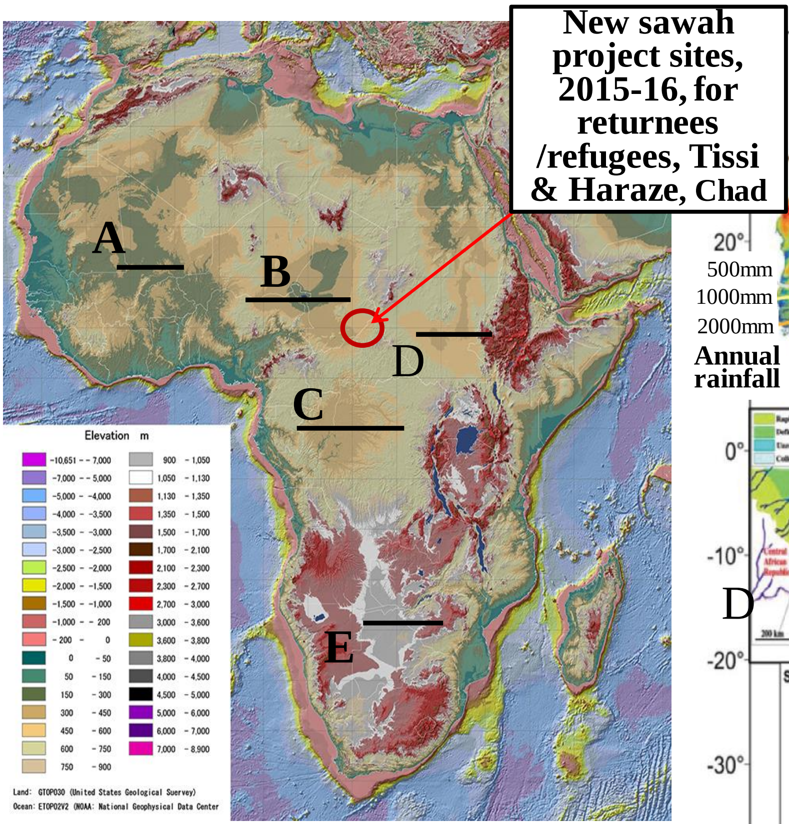
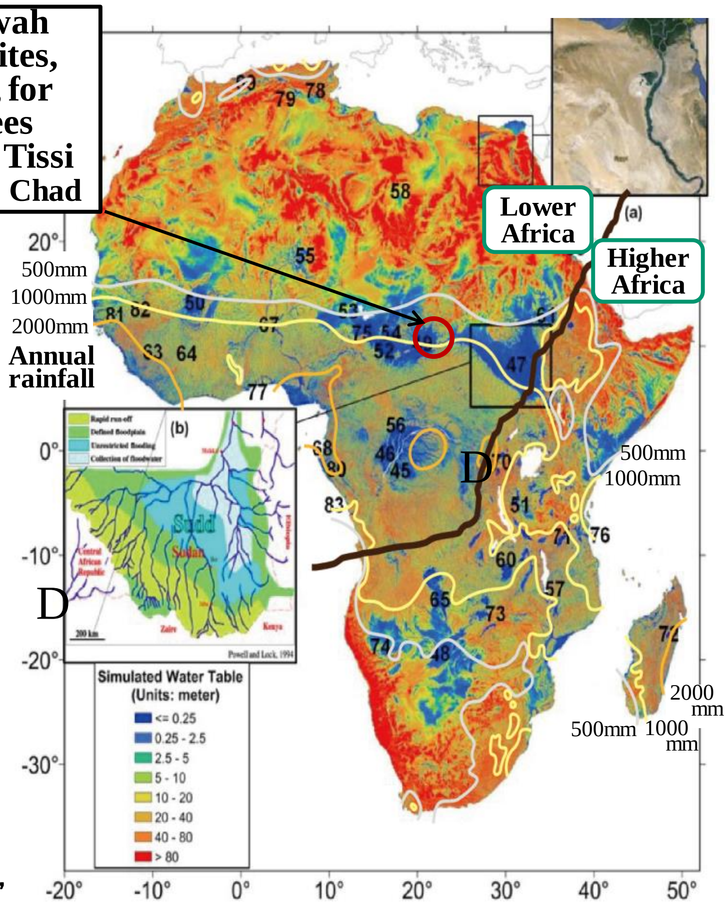




Araki S. 2008. Data base for the world edition, Research group for Virtual Planet Earth (荒木茂, 2008. データベース世界版, 仮想地球研究会); http://virtual-earth.asafas.kyoto-u.ac.jp/ve-world/datac.cgi

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

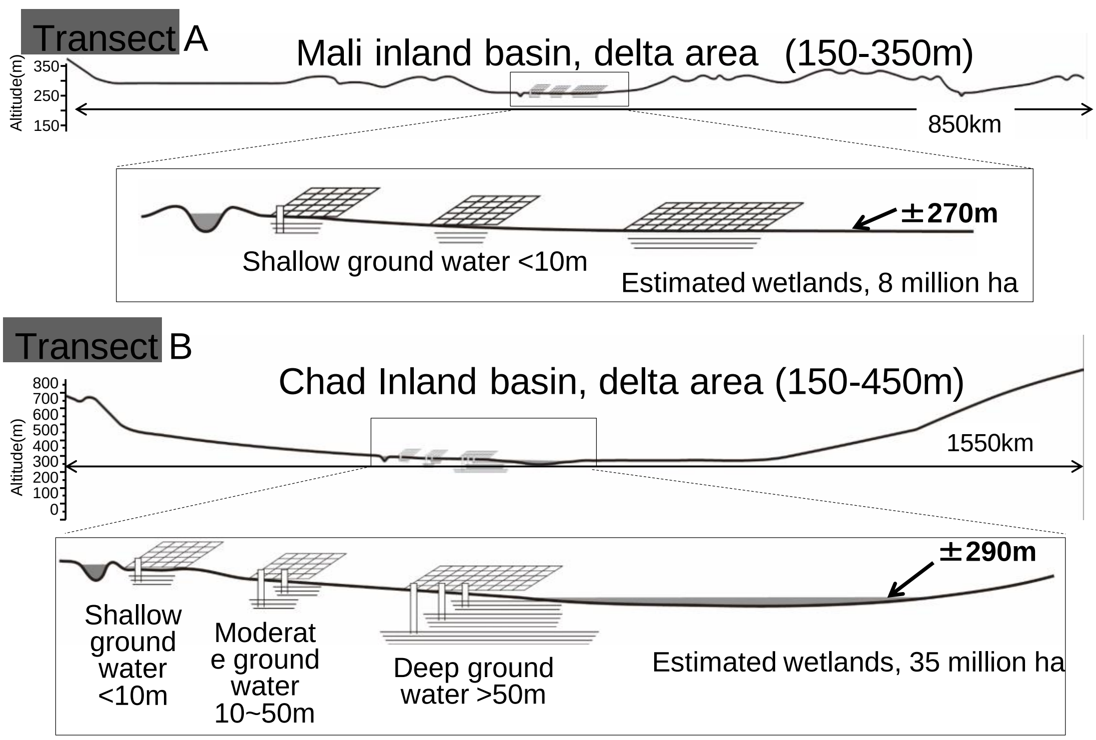


Fig 15. Topographical cross section of the transect lines of A and B in Fig. 14. The two basins have shallow groundwater good for pump irrigated sawah system

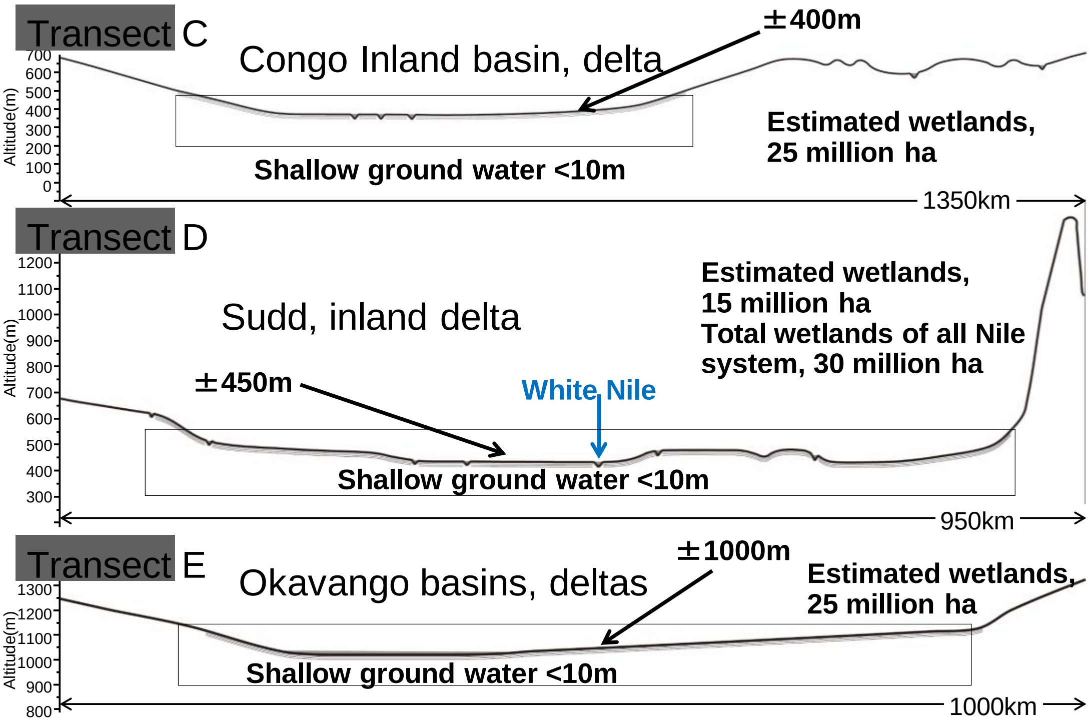


Fig 16. Topographical cross section of the transect lines of C, D and E in Fig. 14. Congo and Sudd basins have shallow groundwater good for pump irrigated sawah system. However, Okavango basins need careful environmental examinations

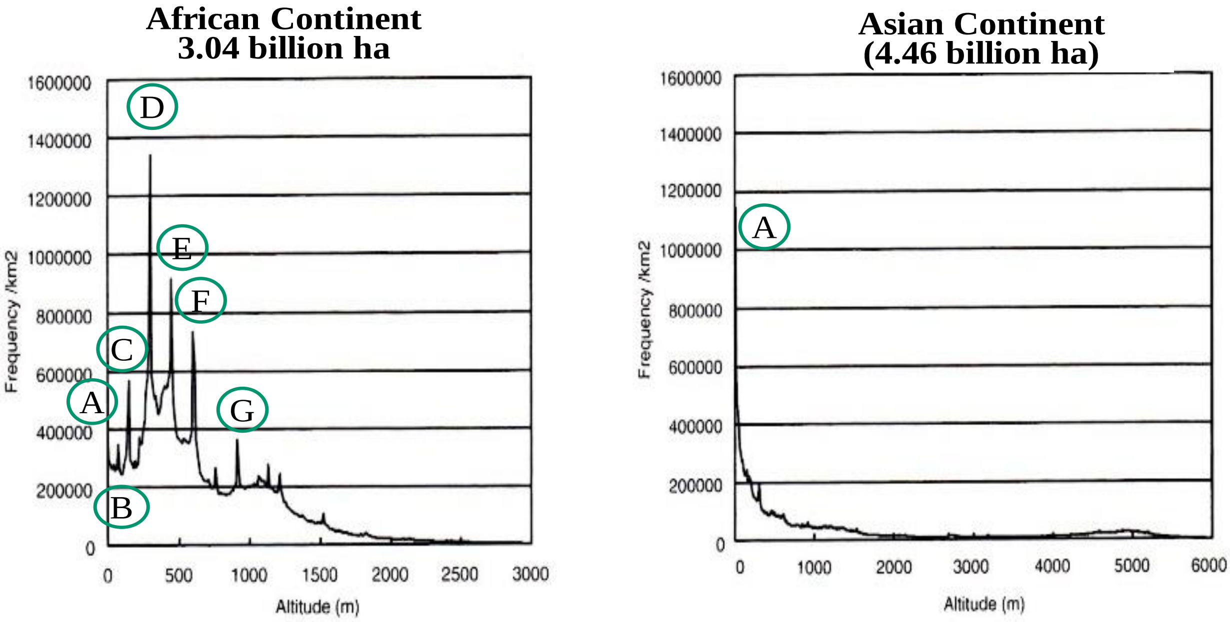


Fig. 17. Frequency distribution of area in each altitude in African and Asian continent by Araki (2008). Africa is stable continent, thus has about 10 steps of flat peneplains of various altitudes between 200-1000m, such as C, D, E, F, and G, which have vast inland basins/wetlands/deltas, except for 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.

4. *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 3. Four Skills of Sawah Technology for Farmers Personnel Irrigated Sawah Systems Development and Rice Farming to Realize Green Revolution in SSA

(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) Oasis type pump irrigation in floodplain (Sudan savanna zone, Kebbi state)
(2) Spring based irrigation system (all climatic zones)
(3) Overflow dykes on small rivers (Guinea savanna zone, forest transition zone, forest zone)

(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: >3-5ha/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 & Mangant
(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

5. 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.

5-1. Site and Right Season Selection and Appropriate Sawah System Design

5-1 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

Note: 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.

5-1B. 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.

5-2. 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

5-3. 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.

5-4: Sawah –based rice farming

5-4A. *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

5-4B. *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

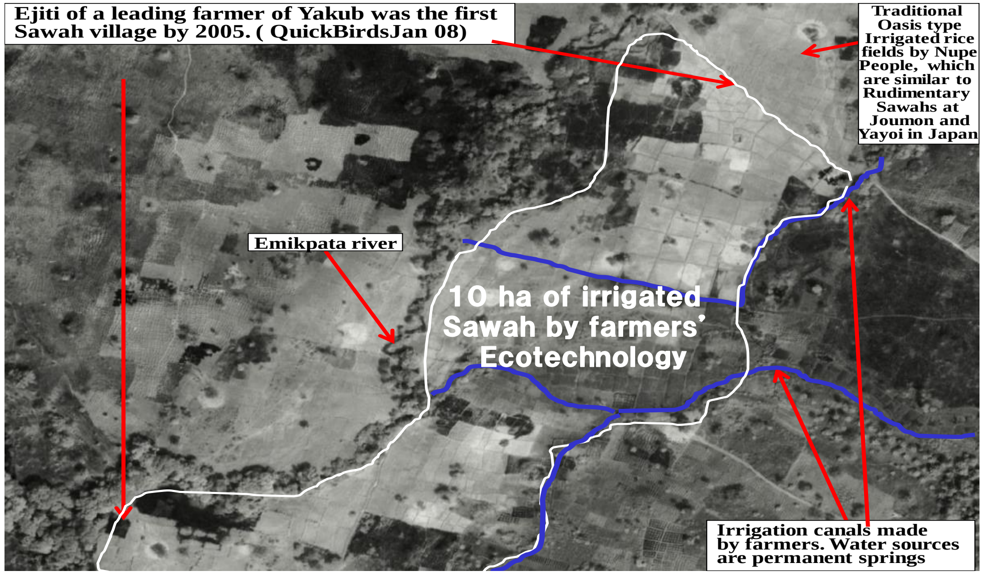
6. Overall Target for Sustainable *Sawah* Development and *Sawah* technology Dissemination

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.

7. 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

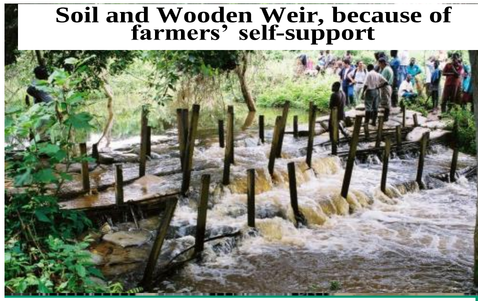
Bida, Shabamaliki

On the job training

Powertiller sinking

Bida, Shabamaliki

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

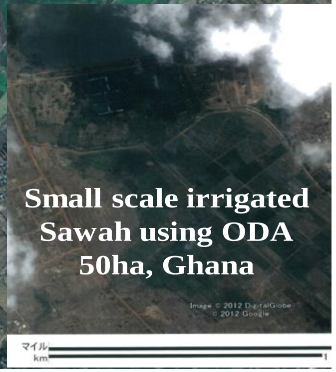


Farmers' to farmers technology transfer

On the job sawah ecotechnlogy training including PhD program, NCAM

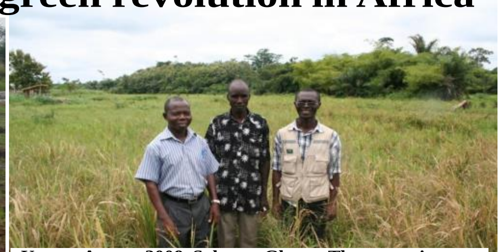
On-The-Job training: Sawah, Fadama and ADP staffs, & farmers

Left: Large scale irrigated sawah system at Mwea, Kenya, 5860ha (potential 8000ha). Right: Small scale irrigated sawah at Tema, Accra, Ghana, 50ha (potential 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, Google earth, 2009 and 2010



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



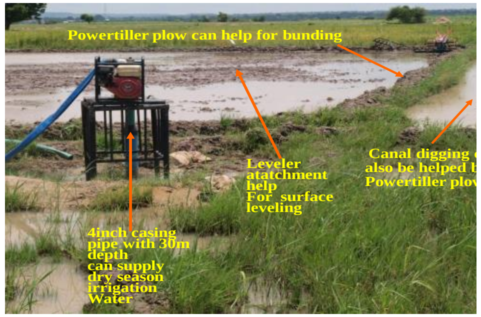
Upper: August 2009, Sokwae, Ghana. The center is a leading farmer and his both sides are Sawah staffs at Crops research Insititute, Ghana. Lower: January 2010. 3ha of irrigated sawah was developed within 3 months. Total sawah became 6ha by November 2011

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