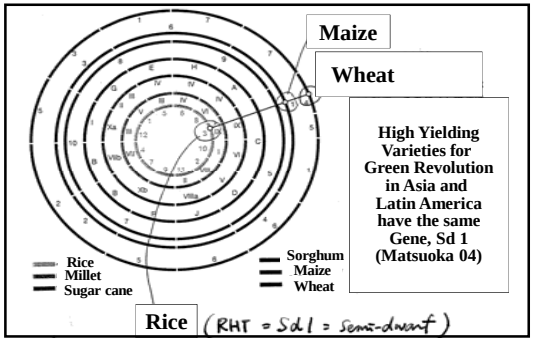
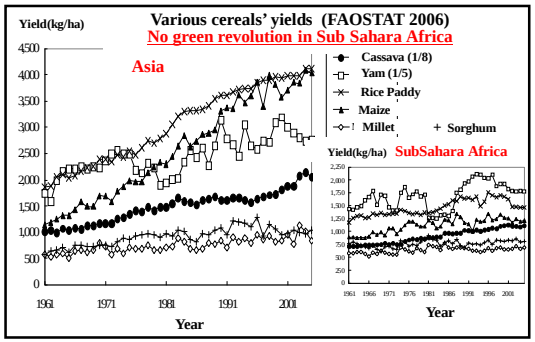
Farmers' personal irrigated Sawah systems to realize Africa's green revolution T. Wakatsuki, Kinki Uni., Japan, 30 April 10

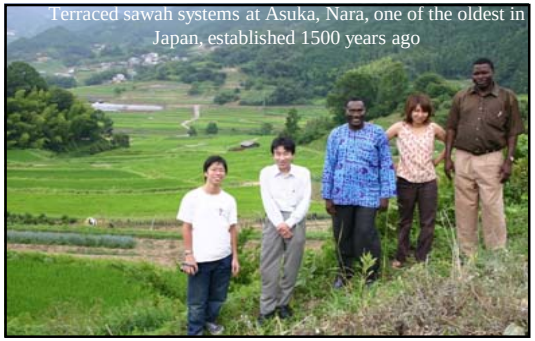
Origin of Asian & Latin Amerian Green Revolution

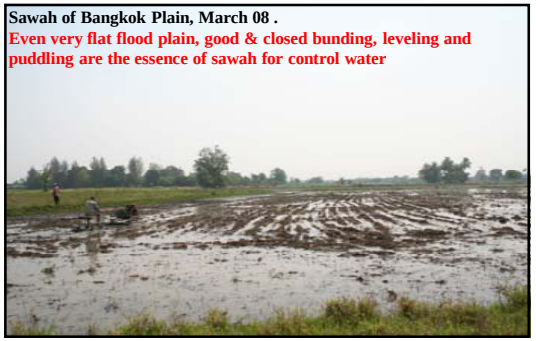
Right:Turkey Red
Center:
Fruit DARUMA
Left: NORIN 10
in 1935

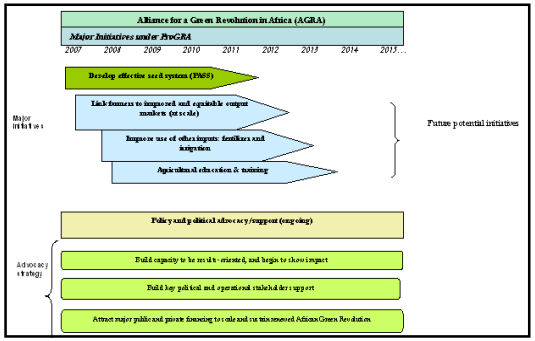
Dr.G. INAZUKA bred Norin 10 of wheat in 1935. The Norin 10 was collected by US occupied force in 1951. Dr. N. Borlaug bred & released 14 HYVs using Norin 10 in 1957. The start of CG center

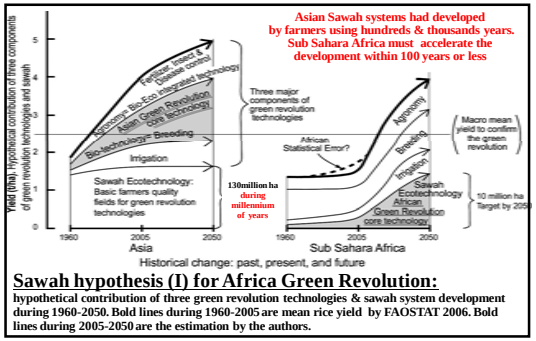








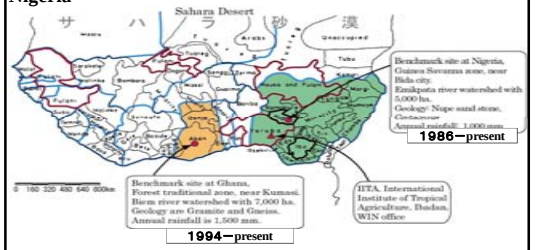




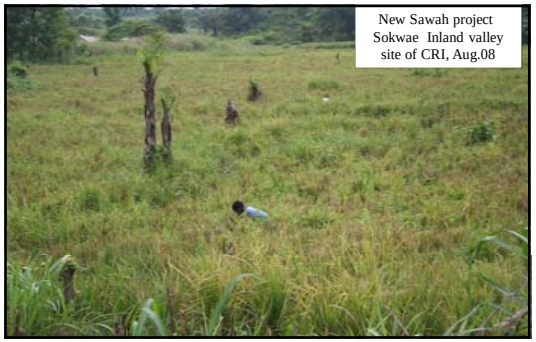
Sawah hypothesis (I) for Africa Green Revolution:

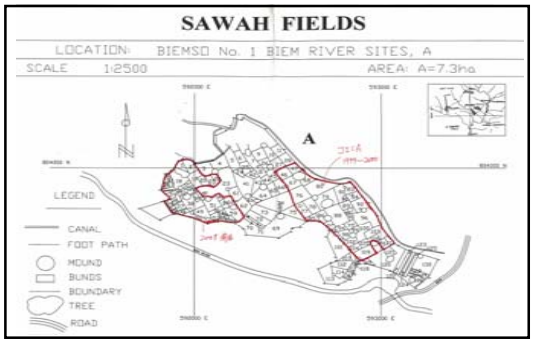
hypothetical contribution of three green revolution technologies & sawah system development during 1960-2050. Bold lines during 1960-2005 are mean rice yield by FAOSTAT 2006. Bold lines during 2005-2050 are the estimation by the authors.

Experiences and examination of Sawah hypothesis I & II through long term massive action researches in Ghana and Nigeria



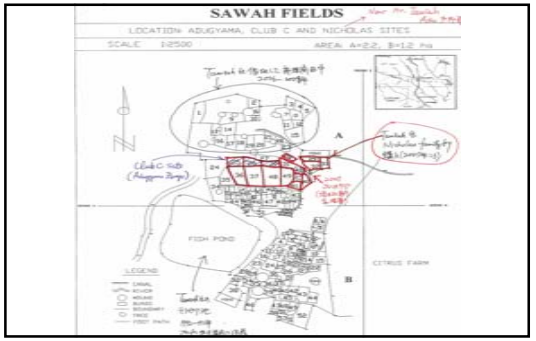
Core benchmark sites with various sized watersheds in Ghana & Nigeria. The action research sites were expanded in 2008 and 2009.





Ghana-Sokwae,Kumasi, CRI sawah Staffs and farmers, Aug. 2008
Rice yield was more than 4t/ha, thus green revolution was realized.
2 ha in 2008, which was expanded to 6 ha by January 2010

Mr. Tawiah developed about 4ha sawah by Sep. 07 surrounding his 1.5ha of fish pond. Total paddy production was more than 20ton annualy, which gave gross revenue about $10,000. Power tiller loan is $1500 per year for four years



Mr. Tawiah and his rice grown on sawah about 4ha developed by himself, with CRI/SRI, and JIRCAS scientists, August 2009

Table. Estimated Revenue of farmer groups under the "Sawah" System (By BURI SRI, based on 2007 before 2008 food crisis)

Farmer-group	Paddy Grain yield (kg/ha)	Gross Revenue (US$/ha)	Production Cost** (US$/ha)	Net Revenue (US$/ha)
Adugyama*	4334	1712	428	1284
Biemso – A*	4675	1847	350	1497

*5ha sawah give about $7000 revenue in 2007 price. After 2008 food crisis the revenue will be more than 30% up, $10,000.
**The production cost does not include sawah development, which will be 2000-4000$/ha including machine and running cost.
One powertiller can develop 1-3 ha per season and 10ha per 5 years of durability. One power tiller can cultivate 10 ha sawah per season & 5years of life. The machine cost is $3000-7000 (Asian price is about $3000)

Bio-technology and Eco-technology

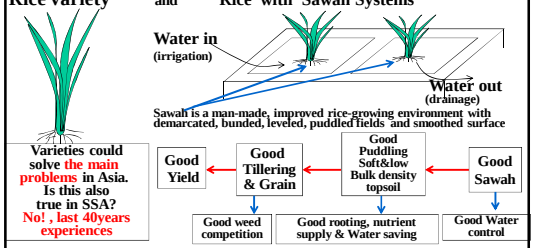


Fig. Rice (variety) and environment (Sawah) improvement. Both Bio & Eco-technologies must be developed in appropriate balance

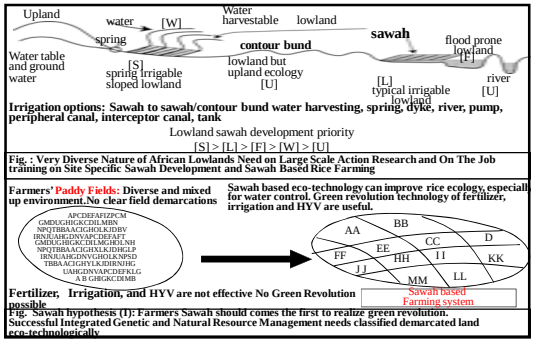


Fig. : Very Diverse Nature of African Lowlands Need on Large Scale Action Research and On The Job training on Site Specific Sawah Development and Sawah Based Rice Farming

Fig. Sawah hypothesis (1): Farmers Sawah should comes the first to realize green revolution. Successful Integrated Genetic and Natural Resource Management needs classified demarcated land eco-technologically

(1) Site Selection and Sawah system design
(a) Water sources for site selection (>10liter/sec, > 5months)
Stream/River, Spring, Seepage, Flood, Rainfed
(b) Topography and soil for site selection
Potential area
Slope and surface roughness
Soil
(c) Socio-economic for site selection
Participating farmers
Land tenure
(d) Sawah system design
Sawah layout and total potential area
Mean sawah size(ha)
Water intake, distribution and control
Spring and sawah to sawah & diversion canal
Stream/Seepage and sawah to sawah & diversion canal
Simple dyke& diversion canal
Weir & Canal
Fish pond or dam lake
Pump
Interceptal canal
Contour bud system
Flood control by drainage/dam
Drought control by pond/waterharvest
Soil movement(t/ha)
Contour bund system
Flood control by drainage/dam
Drought control by pond/waterharvest
Soil movement(t/ha)

At first local farmers never know sawah technologies, they know site specific hydrological conditions which are the most important for site selection

On the job collaboration between farmers and Scientists, engineers, as well as extension office is essentially important

(2) Development skills and cost ($/ha)
(a) Skils for development
Skill for power tiller operations
Plowing and Puddling
Soil Moving
Surface leveling & smoothing
Skill for power tiller management
(b) Cost ($/ha) or (Cedi/ha)
Power tiller for development
Powertiller spare parts
Fuel for development
Bush clearing destamping
Bunding and surface teatment
Canal construction
Dyke construction
Additional hired labours
Tools and materials
Scientist and engineers cost
Extension officer cost
Farmers' training

Action research and on the job training of site specific sawah development and management

(1) Cots of Power tiller for Sawah development: at least 10ha per one power tiller ($5000/10ha)

(2) Cost of scientists, engineers, extension officers, and leading farmers

(3) Target cost: 2000-4000/ha

(4) Agronomic Sawah system management
- Rice mono cropping
- Rice and other 2nd season cropping
- Rice double cropping
- Overall Water Control
- Water sources
- Water distribution
- Leveling & smoothing
- Bunding
- Puddling
- Weed control
- water consumption (ton/season)
- water requirment(mm/day)
- Water quality
- Soil fertility
- Fertilzation(N-P2O5-K2Okg/ha)
- Variety
- Yield (ton/ha)

(1) Immediate target Paddy yield >4t/ha

(2) 3t/ha is not enough to sustain sawah development

(3) >5t/ha will accelerate Sawah development

(4) Basic research on sustainable paddy yield >8t/ha is important

(3) Farmers Group Quality
- Leader and group collaboration
- No. of farmers
- Ethnic composition
- Skills and incentives
- Gender composition

(6) Training
- Trainer
- Trainee
  - International scientists
  - National scientists
  - Extention officers
  - Leading farmers & farmers

To train
(1) Sawah farmers who can develop Sawah and manage Sawah based rice farming by themselves,

(2)Leading sawah farmer and farmers' group who can train another new sawah Farmer and farmers' groups

On the job field training on sawah ecotechnology to researchers, extension officers & leading farmers are the most important

Ejiti Sawah village, Bida, Nigeria, Sep 09

On the job training at Shabamaliki village, Bida, Nigeria, Sep 09

On the job training at Shabamaliki village, Bida, Nigeria, Sep 09
Paradoxically, leading farmers can master the skill within one to two seasons, but extension officers needs more than three seasons

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

Mr. Tawiah trained another farmer to develop 3ha of sawah using small spring water source. Only local farmers know such water source.


New Sawah with paddy yield 4.5t/ha, Etsuzegi, Bida, 31Jan.09


New Sawah, Pampaida, UN millennium village, Zaria


Sawah and traditionak non sawah rice ,
Pampaida, UN millennium village, Zaria


Poor tillering and aggressive weed in non sawah field


Akure Sawah site, 2ha, Farmer, extension and sawah staffs, Sep. 08

①-⑤: Action Research Sites by 2009, ⑥-⑬: New sites in collaboration with NCAM/NCRI and Fadama III in 2010

①-⑤: Action Research Sites by 2009, ⑥-⑬: New sites in collaboration with NCAM/NCRI and Fadama III in 2010

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 and 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%)

Priority target is the inland valley because of easier water control

Max 20million ha (Estimated sawah area came from the relative amount of water cycle in Monsoon Asia, which has 130 million ha of sawah)

Road Map to Realize Africa Rice Green Revolution through Site Specific Sawah Technology by Million Farmers' Self-Support Efforts

- **1986-2003 : (10 sites, 10ha of sawah) : Achieved**
  Baisc research on Site Specific Sawah development by farmers' self support efforts at Bida, Nigeria and Kumasi, Ghana
- **2004-2008: (50 sites, 100ha of sawah): Achieved**
  Basic Action research on Site Specific Sawah development by farmers at Bida, Zaria, Akure, and Ilorin, Nigeria and Kumasi and his surroundings, Ghana
- **2009-2013: (250 sites, 1000ha of sawah): Immediate Target for Action Research for Dissemination of Sawah Technology**
  by Kinki Univ/NCAM/FadamaIII, JIRCAS, SMART-IV and JICA-CARD:
  Large scale Action research on Site Specific Sawah development by farmers at Nigeria, Ghana, Togo, Benin & others
- **2014-2025: (5000 sites or more, 25,000ha of Sawah):**
  Africa wide dissemination of Site Specific Sawah development by farmers self-support efforts
- **2025 and after: African wide spontaneous sawah expansion and the Realization of African Rice Green Revolution: Realization of Africa's Rice Potential**

Comparison between Biotechnology and Sawah based Ecotechnology, which must be integrated

(1) Water shortage: **Bio-technology**:Genes for deep rooting、C4-nature、and Osmotic regulation. **Eco-technology** of Sawah based soil and water management, bunding, leveling, puddling, surface smoothing with various irrigations, Aerobic rice, System rice intensification

(2) Poor nutrition, acidity and alkalinity:Gene of Phosphate and micronutrient transporter. **Eco-technology** of Sawah based N fixation, increase P availability and micro- as well as macronutrient. Geological fertilization and watershed agroforestry(SATOYAMA systems), organic matter and fertilization. Bird feculent are rich in P.

(3) Weed control:Gene of weed competition, rapid growth.
Eco-technology of Sawah based weed management through water control, and tans-planting. Leveling quality and surface smoothing of sawah are important. Duck and rice farming.

(4) Pest and disease control: Resistance genes. **Eco-technology** of Sawah based silica and other nutrients supply to enhance immune mechanisms of rice. Mixed cropping.

(5) Food quality: Vitamine rice gene. **Eco-technology**: Sawah based nutrition control. Fish, duck and rice in sawah systems

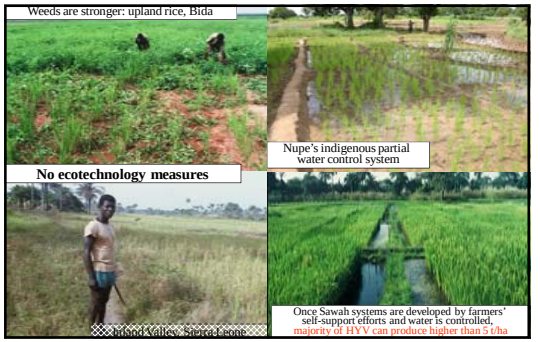


Table Mean gain yield of 23 rice cultivars in low land ecologies at low (LIL) and high input levels (HIL), Ashanti, Ghana (Ofori & Wakatsuki, 2005)

BIOTECHNOLOGICAL IMPROVEMENT →		ECOTECHNOLOGICAL YIELD IMPROVEMENT →					
		Irrigated Sawah		Rainfed sawah		Upland like fields	
Entry No.	Cultivar	HIL (t/ha)	LIL	HIL (t/ha)	LIL	HIL (t/ha)	LIL
1	WAB	4.6	2.9	2.8	1.6	2.1	0.6
2	EMOK	4.0	2.8	2.9	1.3	1.4	0.5
3	PSBRC34	7.7	3.5	3.0	2.1	2.0	0.4
4	PSBRC54	8.0	3.7	3.8	2.1	1.7	0.4
5	PSBRC66	5.7	3.3	3.8	2.0	1.8	0.4
6	BOAK189	7.0	3.8	3.7	2.0	1.4	0.3
7	WITA8	7.8	4.2	4.4	2.1	1.8	0.5
8	Tox3108	7.1	4.1	4.0	2.3	2.3	0.6
9	IR5558	7.9	4.0	3.8	2.0	1.8	0.5
10	IR58088	7.7	4.0	3.7	1.8	1.4	0.3
11	IR54742	7.7	4.3	4.0	2.2	1.9	0.4
12	C123CU	6.9	4.1	4.2	1.9	2.0	0.4
13	C19737	6.5	4.0	4.0	1.7	1.9	0.6
14	CT8003	7.3	3.8	3.8	1.7	2.0	0.5
15	C19737-P	8.2	4.0	4.3	1.8	1.2	0.5
16	WITA1	7.6	3.6	3.3	1.8	0.9	0.3
17	WITA3	7.6	3.5	4.1	2.0	1.3	0.5
18	WITA4	8.0	4.1	3.7	2.1	1.5	0.3
19	WITA6	8.0	3.5	4.0	2.3	1.4	0.3
20	WITA7	7.3	3.7	3.8	2.2	2.0	0.4
21	WITA9	7.6	4.4	4.5	2.8	2.0	0.6
22	WITA12	7.6	4.0	3.8	1.9	1.8	0.4
23	GK88	7.5	3.8	3.5	2.0	1.8	0.5

Because of cost of green revolution technology, yield must be higher than 4t/ha

Table 8: Sawah hypothesis(II): Sustainable Productivity of lowland Sawah is more than 10 times than Upland Field

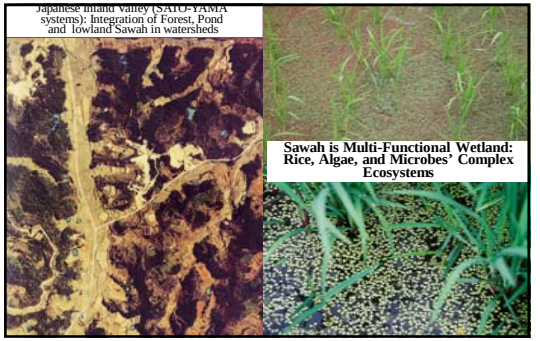
1ha sawah is equivalent to 10-15ha of upland

	Upland	Lowland(Sawah)
Area (%)	95 %	5 %
Productivity (t/ha)	1-3 1 **	3-6 2**

* Assuming 2 years cultivation and 8 years fallow in sustainable upland cultivation, while no fallow in sawah cropping

** In Case of No fertilization

Required area for sustainable1 ha 5 ha : 1 ha



Macro-scale watershed eco-technological mechanisms to support Sawah hypothesis II: Geological Fertilization of eroded top-soils and accumulation of nutrient rich water in lowland Sawah

Sustainable green revolution by sawah and SATOYAMA systems for combating Global warming: (1) efficient use of water cycling and conservation of soil fertility, (2) Ecological safe carbon sequestration by CDM, Bio-char and humus accumulation in sawah Soil layers, which will eventually transfer to sea floor, and (3) increase soil productivity by bio-char and humus accumulation

Micro-scale eco-technological mechanisms to support Sawah hypothesis II: Enhancement of the availability of N, P, K, Si, Ca, Mg, and micronutrients and quality carbon accumulation

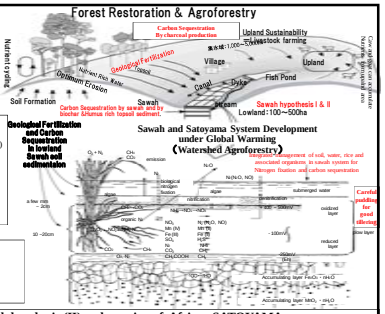


Fig. Sawah hypthesis (II) and creation of African SATOYAMA watershed systems to combat food crisis and global warming

Comparison of large scale, small scale, traditional and site specific sawah ecotechnology approach in inlnd valleys of Ghana & Nigeria

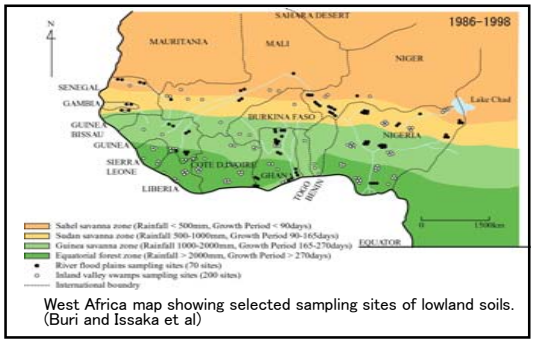
	Large Scale Development	Small Scale Development	Sawah eco-technology approach	Traditional System
Development cost per hectare	20,000-30,000 US$ / ha	20,000-30,000 US$ / ha	2,000-4,000 US$/ha	20-30 US$ / ha
Economic returns of rice and vegetable etc	1,000-2,000+ US$ / ha	1,000-2,000+ US$ / ha	1,000-2,000+ US$ / ha	100-300 US$ / ha
Running cost including machinary	Medium to High (300-600$/ha)	Medium to High (300-600$/ha)	Medium (200-300$/ha)	Low (10-20$/ha)
Farmers participation	Low	Medium to High	High	High
Project ownership	Government	Goverment	Farmer	Farmer
Adoption of Tecnology	Long, Difficult	Short, relatively easy	Medium to short, needs intensive demonstration and On the Job Training (OJT) programme	Low technology transfer
Sustainable development	Low	Low to Midium	High	Medium
Environmental effect	High	Medium	Low	Medium
	Heavy machine use Contractor based		Power tiller (sometimes animal traction) use. Farmer based development Extended agronomy	

No proper English/French &local language in Sub Sahara Africa to describe eco-technological concept and term to improve farmers' rice fields

Sawah (in Indonesian) or SUIDEN (in Japanese)

Suiden (Japanese) =SAWAH (Malay-Indonesian)

	English	Indonesian	Chinese (漢字)
Plant Biotechnology	Rice	Nasi	米, 飯, 稲
	Paddy	Padi	稲, 籾

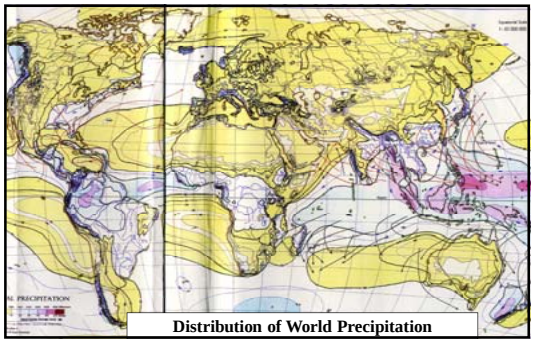


West Africa map showing selected sampling sites of lowland soils. (Buri and Issaka et al)

Mean values of fertility properties of inland valleys (IVS) and flood plains (FLP) of West Africa in comparison with lowland top-soils of tropical Asia and Japan

Location	Total C (%)	Total N (%)	Available P (ppm)**	Exchangeable Cation (cmol/kg)				Sand (%)	Clay (%)	CEC /Clay
				Ca	K	Mg	eCEC			
IVS	1.3	0.11	9	1.9	0.3	0.9	4.2	60	17	25
FLP	1.1	0.10	7	5.6	0.5	2.7	10.3	48	29	36
T. Asia*	1.4	0.13	18	10.4	0.4	5.5	17.8	34	38	47

*Kawaguchi and Kyuma (529 sites), 1977,** Bray II.
Source: Hirose and Wakatsuki (268 sites), 1997.



Distribution of World Precipitation

Can watersheds of in SSA sustain Sawah system? High rate of soil erosion and lowland sawah soil formation can be compensated by high rate of soil formation:Ecological Balance is a Key

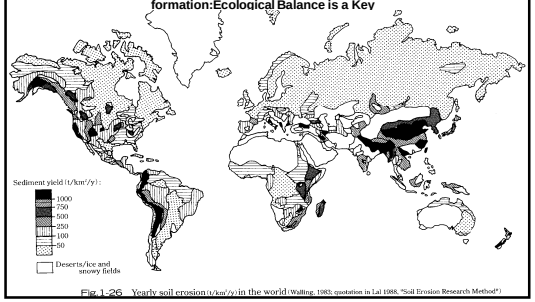


Fig. 1-26 Yearly soil erosion (t/km²/y) in the world (Walling, 1983; quotation in Lal 1988, "Soil Erosion Research Method")

Cost Effectiveness of Power Tiller Based Sawah Rice Farming

2009 estimation at Nigeria

1. Power Tiller cost:$3000 in Bangkok
   $3000-8000 in Nigeria/Ghana :Tentatively $5000 per set
2. Power Tiller life time:3-7years: Tentatively 5 year
   5-15ha sawah development/one power tiller:10 ha per one set
   20ha-100ha sawah rice farming/one power tiller:60ha per set
3. Paddy yield in sawah: 4-6ton/ha: 5ton/ha
   Paddy yield in traditional:1-2ton/ha:1.5ton/ha
   Power Tiller cost:
   Sawah development:$500-700/ha:$600/ha
   Sawah rice cultivation:$100-200/ha:$150/ha
   (For the first 5yrs of sawah development:$750)
4. Gross revenue and gross cost :
   Sawah based farming : Revenue: $3000/ha, 1ton paddy=$500
   Production cost:$800/ha=$600+$200
   Net income for the first 5yrs of sawah development stage:$2200
   Traditional farming : Revenue: $750/ha, no power tiller cost
5. Other development cost for land clearing, bunding, canal, dyke, soil movement and fuel cost have to be separately budgeted to the cost of sawah based rice farming, such as nursery, seed, bund and canal repair, dyke repair, pumping machine cost, flood control measures, plough, puddling, minor levelling, tarns planting, weeding, fertilizer, pesticides/herbicides, bard scaring, threshing
6. Rough estimation of new sawah development,
(1) $6000/ha in demonstration stage including vehicle, powertiller, scientist/engineer cost: e.g., NCAM to FadamaIII project in 2010 to 2011
(2) $3000/ha for dissemination stage by well trained extension officers
(3) $1500/ha by the technology transfer from leading farmers to new farmers:Mr. Tewaih, Suleiman in Ghana, Mr. Yakubu and Suleiman at Bida

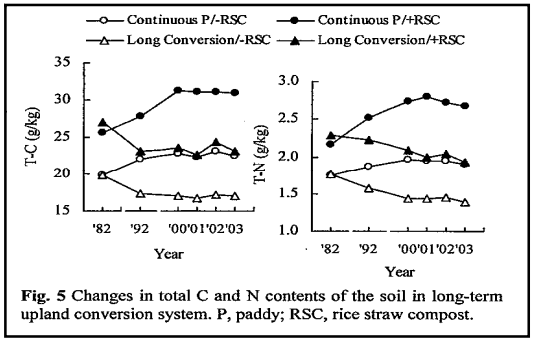


Fig. 5 Changes in total C and N contents of the soil in long-term upland conversion system. P, paddy; RSC, rice straw compost.

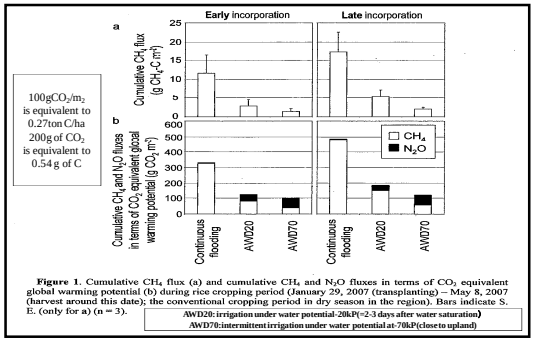


Figure 1. Cumulative CH_4 flux (a) and cumulative CH_4 and N_2O fluxes in terms of CO_2 equivalent global warming potential (b) during rice cropping period (January 29, 2007 (transplanting) – May 8, 2007 (harvest around this date); the conventional cropping period in dry season in the region). Bars indicate S. E. (only for a) (n = 3).

AWD20: irrigation under water potential-20kPa(=2-3 days after water saturation)
AWD70:intermittent irrigation under water potential at-70kPa(close to upland)