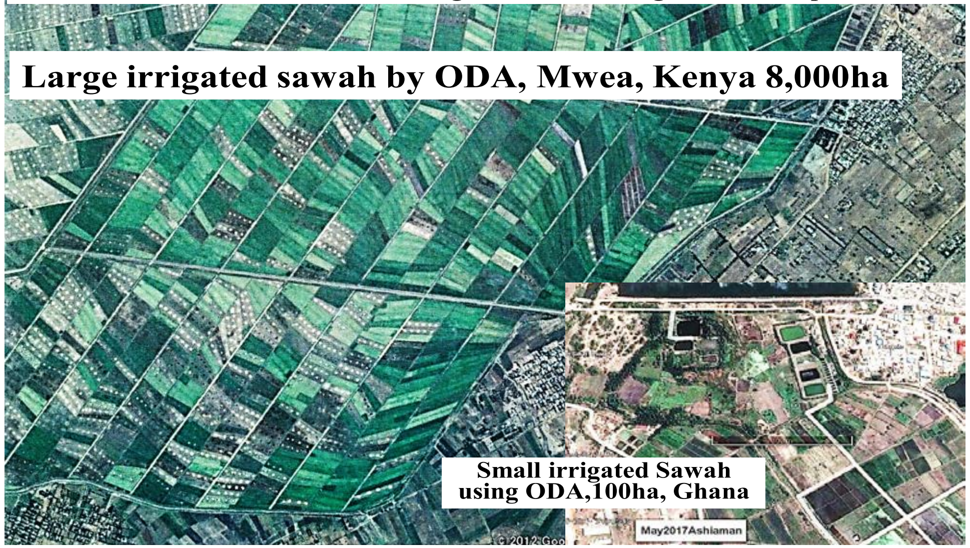


Farmers' to farmers technology transfer

On the job sawah ecotechnlogy training including PhD program, NCAM

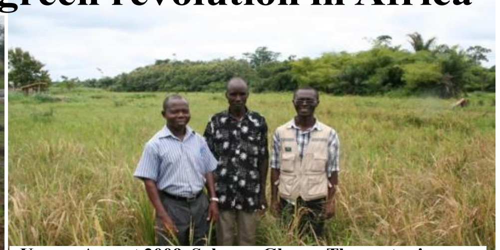
On-The-Job training: Sawah, Fadama and ADP staffs, & farmers

Left: Large scale irrigated sawah system at Mwea, Kenya, 8000ha. **Right down:** Small scale irrigated sawah at Tema, Accra, Ghana, 100ha. Both sites have been received continuous huge ODA support since 1960. Both have problems in terms of cost-effectiveness, sustainable management, and endogenous development.



Site Specific and farmers' personal irrigated Sawah systems to realize green revolution in Africa

Rice transplanting at sawah plots, which water conditions can be controlled by farmers using bunding, leveling, puddling, water inlet & outlet



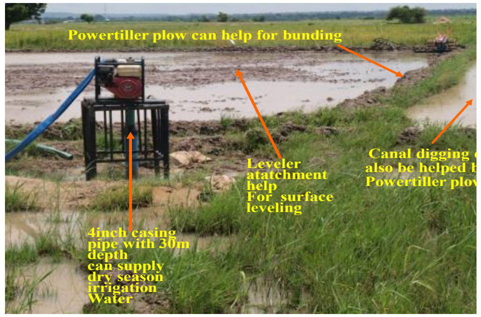
Upper: August 2009, Sokwae, Ghana. The center is a leading farmer and his both sides are Sawah staffs at Crops research Insititute, Ghana. Lower: January 2010. 3ha of irrigated sawah was developed within 3 months. Total sawah became 6ha by November 2011

Farmers sawah technology will prepare the platform for the green revolution technologies

Restoration measure to connect spring water and sawah by irrigation canal and syphon pipes at Adugyama, Mr. Tawiah's site, August 2011

Powertiller leveler can move soil >25m. Plow can help strong bunding & wider and deeper canal digging even at the flood plain. Lower right is puddler.

Canal construction by power tiller plow



20-30 m depth Tube well digger Cost

(1) $300 for Tube well digging & 4 inch pipe installation
(2) $250 for pump, 3inch, 600liter/min and $180 for 12m suction & 70m extension horse in case groundwater depth is shallower than 8m.
(3) $400 for submerged pump with 2.2inch pipes lifting water 500liter/mine from 20m depth of groundwater using generator of $1000, which can drive two to three submerged pumps
(4) 1ha sawah needs 100ton of water per day
(5) Tubewell digger machine cost $2500-5000

Indonesian G1000 Boxer can move soil 25m for leveling(10th Dec 2015)

Sawah technology training and demonstration at Haraze, border town of Central Africa Republic, and Tissi, border of Sudan, during December 2015 to April 2017

Sawah technology training and demonstration at Haraze, border town of Central Africa Republic, and Tissi, border of Sudan, and Baga Sola, Nigeria, June 2015 to April 2017

On the job training has expanded to the staffs of AfricaRice, Togo and Benin on various skills of sawah eco-technology (Afari, Ghana, Nov.2011)

International workshop on sustainable sawah development by farmers' self-support efforts was organized at Kumasi, Ghana in collaboration with Agric. ministries of Ghana & Nigeria, JIRCAS-Japan, AfricaRice and our Sawah project. Now leading farmers can develop 5-10ha of new sawah fields within 1-2 years and produce 20-50 ton of paddy per year (Nov. 2011)

Small pump based Oasis type sawah development at savanna floodplain performed paddy yield 7t/ha at Jega, Kebbi state, Nigeria(May 2011)

7. Case study on Sawah Technology Dissemination in the South Nkwanta District, Volta Region, Ghana

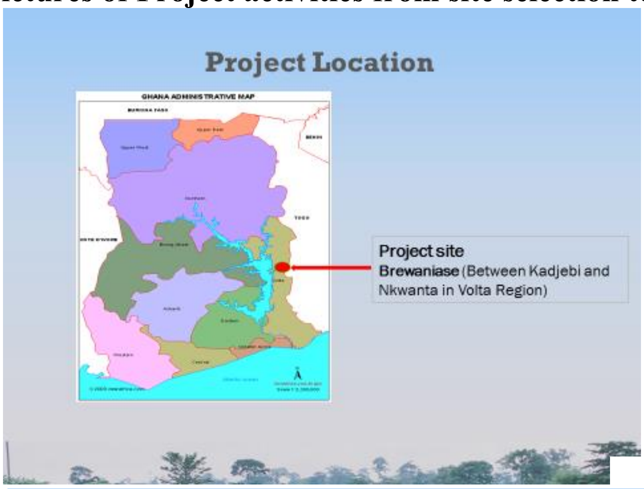
(Introduction)

Lowland area in Ghana estimated to be 800,000 hectares, offers huge potential for intensive and sustainable rice production due to relatively good hydrological condition. This ecology is however prone to flooding, surface run-off leading to soil erosion and therefore soil fertility challenges. There is also the issue of drought in the event of low and erratic rainfall situation leading to poor crop performance and at times complete crop failure. However, lowland rice farmers in the Northern Volta region cultivate rice mostly under rainfed conditions with little or no bunding and leveling. Since the field condition usually alternate between flooding and drought condition, added plant nutrients are prone to leaching, surface run-off or poor uptake, hence low utilization efficiency.

It is believed that suitable growing environment and appropriate management practices are pre-requisite to increased productivity of lowland rice production. Therefore, to address the rice production challenges facing farmers in the northern part of Volta Region of Ghana, innovative technology called Sawah - based farming system was introduced in 2016.

This African adaptive irrigated *sawah* rice farming system is a type of lowland rice cultivation technology developed in a lowland ecology of Ghana to manage challenges such as flood and drought situations faced by rice farmers in the inland valleys and flood plains. This technological innovation involves using simple agricultural machinery (Power tiller) and tools such as mattocks, pick- axes, soil chisels, machetes and hoes, through farmer participatory approach, to construct leveled fields with bunds and inlet and outlets canals for irrigation and drainage. To avoid heavy movement of top soil from higher spots to lower portions of the field, leveled rice basins are developed by resorting to contour bunding of the valleys or flood plains which are mostly sloping. The simple structures constructed by this practice turns to prevent erosion, and thus conserve soil and water for intensive and sustainable rice-based farming practices.

(Pictures of Project activities from site selection to harvest)



Using power tiller to prepare field for planting

Lifting seedlings for transplanting

Hands - on - training in transplanting

Transplanting of rice on puddled field

Broadcasting rice seed: Demonstration

Broadcasting rice seed on field

Training in basal fertilizer application

Demonstration Field 1 (Dibbling method of crop establishment)

Demonstration Field 3 (Transplanting method of crop establishment)

Use of sickle to harvest rice at project site

(Training methods and Activities)

For the construction of suitable structures to conserve soil and water, irrigation systems, mechanized land preparation techniques and good agricultural practices (GAP) in rice production, FAO's Farmer Field School (FFS) approach was employed. This involved class room instruction and on-the-job or hands - on field training for a group of farmers and Agricultural extension agents (AEAs) on the following activities;

i. *Sawah* system design, i.e., *sawah* layout by bunding - necessary flood and drought control measures, as well as path to facilitate movement of power tiller and people
ii. Design of water intake, storage, distribution and drainage and the installation of water intake and drainage systems, including surface pond (dugout), water pumping system and dyke/weir gravitational water use systems
iii. Basic power tiller operations and management,
iv. Skills for bunding, leveling, puddling and construction of irrigation/drainage canals
v. Good agronomic practices - rice seed selection, nursery preparation and transplanting, management of soil fertility, weeds, pests, birds and rodents
vi. Skills of harvesting, threshing, and winnowing and storage

(Results)

The use of sawah rice farming system resulted in increase of rice yield from 2.2 MT per hectare (as pertained in traditional lowland farming practice) to 6.3 MT per hectare. Additionally, farmers gained skill in establishing bunds and canals around rice fields. Also, technical know-how was gained in puddling and levelling of fields, resulted in reduction in water run-off. Rain harvesting in the farmers' rice fields greatly enhanced due to the dug-out and the bunded fields. Farmers established rice nurseries very well on their own, gained skill in transplanting of rice in puddled field and sowing of dry seeds of rice either by dibbling or broadcasting. They also developed the know-how in measuring right amount of fertilizers (NPK) and application in the rice field. Farmers were able to identify and removed rice off-types at some stages of growth. Through the training farmers could harvest, threshed their rice timely. They also adopted good drying technique to ensure uniformity in drying to enhance milling quality.

8. Cost effectiveness of the *Sawah* Eco-technology

Cost-effective *sawah* development is critical (Table 6, 7 and 8). Although the cost of applying the *sawah* technology is less than 10% of the cost of traditional contractor based ODA-style irrigation schemes (**Table 8 of the Sawah Technology (4): Principles and Theory**), the initial *sawah* development relies heavily on use of a power tiller, which makes up 50% of the development cost.

Table 6. Cost and income (US$) of new sawah development (Nigeria and Ghana, 2013).

Activity	Cos/income elements, performance or durability of Agric. Machineries	Spring-based (slope 1.5%)	Floodplain -like (mean slope 1%)	Stream dike-based (slope 1%)	Pond-based (mean slope 1%)	Pump-based (mean slope 1%)	Non-sawah (mean slope 2%)
A. Sawah development activities (first year only, per ha)							
Clearing, Bunding	30–50 work-days†	200	150	150	150	150	75
Plow, Puddling, leveling	14-21 days powertiller operation	300	250	250	250	250	NA
Pumping cost	Minimum 3 ha/year‡	NA	150	NA	100	250	NA
Powertiller cost §	2–3 ha/year, 6–15 ha/life	700	600	600	600	600	NA
Canal	$1000 for 100 m per ha	100	50	200	200	100	NA
Dike/weir	$450 for 20 m×5 m×3 m per 3 ha	NA	NA	150	NA	NA	NA
Flood control	$700 for 150 m×2 m ×2 m per 3 ha	NA	300	100	NA	NA	NA
Pond construction	$1500 for 20 m×20 m ×2 m per 3 ha	NA	NA	NA	500	NA	NA
Personnel cost for on the Job training ($/ha)		**Scientists/engineer ($1000/ha) , Extension officer ($500/ha), Leading farmers($250/ha)**					
Cost including training cost		2300-1550	2500-1750	2450-1675	2800-2050	2350-1600	75

† 1 work-day costs $3.5.
‡ Pumping machine: $500-1000 of two sets for 1ha irrigation, 30% $150-300 for spare parts, 3-5 years of life
§ Power-tiller cost: $5000 for 3–7-year life, 20% depreciation, 20% spare parts; initial sawah development claims heavy load on power-tiller, which comprises 50% of cost of development.

Table 7. Cost and income (US$) of sawah-based rice farming in the first development year and total cost (Ghana and Nigeria, 2013).

Activity	Cost/income elements, performance or durability of Agric. Machinery	Spring-based (slope 1.5%)	Floodplain-like (mean slope 0.5%)	Stream dike-based (slope 1%)	Pond-based (slope 1%)	Pump-based (mean slope 1%)	Non-sawah (slope 2%)
B. Sawah-based rice farming cost (first year only, per ha)							
Nursery, seed	3 work-day, 60-90kg	90	90	90	90	90	130*
Water management	20–50 work-days†	50	50	50	50	150	NA
Transplanting	30 work-days	100	100	100	100	100	NA
Weed control Herbicide	10-14 work-days	100	100	100	100	100	100
Fertilizing	6 work-days	200	200	200	200	200	NA
Bird-scaring Harvesting Winnowing	30-40 work-days 30-40 work days	75 200	75 200	75 200	75 200	75 200	75 75
Threshing,	20-25 work-days†	100	100	100	100	100	50
Sawah-based rice farming cost except for OJTCB training		915	915	915	915	1015	450
Total cost in the first year except for training cost		2215	2415	2365	2715	2365	525
Yield	4–5 t/ha	4.0	4.5	4.5	4.5	5.0	1.5
Gross income	$500/t of paddy	2000	2250	2250	2250	2500	750
Net income		-215	-165	-115	-465	135	225

† 1 work-day costs $1.5-3.5, *direct sowing and/ or dibbling

Although sawah approach gives sustainable low-cost personal irrigated sawah system development, which costs about 10% of ODA-based irrigated sawah development, there may need to be special subsidization to encourage sawah development by farmers in the first year.

Table 8. Cost and income (US$) of sawah based rice farming (Nigeria and Ghana, 2013).

Activity	Cost/income, work days, performance machinery	Spring-based	Floodplain-like	Stream dyke	Pond-based	Pump-based	Non-sawah
C. Sawah-based rice farming cost (subsequent year, per ha)							
Pump	2–10days ($15/day)	NA	75	NA	50	200	NA
Power-tiller, Plow, Puddling	10 days per powertiller 10 ha/year, life 5–7 years	150	150	150	150	150	NA
Maintenance, canal,dyke,pond	15% of new construction	50	100	100	150	50	NA
Water management	20–50 work-days ($3/work-days)	50	50	50	50	25	NA
Transplanting, Seed, nursery	30-40 work-days	150	150	150	150	150	200*
Weeding, Herbicide	10-14 work-days	100	100	100	100	50	100
Fertilizing	6 work-days	200	200	200	200	200	NA
Bird-scaring	30–40 work-days	75	75	75	75	75	75
Harvesting, winnowing	30–40 work-days	200	200	200	200	200	75
****Harvester**	6–10 work-days	200	200	200	200	200	NA
Threshing	20-25 work-days†	100	100	100	100	100	40
Sawah-based rice farming cost with and without harvester		**1075-975**	**1200-1100**	**1125-1025**	**1225-1075**	**1200-1100**	**490**
Yield	**4–7 t/ha**	**4-5**	**4-6**	**4-5**	**4-5**	**5-7**	**1-2**
Gross income	**$500/t paddy**	**2000-2500**	**2000-3000**	**2000-2500**	**2000-2500**	**2500-3500**	**500-1000**
Net income		**925-1525**	**800-2900**	**875-1475**	**775-1425**	**1300-2400**	**10-510**

† 1 work-day costs $1.5-3.5. In case of Non-Sawah, threshing day is less than half, because of lower yield
*** Including annual land clearing. direct sowing and/ or dibbling need 3-6 times higher seed rate than transplanting**
**** if harvester available we can save $100 if quality sawah area is available larger than 25ha**

9. The roadmap for Rice Green Revolution by Sawah Technology

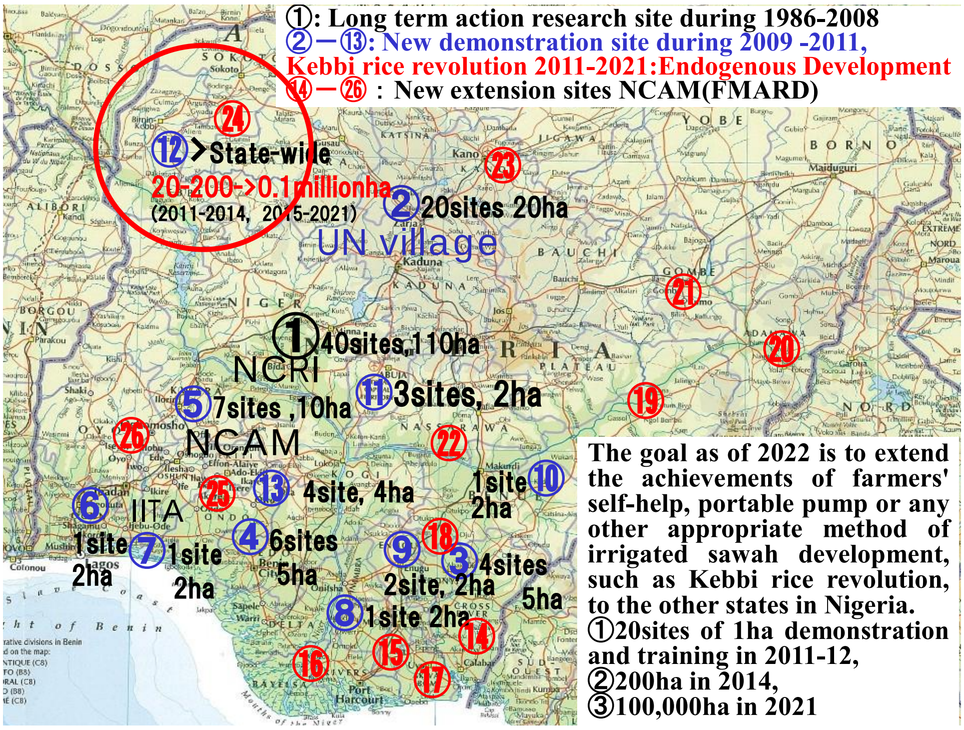


Figure 18: The goal as of 2022 is to extend the achievements of farmers' self-help, portable pump or any other appropriate irrigated sawah development, such as Kebbi rice revolution, to other states in Nigeria.

Table 9: Road map and Summary data on past irrigation projects in SSA by contractor development and possible dramatic reform by Sawah (Eco)-technology

1. Lower Anambra, Nigeria: Total 22 billion Yen, ≒$100million, 17 billion was Yen loan. Huge pump irrigation of 3850ha developed by Japanese companies, full mechanization during 1981-1989. JICA grant for technical cooperation, 1989-1993. High development cost $30,000/ha, Malfunction of both irrigation & mechanization since 1993. Both management and endogenous development are difficult.

2. Mwea, Kenya: 3000ha of new irrigation and 5860ha of rehabilitation during 2011-2016, 14 billion Yen loan, including planning consultant cost 0.7billion Yen in 1993-1996. Technical cooperation in 1989-1998 with 4billion Yen grant for rehabilitation of 5860ha. High development cost >$20,000/ha and management. Difficult endogenous development.

3. JICA/MoFA Sustainable Development of Rain-fed Lowland Rice Production Project. Even though results from this project look encouraging with yields of over 5t/ha recorded, it is on a micro-scale where demonstration sites are only micro-plots (0.1ha) with high cost. Net returns will therefore be very low and its economic impact negligible. Scaling up using sawah ecotechnology and effective collaboration in technology transfer is necessary to achieve the desired results

The dramatic improvement of rice projects by farmers' endogenous efforts

4. Kebbi Rice Revolution by the integration of Sawah technology and Fadama III project by the World bank in 2010-2016 and the promotion of dry season rice production in 2013-2022 to date by FMARD: >100,000ha of Sawah development during 2011-2021
5. Sukuma farmers' endogenous irrigated sawah development in Tanzania: >100,000ha
6. CARD goal achievement in 2008-2018: 14 million to 28 million tons of paddy
7. >10 Millions ha of irrigated Sawah platform development during 2022-2032: African wide rapid expansion and Realization of African Rice Green Revolution

Therefore, apart from the importance of training power-tiller operators (Ademiluyi 2010), high-quality, durable, and low-cost power tillers are necessary. Once the *sawah* is developed, the power- tiller cost for rice farming will not be a major problem. Since farmers are well trained during the first year in difficult *sawah* development operations, *sawah*-based rice farming will be more sustainable than old-style ODA-based irrigation projects. Although the *sawah* technology provides sustainable low-cost personal irrigated *sawah* system development, there may be a need for special subsidization to encourage *sawah* development by farmers in the first year especially. However because of sustainability, power tiller and pump should be supplied to farmers as subsidized loan, 30 to 50% discount or less/more?. Payment will be done by paddy and repayment should be 3-5 years.
Asian farmers can buy similar power tillers for just $1,500–$3,500, whereas the commercial prices of power tillers in Ghana and Nigeria are $3,000–$5,000. Of course, if *sawah* developments are accelerated and power-tiller markets are expanding in the near future, power-tiller costs may decrease to the same price ranges obtainable in Asia, to $2,500-$3,500 (including shipping costs).

Kebbi state sawah rice revolution process 2011-2014:Fortunately and paradoxically, African lowland, especially inland valleys and flood plains, have quite adaptable topography and wide areas of virgin but bush land that could be used to rapidly develop *sawah* systems. Since rice farmers have to master a wide range of skills, including ecological engineering, intensive on-the-job training continuing for 5–6 months is very important. Once mastered, the skills can be transferred from farmer-to-farmer and *sawah*-to-*sawah* to scale up the success from Kebbi, Niger (Bida) and Kwara (Patigi) states in Nigeria and Ashanti in Ghana to the wider potential rice-growing areas in SSA to realize Africa's green revolution in rice cultivation. One of the factors working against the realization of a green revolution in Africa is the failure to scale up successful results of past agricultural research (Ejeta 2010). The *sawah* approach has arrived at a scaling-up stage to show a clear road map for rice green revolution in Africa (Table 7). Thus, our *sawah* approach becomes comparable to the research, development, and dissemination of good varieties.
As Kebbi state governor Alh SU Dakingari described as Rice Revolution (Dakingari 2013) and Kebbi state Fadama III facilitator, Mr. HM Yeldu (2014) reported that Sawah team hosted by NCAM demonstrated 20 ha of sawah development using two sets of power tillers and trained sawah technology in 2011/12. During 2013/14 wet and dry season, additional 22 new powertillers were bought by farmers to cultivated 326ha sawah and produced 2100 tons paddy (mean yield 6.45 t/ha). Based on this result, the Governor bought 1000 set of power tillers in June 2014 to supply farmers. If sawah development will be realized at the scale >10,000ha, Kebbi state will be pioneer of rice green revolution in SSA.

10. New Business Model of Sawah Technology for Africa Green Revolution Innovation

***Summary*:** If we get US$18 million initial investment, of which US$14 million for *sawah* technology operation and US$ 4 million for On-the-Job Capacity building (OJTCB) including 10% miscellaneous cost, 5000ha irrigated *sawah* can be developed in 5 years, and annual paddy production reach to up to 30,000 ton (5t/ha, 20% of double cropping), which equivalent to $15million at the 6th year. The OJTCB trains 300 *Sawah* technology extension officers and about 3000 *sawah* rice farmers and youths, including 500 qualified lead farmers and youths, which will make ready to next scale up, i.e., 50,000ha of irrigated *sawah* development.

Phase I, duration of two years 2014-15, target 500ha irrigated sawah development, 20 sites, 25 ha each. OJTCB of 7-8 extension officer and 15 lead farmers/youths per site, total 150 extension officers and 300 lead farmers will be trained by 10 sawah teams. Each sawah team includes one sawah expert and 2-3 sawah technicians including power tillers operators/trainer.

(1) Targeted irrigated sawah development, 150ha at the first, and 350ha the second year.

(2) Produced paddy price in US$ per year in both wet and dry season (assuming to 20% of wet season sawah can cultivate in dry season) from 780 ha of sawah (150x1.2+500x1.2ha cultivation) with 3120 ton of paddy production, which give US$1.56 million.
(3) Total cost of Phase I is $3.3 million, of which $2.1million for 500ha sawah development including 10 sets of pickup trucks, 150 sets of motor bikes and 10 ha of seed farms, and $1.2 million for OJTCB of 150 Extension officers and 300 lead farmers. This cost is expected by investor. We estimate all necessary cost for sawah based rice farming to get 4-8 t/ha to be incurred $1000 per ha (Table 6). Rice farmer will pay this cost.

Phase II, duration three years 2015-17, target 1000ha new irrigated sawah development, 60 sites, 25 ha each, total 1500ha including the Phase I. OJTCB by extension officer and backstopping by NCAM, Nigeria or CSIR, Ghana, sawah team, total 700 lead farmers will be trained. Additional 150 extension officers will be trained by their colleagues of extension officers.

(1) Targeted irrigated sawah development and OJTCB are, 200ha, 200 lead farmers in the first, 300ha and 200 lead farmers in the second, and 500ha and 300 lead farmers in the third year respectively.
(2) Targeted establishment of new institutional organization: Sawah project at Federal Ministry of Agriculture and Rural Development (FMA&RD) to realize 3 to 5 million ha of irrigated sawah in Nigeria and Ministry of food and agriculture (MOFA) to realize half million ha of irrigated Sawah in Ghana.
(3) Total 12,960 ton of paddy in 3240ha of sawah cultivation, gives, US$6.5 million.
(4) Total cost of Phase II is $5 million, of which $3.4million for 1000ha sawah development including 40 ha of seed farms, and $1.6 million for OJTCB of 700 farmers. This cost is expected to also be incurred by investor. All cost estimate that is necessary for sawah based rice farming to get 4-8 t/ha will be paid by farmers.

Phase III, duration four years 2016-19, target 3500ha of new irrigated sawah will be developed, 100 sites, 50 ha each, total 5000ha including the Phase I and II. OJTCB by lead farmers and backstopping by extension officers and sawah teams, totalling 2000 farmers/youths will be trained.
(1) Targeted new irrigated sawah development and OJTCB are, 500ha, 500 lead farmers in the first, 1000ha and 500 farmers in the second, and 2000ha and 1000 farmers in the third year respectively. 5000ha in wet and 1000ha in dry season
(2) Sawah based rice farming will be practiced routinely at the third year in Phase III, i.e., after 5 years from the initiation of the project.
(3) Total 33,600 ton of paddy in 8400 ha of sawah gives US$16.8 million.
(4) Total cost of Phase III is $8.2 million, of which $7.1million will be required to develop 3500ha of sawah fields including 100 ha of seed farms, and $1.1 million for OJTCB of 2000 farmers and youths. This cost is expected to be incurred by investors. All cost estimate that is necessary for sawah based rice farming to get 4-8 t/ha will be paid by farmers.

Overall 10 years cost & benefit during the first 5 years including sawah development cost and OJTCB including additional 5 years for sawah farming stabilizing period.

I. Overall cost and benefit during the first 5 years including *sawah* development cost.
(1)Total production of paddy: 49680 ton/12420ha/5years= $25 million
(2)Total cost for both development and 50% of rice farming = $27 million, of which Government or investors will be responsible Sawah Development and Seed farm cost, 5000 (84 seed farm) ha=$13 million. OJTCB=$4million, Farmers will be responsible for rice farming cost, $10 million.
(3)Sawah rice farmers profit=$ 15 (25-10) million/12420ha=1208 $/ha

II. Overall cost and benefit during the next 5 years after the stabilization of *Sawah* based rice farming

If additional 5 years included, and yield increase to 5t/ha, total paddy selling is 5x5000x1.2x5x500 =$75 million, but total cost for rice farming=1100x5x5000x1.2= $33 million,
therefore *sawah* rice farmers profit= $42 (75-33) million/3000ha=$1400/ha

III. Overall 10 years cost and benefit of various rice sector businesses

(1) Farmers profit: $15 million in first 5 years+ $42 million in next 5 years= $57million/42420ha =1344 $/ha
(2) 3000 farmers/youths can be trained as professional rice farmers with annual profit of $7000 (in case 5ha is cultivated with 5t/ha model)
(3) Rice millers gross selling: 199,700tonx$75=$ 15 million /10 years
(4) Milled rice selling retailer: 15% of paddy selling: 199.7x500x0.15=$15 million per 10 years
(5) Power tiller market: 500 sets in 5000 ha development+350 sets for OJTCB+750 sets in 37420ha rice farming: 1600x1.5x3500= $8.4 million, 18 sets of pickup trucks:18x40000= $0.72 million
(6) *Sawah* irrigation and drainage engineering service at the first year development, ($450/ha)x5000= $2.25 million
(7) Powertiller assisted *sawah* development and cultivation service: ($250/ha)x42420=$10.6 million
(8) Agrochemical market:200x42420= $8.5 million
(9) Harvest, threshing and winnowing service labours =300x42420= $12.7million, or Harvester 200x42420= $8.5 million
(10) Research, Consulting and training services, and awards $ 4.6million, of which breakdown is
NCAM in Nigeria or CSIR institutions in Ghana = $0.76 million and establishment core seed farms.
Innovation award=5% of VAT increment= $0.73million for new research budget
National extension services= $0.76 million and establishment regional seed farms
Extension officers award=5% of VAT increment= $0.76 million for free use
Lead sawah farmers/Youths= $0.88million, Lead farmers/Youths award= $0.76 million for free use
(11) Government profit for various selling through VAT (15%) =115x0.15= $17.3million during 10 years
Initial Investment necessary is only $14 million for development and $4 million for OJTCB. This Investment cost will be obtainable as soft loan from IFAD, World Bank, USAID, or JICA Yen loan.
(12) After this project, FMA&RD in Nigeria and MOFA in Ghana will be able to expand 50,000 ha of new irrigated *sawah* program and farmers OJTCB during 2020-2025, the half million ha of new *sawah* development during 2025- 2030

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