(Scientific session 3)

Sawah Ecotechnology: Farmers' personal irrigated *sawah* systems to realize the green revolution and Africa's rice potential

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Abstract

Among the 250 million ha of lowlands in Sub Sahara Africa (SSA), only about 10% (20 million ha) are estimated as appropriate sites for sustainable irrigated *sawah* system development because of hydrological, topographical, and pedological limitations. Of all lowland types, inland valley is the priority because of relatively easy water control. However in 2011 it was clear that some huge flood plains in Guinea savanna zone can also be given priority if appropriate cropping season can be selected. Both large-scale and small-scale irrigation projects, typically Official Development Assistance (ODA) assisted, have been very costly because of major dependency on heavy engineering works by outside expertise. Due to the high construction costs, the economic returns remain negligible or negative for a long period of time (20-30 years). Project ownership remains with the government (engineers) rather than with the farmers. Therefore neither the development nor the management is sustainable.

The site specific farmers' personal irrigated *sawah* system development (sawah ecotechnology) offers low cost irrigation and water control for rice intensification, with sustainable paddy yield of 4-6 t/ha. If we apply improved agronomic practices, such as System Rice Intensification (SRI), based on the *sawah* systems, paddy yield can be higher than 10t/ha. However, African lowlands are quite diverse and different from Asian lowlands. Therefore careful site-specific *sawah* development and management technologies have to be researched, developed and disseminated. To develop and manage *sawah* systems by local farmers, self-propelled efforts and small-scale equipment such as hydropower tillers are needed. After many trial and error processes, the *sawah* ecotechnology has been successfully tested from 1997 to 2011 in Ghana and Nigeria, especially in locations where appropriate sites were selected and trained local leading farmers backstopped properly.

The presentation will discuss main target to realize sustainable dissemination of sawah ecotechnology which composed from four important skills and technologies in details: (1) site selection and site specific *sawah* system design, (2) skills for efficient

and cost effective *sawah* systems development using hydro-powertiller, (3) rice farmers' empowerment for successful development and management of sawah systems, and (4) sawah-based rice farming to realize at least the sustainable paddy yield > 4t/ha and 20 ton annual paddy production per one set of powertiller three years after the initiation of new sawah development. The establishment of institutional training and dissemination systems for *sawah* ecotechnology and the basic research on to get sustainable paddy yield > 10t/ha are important too. Since rice farmers have to master relatively wider range of skills including ecological engineering, intensive on-the-job training is very important. Once mastered, however, the skills can be transferred farmer-to-farmer to scale up the success in Ashanti in Ghana and Bida, Kebbi, Abakaliliki, Akure, Zaria, Adani and Ilorin in Nigeria to wider areas in SSA to realize Africa's rice green revolution.

Introduction

As we described in a separate paper in this workshop (Wakatsuki, et al, 2011) and others published elswhere (Wakatsuki et al. 1998, Hirose and Wakatsuki 2002, Wakatsuki and Masunaga 2005), the sawah eco-technology is a missing technology to improve soil and water as well as rural society in sub-Saharan Africa (SSA).

Among the 250 million ha of lowlands in SSA (Windmeijer and Andriesse, 1993), only about 10% (20 million ha) are estimated to be appropriate sites for sustainable irrigated *sawah* system development, of which 9-20 million ha are in small inland valleys, 8-15million ha in floodplains, 4-9 million ha in coastal deltas, and 1-5 million ha in inland basins as shown in Table 1 (Wakatsuki et al. 1998, Abe and Wakatsuki 2011).

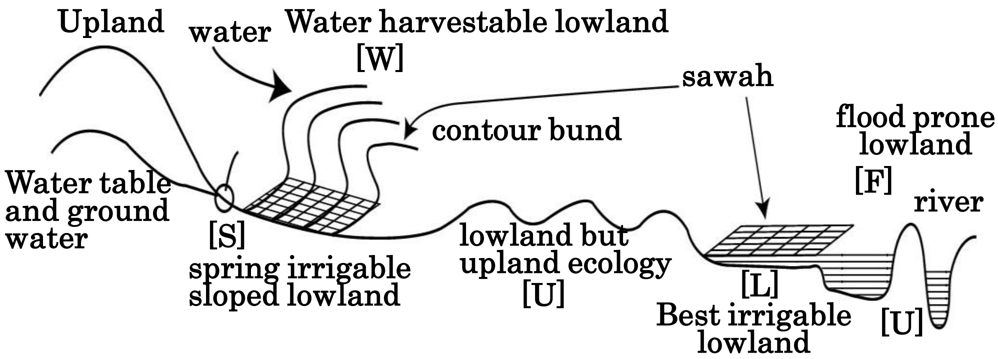
Table 1 Distribution of lowlands and potential irrigated sawah in SSA (Hekstra, Andriesse, Windmeijer 1983 & 1993, Potential Sawah area estimate by Wakatsuki 2002)

Classification	Area (million ha)	Area for potential sawah development	
Coastal swamps	17	4-9	millon ha (25-50%)
Inland basins	108	1-5	million ha (1-5%)
Flood plains	30	8-15	million ha(25-50%)
Inland valleys	85	9-20	million ha(10-25%)

<u>Although priority target is the inland valley because of easier water control, some flood plains can be high priority,such as Sokoto & Kebbi where personal pump irrigated sawah is efficient</u>

<u>Total maximum sawah area : 20million ha</u> (Estimated sawah area came from the relative amount of water cycle in Monsoon Asia, which has 130 million ha sawah)

As shown in Figure 1, appropriateness is affected by hydrological, topographical, and pedological considerations (Hirose and Wakatsuki 2002). Of all the lowland types, inland valley land is the priority for application of the *sawah* ecotechnlogy, because controlling water in them is relatively easy. However just in 2011 growing season April to September, now it was clear that some huge flood plains in Guinea savanna zone, such as Sokoto or Kebbi state in Nigeria can also be given high priority if appropriate cropping season can be selected.



Irrigation options: Sawah to sawah/ contour bund water harvesting,
spring, seepage, river by dam and dyke, peripheral
canal, interceptor canal, tank, pump

Lowland sawah development priority
[S] > [L] > [F] > [W] > [U]

Figure 1. Diversity in topography and hydrology of inland valley in Sub-Saharan Africa. Topography and hydrology are also changed in various agro-ecological zones. Pedological characteristics are changed depending on geology, climate, topography, and vegetation

Both large-scale and small-scale irrigation projects, typically created under Official Development Assistance (ODA), have been very costly because of dependence on heavy engineering works and outside expertise (Table 2) (FAO 1998, Wakatsuki et al. 2001, JICA 2008, MOFA and AfDB 2008). Due to the high construction costs, the economic returns remain negligible or negative for a long period of time (20-30 years). Project ownership remains with the government (engineers) rather than with the farmers, because farmers cannot develop the systems by themselves. Therefore, neither the development nor the management is sustainable.

The *sawah* ecotechnology offers low-cost irrigation and water control for rice intensification with sustainable paddy yield of more than 4t/ha with sufficiently large area of 5-10ha using one powertiller per farmer or farmers' group. Although our team at Kebbi state fadama III and ADP, Nigeria, got more than 7t/ha in 2011 using standard sawah technology described in this paper, if we apply improved agronomic practices, such as the System of Rice Intensification (SRI) or others with the *sawah* systems, paddy yield can reach more than 10t/ha (Tsujimoto et al. 2009).

However, African lowlands are quite diverse and different from Asian lowlands as shown in Figure 1 above. Therefore careful site-specific *sawah* development and management technologies must be researched, developed, and disseminated through intensive On-The-Job training (OJT) as described below. The development and management of *sawah* systems requires that local farmers be self-motivated and have access to small-scale equipment, such as hydro-power tillers. After many trial-and-error and the addition of numerous innovation processes, the *sawah* system was successfully tested from 1997 to 2011 in Ghana and Nigeria, especially in locations where appropriate sites were selected, local leading farmers trained and proper backstopping provided by scientists (Hirose and Wakatsuki 2002; Wakatsuki et al. 2001; Wakatsuki and Masunaga 2005; Oladele et al. 2010; Abe and Wakatsuki 2011).

Table 2. Comparison of farmers' site-specific personal irrigated *sawah* system development with large- and small-scale ODA-based developments, and traditional rice cultivation system in inland valleys of Ghana and Nigeria.

	Large-scale development	**Small-scale development**	***Sawah* approach**	**Traditional system**
Development cost ($/ha)	20,000–30,000	10,000–30,000	1,000–3,000	30–60
Gross revenue ($/ha)†	2,000–3,000	2,000–3,000	2,000–3,000	500–1,000
Yield (t/ha)	4–6	4–6	4–6	1–2
Running cost, including machinery ($/ha)†	600–800	600–800	400–600	200–300
Farmer participation	Low	Medium–High	High	High
Project ownership	Government	Government	Farmer	Farmer
Adoption of technology	Long, difficult	Slow, relatively easy	Medium to short, needs intensive demonstration and on-the-job training (OJT) program	Low technology transfer
Sustainable and endogenous development based on innovation and adaptive evolution	Low(contractors' heavy machinery used by contractors in development)	Low to medium	High (farmer-based and small power-tiller used in development and management)	Medium
Adverse environmental effect	High	Medium	Low	Medium

† Assuming 1 ton paddy is worth US$ 500; one power-tiller costs $3,000-9,000 in West Africa depending on the brand quality and accessories (2010 values). Selling prices, however, are $1,500-$4,500 for farmers in Asian countries.

Sawah ecotechnology ***Farmers' personal irrigated sawah systems through site-specific sawah developed and managed by farmers to realize a green revolution and Africa's rice potential***

The *sawah* approach involves four important skills and technologies (Table 3): (1) site selection and site-specific *sawah* system design, (2) skills for cost-effective *sawah* system development using a small hydro-powertiller, (3) rice farmers' empowerment for successful development and management of sawah systems, and (4) *sawah*-based rice agronomy, including best variety selection and 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 (Buri et al. 2009) is necessary. The co-ordination of farmers' group formation and land-tenure arrangements at least secured rent (Oladele 2010) to sustain *sawah* development are important, too. To train the leading *sawah* farmers is the key. The leading *sawah* farmers can train farmers and farmers group to develop *sawah* and manage sawah-based rice farming by themselves. This is the final goal of our *sawah* ecotechnology.
In 2011, the sawah ecotechnology reached the stage to make strong impact to farmers to realize Green Revolution. If farmers master the four components of the sawah ecotechnology, they can develop their personal irrigated sawah systems and realize 20-50 tons of paddy production per season using one powertiller within three years after the initiation of new sawah development. The technology can transfer from farmers to farmers. This means if we can train 500 leading farmers, the technology can spread like wild fire to realize long-waited Green Revolution in Africa. Only high yield is not enough. Rice farmers have to cultivate enough area of sawah to get enough income.

Specific target is to train more than 500 qualified leading sawah farmers who can develop their personal irrigated sawah systems and realize 20-50 ton of paddy production per season, which is equivalent $10,000 to $25,000 of gross selling, using one power tiller, which costs $3000-$5000 per set, within three years after the initiation of new sawah development, resulting to new irrigated rice field of 2,500-5,000 ha in inland valleys and other major lowlands. Traditional ODA-based development of such 2,500-5,000ha irrigation systems for rice cultivation claims $50-100million only for development without any training for management. In addition the development is done by outside experts. Therefore the systems cannot be expanded if ODA stops. This sawah ecotechnology, however, makes realize the same scale of development only by $3-5million as described below with sustainable development because of the on-the-job training of 500 qualified leading sawah farmers at the same time. Then they will be able to develop new sawah fields endogenously .

Therefore now we need large scale action research and dissemination actions both at inland valley and flood plains in major agroecological zones of all 10 states in Ghana and at least 20 major states in Nigeria to make adaptive evolution and endogenous development of prototype Sawah ecotechnology to scale up past successful results achieved during MEXT project in 2007-2011 and JIRCAS project in 2008-2011 to whole Ghana and Nigeria, as primary target, as well as Togo and Benin under the SMART project, then finally all West & Sub Saharan Africa to make real impact to realize rice Green Revolution.

Table 3. Four important skills for *sawah* ecotechnology (approach) required by farmers' to develop and manage site-specific personal irrigated *sawah* systems and sawah based rice farming (SERIF) through their own efforts.

(1) <u>Skills for Site Selection and *Sawah* system design</u>

(a) Water sources & quality
(>10 L/s, >5 months/year)
Stream/River, Spring,
Seepage, Flood, Rainfed

(b)Topography and soil
Ongoing & potential rice area >10ha,
Slope <1-2%,
surface roughness
Soil texture
Soil fertility

(c) Socio-economics
Strong will
Market access
Land tenure
Secured lent

(d) *Sawah* system design
<u>*Sawah* layout and total potential area</u>
<u>Shape & sawah size</u>
<u>Water intake, distribution and control</u>
Spring & sawah to sawah, and diversion canal
Stream/seepage
Simple dyke & diversion canal
Weir and Canal
Fish pond, dam lake
Pump irrigation
Interceptor canal
Contour bund system
Flood control by drainage or dam
Drought control by pond/water-harvest
<u>Soil movement and quality of leveling</u>
<u>Bund layout and quality</u>

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

On the job collaboration between farmers & scientists, engineers, and extension office is essentially important

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

The successful example of *Sawah* system development:
(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) <u>Efficient and Low cost Sawah Development: Skill & Technology</u>

(a) Skills for development
Skill for power-tiller operations
Plowing and Puddling
Soil Moving
Surface leveling & smoothing
Powertiller management

(b) Cost
Power-tiller for development (10ha /power tiller)
Power-tiller spare parts
Fuel for development
Bush clearing, destumping
Bunding and surface treatment
Canal construction
Additional hired labors
Tools and materials
Scientist & engineers cost
Extension officer cost
Farmers' training cost

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

***Sawah* development: at least 10ha per one Power-tiller**

Target cost: $1000-3000/ha

Target speed of development: >3ha/year /powertiller

(3) <u>Rice farmers enpowerment</u>
Group organization
Selection of leader
Support to the group and leader
Training powertillers' assisted sawah development
Training powertillers assisted sawah based rice farming
Post harvest technology
Marketing and profit equity
Loan condition to acquire powertillers
Support for rental and acquire land for sawah development

(4) <u>Sawah based rice farming</u>
Management of water control facilities: water sources, intakes, and distributions
Water equity and canal management
Sawah water control
Leveling, smoothing
Bunding
Puddling skills
Nursery and trans-planting
Weed, pests, and birds management
Carbon sequestration and organic matter management
Fertilization and nutrient management
Variety election
Yield target
Cost effective *sawah* based farming
Mono, two, double,& other cropping
Advanced *sawah*-based farming

(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 for sawah development, sawah is developed more easier in Africa than that in Asia.

<u>Minimization of outside funds is key for sustainable and endogenous development</u> : farmers to farmers technology transfer sites > > sites of extension officers > researchers' demonstration sites

General time schedule for *sawah* ecotechnology to establish a model *sawah* system of 2-3 ha

I. Site selection: 2-3days per potential area where distributes various appropriate sites

(1) The priority site is ongoing major area of Fadama and lowland rice cultivation: Potential area should be larger than 5-10ha for the sustainable application of sawah ecotechnology. The best season for the site selection will be September/October, just before harvesting, to January/February, just after harvest. Intensive hearing from rice farmers on the local hydrological conditions for the past 10-15 years is important.
(2) Secured continuous water flow: >5months, base water discharge: >20l/sec, i.e., >1500-2000m^3/day, potential irrigated *sawah* area:>10-20 ha,
(3) No strong flood attack: Flood depth will be <50cm and continuation of the flood will be <3-4days, Flood water discharge will be <10 ton/sec
(4) Flat and very gentle slope: <2%, if slope is <0-1%, levelling operation is easy.
(5) Strong will of rice farmers to master *sawah* technology skills and *sawah* development by farmers' self support efforts
(6) Good road access, in case for the demonstration

II. New Sawah Development for demonstration: Two to Three months

Three to four extension officers from state Agricultural Development Project (ADP) or Fadama III offices and 3-10 active farmers which will be trained through intensive OJT by one or two sawah specialists (Sawah specialists of SRI and CRI as well as MOFA extension officers in Ghana, IITA's Hirose Project, NCAM *sawah* team, UNN and Abeokuta *sawah* teams in Nigeria).

(1) 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
Put in 1-3 of about 100 m X and Y axis lines using survey tools, such as laser assisted Total Station (Cannon Co. Ltd.) if possible. If not available, use 90° crossed line using simple measuring tools, then draw upland and lowland border and river/canal line, land owner/tenure lines.

Note: Since farmers cannot use such tools, sawah ecotechnology use water as a guidance of topography. Therefore sawah system development must be done using water. Water shows us the height difference. Skilled sawah staffs can make good canal line slope, not too steep to avoid canal cutting, using water. Sawah plot leveling can be also done using water and soil as a maker within ±5cm height difference without using such sophisticated laser apparatus. Water tell us everything if sawah staffs have skills and eyes.

(3) *Sawah* delineation based on contour line with 30 cm height difference: 5 work-days
(a) Should be started from the lowest valley bottom at each land owner/tenure lines, (b) Should be straight line and large size as possible as we can because of efficient use of power tiller, (c) use pegs and white rope to delineate bunding, border of land, existing canal lines
(4) Bunding: 15-25 work-days/ha
standard size is 50 cm x 50 cm ± 20 cm
A: Big bund: Flood prone area, land tenure line

B: Standard: major *sawah* delineation
C: small bund: sub-*sawah* delinieation

(5) Canal and drainage lines: 10-60 work-days/ha
Appropriate slope of canal will be less than 1%, preferably 0.1-0.5%, if too steep, bottom soils will be eroded.

(6) Dyke: 30-50 work-days/ha. About 500 sand bags 30kg each reinforced with wooden piles and plank can manage to lift the central river water height 1-1.5m with 10-15m width of about 5,000-10,000ha size of watershed under 1500mm annual rainfall. If watershed size is 2500-5000, about 300sand bags can be enough. Labour works will be 30mandays.

(7) Nursery preparation: 3 work-days/ha in three phases about three weeks intervals, one day for each phase: nursery must prepare 15 to 25 days before transplanting

(8) *Sawah* ploughing, puddling, leveling and smoothening: 50-80 work-days/ha

III. Sawah based rice farming in the first year of new sawah development

(1) *Sawah* water control: 10-40 work-days/ha
(2) *Sawah* systems maintenance: 10-30 work-days/ha
(3) Transplanting: 10-20 work-days/ha
(4) Fertilization: 2-3 work-days/ha
(5) Weeding:6-7 work-days/ha
(6) Bird-scaring:10-30 work-days/ha
(7) Harvest: 7-15 work-days/ha
(8) Threshing:10 work-dasy/ha

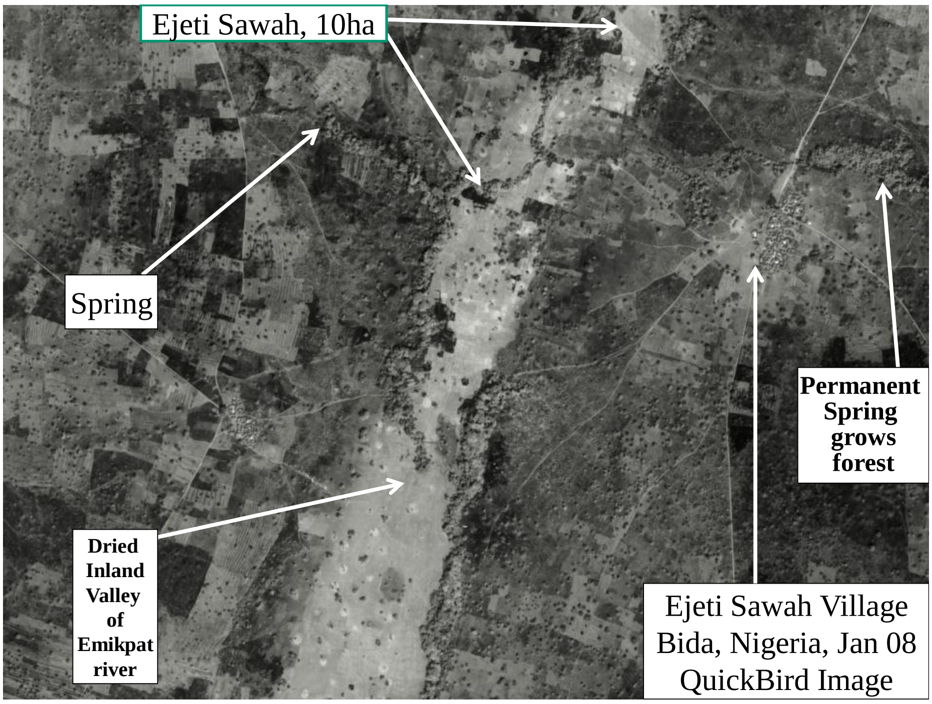
IV. Overall Target for sustainable sawah development and sawah ecotechnology dissemination

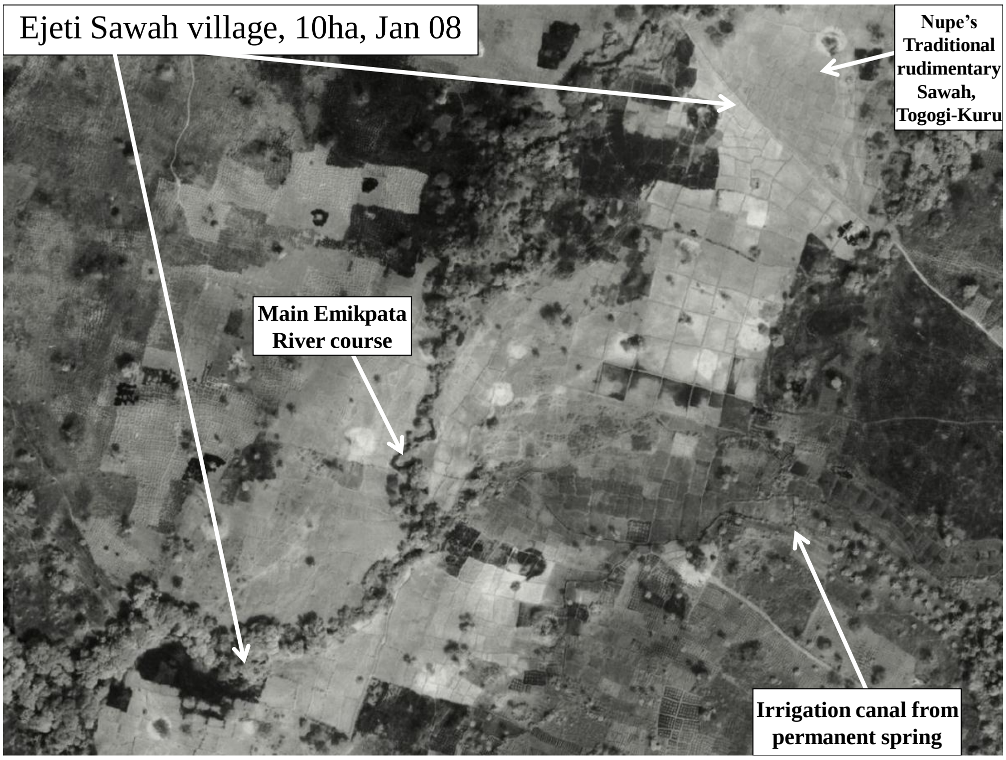
To realize 20-50 tons of paddy production, total selling $10,000-25,000, per year using one powertiller, which cost is $3,000-$5,000, within three years after the initiation of new sawah development. If paddy yield is 4t/ha and only mono cropping is possible, al least 5ha of sawah have to developed using one powertiller.

The most important factor in site selection, appropriate *sawah* system design, development and management is collaboration between researchers and farmers. Scientists and extension officers should have the skills for *sawah* development. Although local farmers do not know *sawah* technologies (before the project starts), they are very familiar with the site-specific hydrological conditions that scientists and extension officers need to know for *sawah* development. Thus, collaborative action-research between farmers and scientists is essential. The priority for site selection is inland valleys. Flood-plains will be a lower priority at the beginning of the application of the *sawah* approach. The water conditions of inland valley streams are critical. Water has to flow for more than 5 months continuously, with a discharge of more than 10 l/s. Otherwise, farmers have to develop additional ponds and tanks to secure water for sustainable *sawah*-based rice cultivation. If floods reach deeper than 50 cm and continue longer than 1 week and/or the discharge of more than 10 m^3/s, major flood control measures have to be put in place. This is difficult for farmers' groups at the first stage of *sawah* development. Therefore, inland valleys that will require such extra inputs should be avoided in the demonstration and training stage.

(Photographs)

Some examples of following photographs in next four pages showing autonomous expansion of Sawah system in inland valley ecosystems at Bida and Zaria, UN-vilalge, Nigeria and Adugyama, Biemso No1, Baniakrom, and Sokwae in Ashanti, Ghana





Top-survey, Inland valley, Ashanti, Ghana

Canal construction by farmers

Simple barrage by farmers' efforts

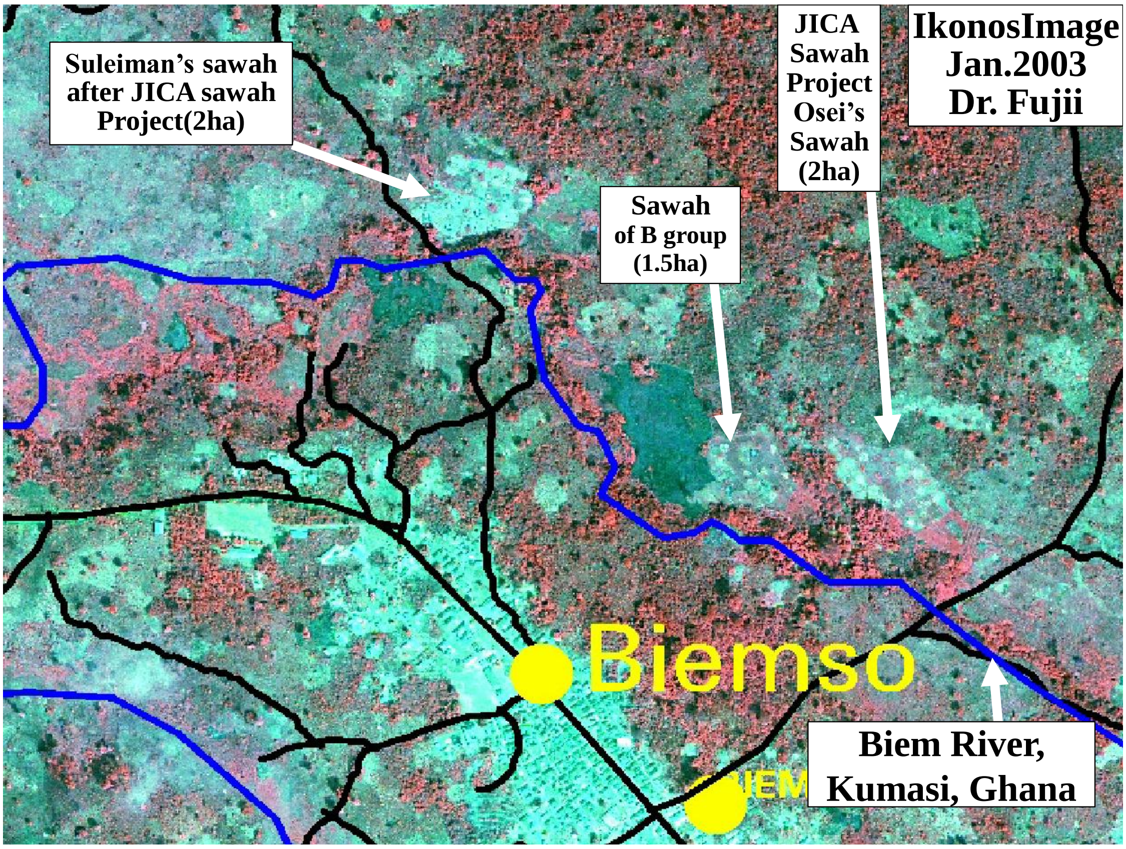
Spring Irrigated Rudimentary Sawah, Nupe

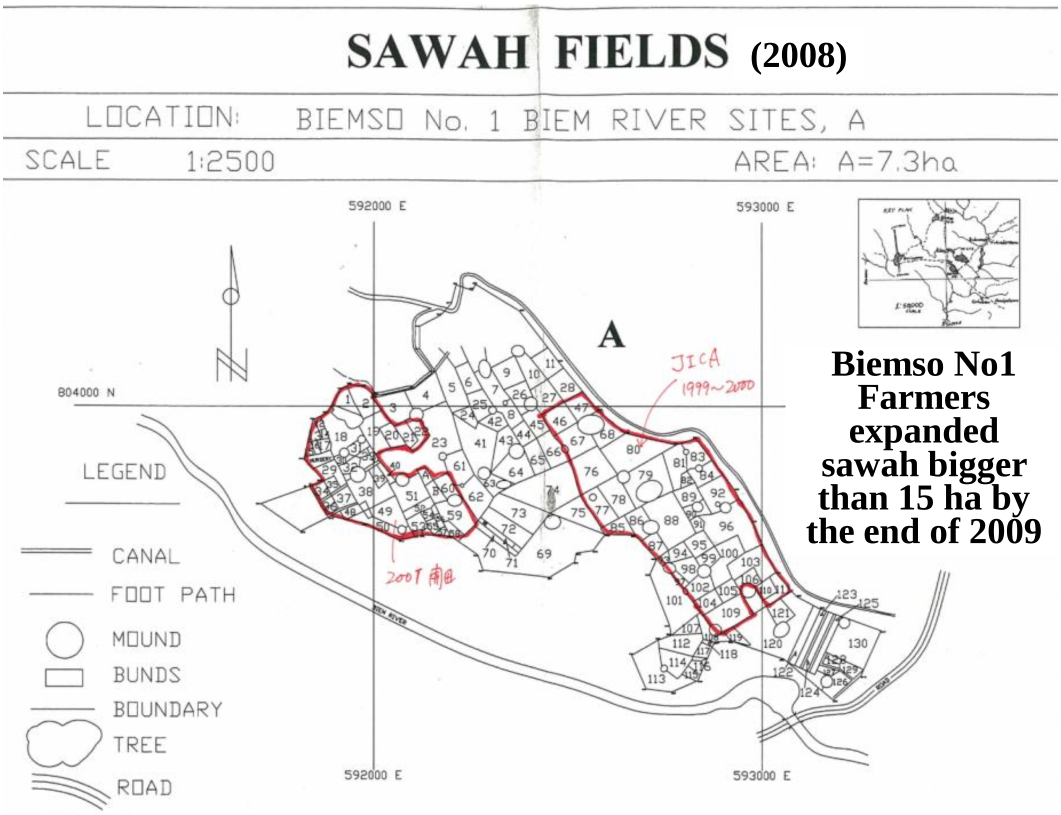
Lowland paddy field, before sawah. Green Revolution technologies can't apply

Sawah development can be done by farmers' self-support efforts if trained necessary skills

Once Sawah system was developed, yield can be >4t/ha. If agronomical practices improve, such as system rice intensification, yield can reach to 10t/ha

Power-tiller assisted puddling & soil moving for leveling are necessary key skills for sawah


Suleiman's sawah after JICA sawah Project(2ha)
JICA Sawah Project Osei's Sawah (2ha)
IkonosImage Jan.2003 Dr. Fujii
Sawah of B group (1.5ha)
Biemso
Biem River, Kumasi, Ghana


SAWAH FIELDS (2008)
LOCATION: BIEMSO No. 1 BIEM RIVER SITES, A
SCALE 1:2500
AREA: A=7.3ha
592000 E
593000 E
804000 N
A
JICA 1999~2000
2007 開田
LEGEND
CANAL
FOOT PATH
MOUND
BUNDS
BOUNDARY
TREE
ROAD
Biemso No1 Farmers expanded sawah bigger than 15 ha by the end of 2009

Farmers' to farmers sawah technology transfer, SRI site, Ghana, Jan 2010

Rice growing Sawah has aggressive tillering, thus sawah system can control weed. Left, sawah rice, Sept.2009; right, before sawah, Jan, 2008, Pampaida, Zaria

Cost effectiveness of *sawah* approach

Cost-effective *sawah* development is critical (Table 4). Although the cost of applying the *sawah* approach is less than 10% that of the cost of ODA-based irrigation schemes (Table 1), the initial *sawah* development relies heavily on use of a power-tiller, which makes up 50% of the development cost. Therefore, apart from the importance of training power-tiller operators (Ademiluyi 2010), high-quality, durable, and low-cost power-tillers are necessary (Kolawole et al. 2011). Once *sawah* is developed, power-tiller cost for rice farming will not be a major problem. Since farmers were well trained during the first year in difficult *sawah* development, *sawah*-based rice farming will be more sustainable than old-style ODA- based irrigation projects. Although *sawah* approach gives sustainable low-cost personal irrigated *sawah* system development, which costs about 10% of ODA-based irrigated *sawah* development, there may be need for special subsidization to encourage *sawah* development by farmers in the first year.

Asian farmers can buy similar power-tillers for just $1500-4500, while commercial prices of power-tillers in Ghana and Nigeria are $3000-9000. So it may be necessary to apply a special subsidy to encourage farmers to develop *sawah* in the first year. Of cause if sawah developments are accelerated and powewrtiller markets are expanding in near future, powertiller cost will be the same price ranges of Asia, $2000-$5000 including shipping cost. Fortunately and paradoxically, African lowland, especially inland valleys have quite adaptable topography and wide areas of virgin land to develop *sawah* systems rapidly. Therefore, once African farmers master the necessary skills and *sawah* systems developed, power-tiller costs for rice farming will not be a major problem. Since farmers can be trained well during the first year in the difficult practice of *sawah* development, *sawah*-based rice farming will be more sustainable than the old-style ODA-based irrigation projects.

Table 4. Cost and income (US$) of site-specific personal irrigated *sawah* development and *sawah*-based rice cultivation (Ghana and Nigeria, 2009).

Activity	Cos/income elements, performance or durability of pump and Power-tillers	Spring-based (mean slope 1.5%)	Floodplain-like (mean slope 0.5%)	Stream dike-based (mean slope 1%)	Pond-based (mean slope 1%)	Pump-based** (mean slope 1%)	Non-*sawah* (mean slope 2%)
A. *Sawah* development activities (first year of New Sawah development only, per ha)							
Clearing & destumping	10–20 work-days†	70	70	70	70	70	35
Bunding	20–30 work-days†	100	70	85	85	85	NA
Plowing	20–30 work-days†	100	70	85	85	85	NA
Puddling, soil movement, leveling	30–50 work-days†	200	135	170	170	170	NA
Pumping machine cost	**3 ha/year‡**	NA	50	NA	30	200	NA
Power-tiller cost§	**2–3 ha/year, 6–15 ha/life**	700	500	600	600	600	NA
Main canal	$1000 for 100 m per ha	NA	NA	100	100	NA	NA
Branch canal	$35 for 100 m per ha	70	35	70	70	70	NA
Interceptor canal	$35 for 100 m per ha	35	NA	35	35	35	NA
Dike/weir	$400 for 20 m×5 m×3 m per 3 ha / 3	NA	NA	150	NA	NA	NA
Pump fuel	3–20 days ($20/day)	NA	100	NA	60	400	NA
Flood control	$700 for 150 m×2 m×2 m per 3 ha / 3	NA	270	70	NA	NA	NA
Pond construction	$1400 for 20 m×20 m ×2 m per 3 ha / 3	NA	NA	NA	500	NA	NA
Total cost of development		1275	1300	1435	1805	1715	35

† 1 work-day costs $3.5.

‡ Pumping machine: 15% depreciation, 10% spare parts.

§ Power-tiller cost: $5000 for 3–5-year life, 15% depreciation, 10–20% spare parts; initial *sawah* development claims heavy load on power-tiller, which comprises 50% of cost of development cost.

*direct sowing and/ or dibbling

**Pump based systems have poor economic return, if the yield is the same to other systems. However, the new sawah demonstration during April to September, on Sokoto river flood plains at Kebbi state showed, paddy yield reached 7.4t/ha. Pump irrigation system gives intermittent irrigation, 8 times per month, this irrigation method and fertile deep flood plain soil as well as ample amount of animal dung and good puddling, i.e., farmers' good skill of rice agronomy encouraged such very high rice yield.

Table 4 (continued).

Activity	Cos/income elements, performance or durability of pump and Power-tillers	Spring-based (mean slope 1.5%)	Floodplain-like (mean slope 5%)	Stream dike-based (mean slope 1%)	Pond-based (mean slope 1%)	Pump-based (mean slope 1%)	Non-sawah (mean slope 2%)
B. *Sawah*-based rice farming cost (first year only, per ha)							
Nursery bed	1-2 work-day†	5	5	5	5	5	15*
Seed cost	30–90 kg ($10 per 10 kg)	30	30	30	30	30	90
Sawah water management	12–35 work-days†	40	40	40	40	120	NA
Transplanting	15 work-days ($3/work-day)	45	45	45	45	45	NA
Rope & markers	5 bundles ($2/bundle)	10	10	10	10	10	NA
Weeding labor	6-7 work-days ($3/work-day)	20	20	20	20	20	50
Herbicide	5 L ($8/L)	20	20	20	20	20	NA
Fertilizer	4 bags ($20 per 50 kg)	80	80	80	80	80	NA
Fertilizing	3-4 work-days ($3/work-day)	10	10	10	10	10	NA
Bird-scaring	10–30 work-days ($1.5/work-day)	20	20	20	20	20	40
Harvesting	7-15 work-days ($4/work-day)	60	60	60	60	60	30
Threshing	10 work-days†	35	35	35	35	35	15
***Sawah*-based rice farming cost**		375	375	375	375	465	240
Total cost in the first year		1650	1675	1810	2180	2180	275
Yield	4–4.5 t/ha	4.5	4.0	4.5	4.5	4.0**	1.5
Gross income	$500/t paddy	2250	2000	2250	2250	2000	750
Net income		600	325	440	70	–180	475
C. *Sawah*-based rice farming cost (subsequent year, per ha)							
Pump	2–10days ($15/day)	NA	50	NA	30	150	NA
Plowing	5–7 work-days†	15	15	15	15	15	NA
Puddling, leveling	6–9 work-days†	30	20	30	30	30	NA
Power-tiller	**10 ha/year, life 5–7 years**	90	80	90	90	90	NA
Maintenance of canal, dike, pond	15% of new construction	15	70	70	90	15	NA
Nursery bed	1–2 work-days†	5	5	5	5	5	15*
Seed cost	30–90 kg ($10 per 10 kg)	30	30	30	30	30	90
Water management	20 work-days ($2/work-day)	40	40	40	40	40	NA
Transplanting	15 work-days ($3/work-day)	45	45	45	45	45	NA
Rope, etc.	5 bundles ($2/bundle)	10	10	10	10	10	NA
Weeding labor	7 work-days ($3/work-day)	20	20	20	20	20	50
Herbicide	5 L ($8/L)	20	20	20	20	20	NA
Fertilizer	4 bags ($20 per 50 kg)	80	80	80	80	80	NA
Fertilizing	3 work-days ($3/work-day)	10	10	10	10	10	NA
Bird-scaring	15–30 work-days ($1.5/work-day)	20	20	20	20	20	40
Harvesting	15 work-days ($4/work-day)	60	60	60	60	60	30
Threshing	10 work-days†	35	35	35	35	35	15
***Sawah*-based rice farming cost**		525	610	580	630	675	240
Yield	4–4.5 t/ha	4.5	4.0	4.5	4.5	4.0**	1.5
Gross income	$500/t paddy	2250	2000	2250	2250	2000	750
Net income		1725	1390	1670	1620	1325	510

Roadmap for African Rice Green Revolution by Sawah Ecotechnology

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 farmer-to-farmer and *sawah*-to-*sawah* to scale up the success from Ashanti (Ghana) and Bida, Abakaliliki, Akure, Zaria, Adani, and Ilorin (Nigeria) to the wider potential rice-growing areas in SSA to realize Africa's green revolution in rice cultivation. One of the factors working against realization of green revolution in Africa is the failure to scale up successful results of past agricultural research (Ejeta 2010). We do not want this to be the lot of this promising technology. The *sawah* approach has therefore arrived at a scaling-up stage to show clear road map for rice green revolution in Africa (Table 5). Thus our *sawah* approach becomes comparable to the research, development, and dissemination of good varieties.

Table 5. Road Map to Realize Africa Rice Green Revolution through the *Sawah Ecotechnology* (Site Specific Farmers' Personal Irrigated *Sawah* Development by Million Farmers' Self-Support Efforts)

(1) 1986-2002 : (10 sites, 6ha of sawah, 17 years of trials and errors) :JICA/CRI and MEXT assisted Sawah project: West African wide survey on traditional rice farming and basic research on Site Specific Sawah development by farmers' self support efforts at Bida, Nigeria and Kumasi, Ghana

(2) 2003-2007: (20 sites, 30ha, benchmark waterhshed): MEXT assisted basic research S: Basic Action research to develope Site Specific Personal Irrigated Sawah development by farmers at Bida, Nigeria and Kumasi area, Ghana

(3) 2007-2011:(>100 sites, >200ha, Sawah Ecotechnology): MEXT assisted specially promoted research: Kinki Univ/NCAM/FadamaIII/SRI/CRI, JIRCAS, and SMART-IV: Sawah ecotechnology establishment and to prepare large scale action research on *Sawah* ecotechnology dissemination at Nigeria, Ghana, Togo and Benin

(4) 2012-2016: (>500 sites, >2500ha of sawah in each country): African adaptive Sawah ecotechnology dissemination and evolution and endogenous development Kinki Univ/NCAM/FadamaIII/SRI/CRI, JIRCAS, SMART-IV and JICA-CARD; To start Large scale Action research on Sawah ecotechnology in whole Ghana and Nigeria as well as Togo, Benin & others in West Africa and SSA

(5)2017-2022: (>2500 sites , >25,000ha of Sawah): Africa wide adaptation and dissemination and endogenous *Sawah* Ecotechnology development

(6)2022-2026: (>20000 sites , >200,000ha of Sawah): African wide spontaneous *and rapid sawah* expansion and the Realization of African Rice Green Revolution: Realization of Africa's Rice Potential

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