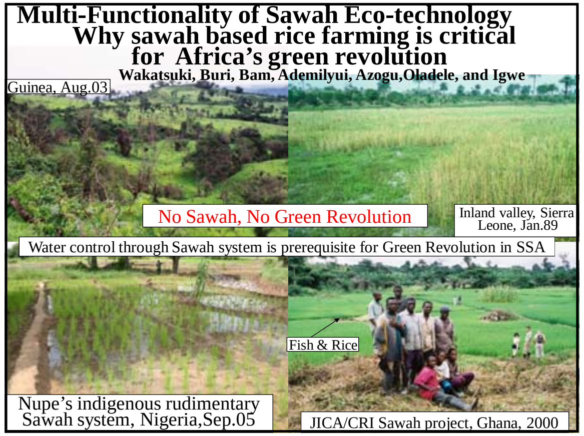
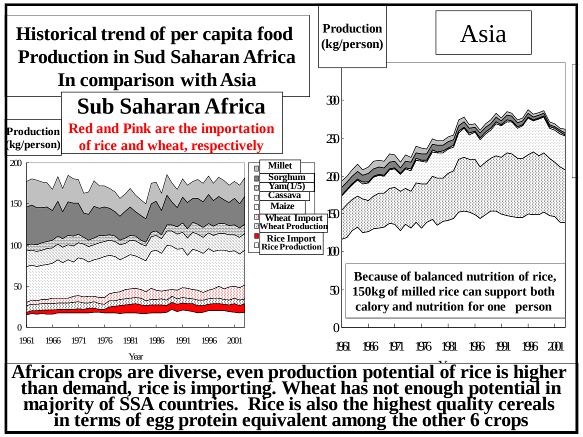
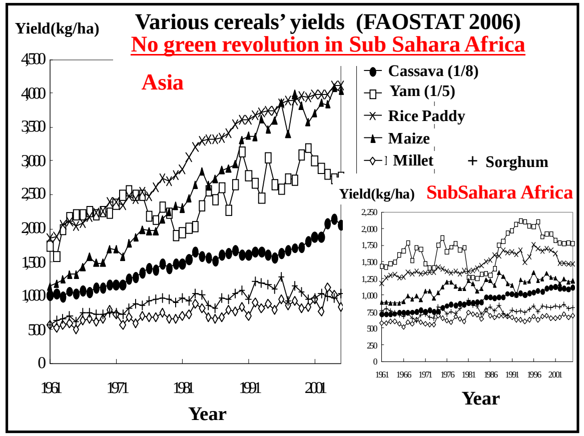
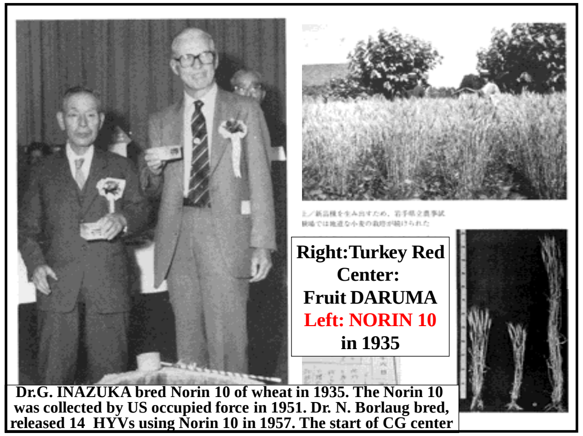
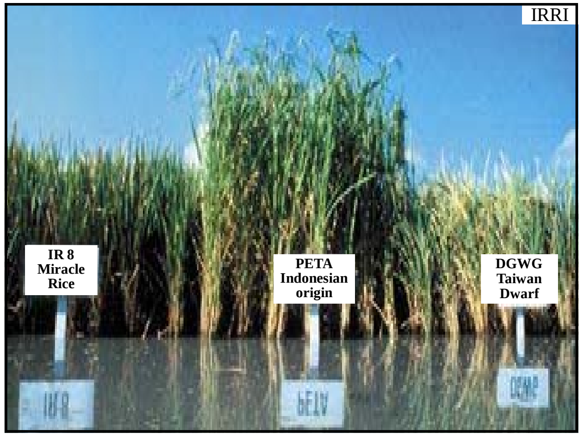
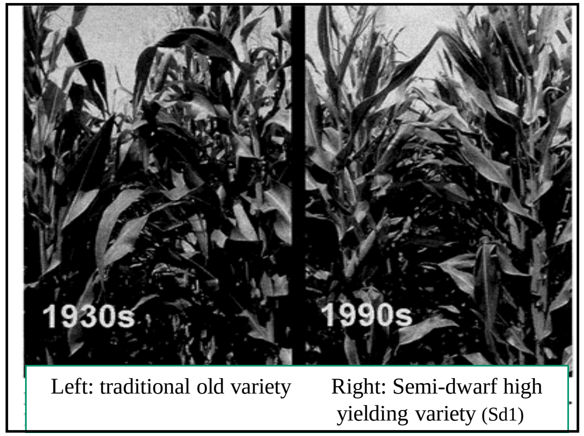

Multi-Functionality of Sawah Eco-technology
Why sawah based rice farming is critical
for Africa's green revolution
Wakatsuki, Buri, Bam, Ademilyui, Azogu,Oladele, and Igwe
Guinea, Aug.03
No Sawah, No Green Revolution
Inland valley, Sierra Leone, Jan.89
Water control through Sawah system is prerequisite for Green Revolution in SSA
Fish & Rice
Nupe's indigenous rudimentary Sawah system, Nigeria,Sep.05
JICA/CRI Sawah project, Ghana, 2000

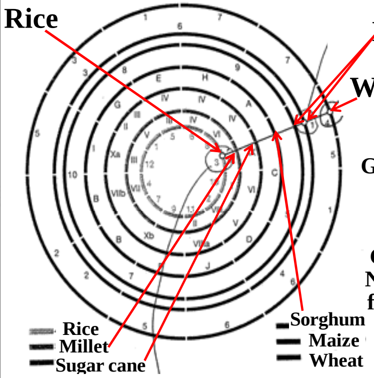

Historical trend of per capita food Production in Sud Saharan Africa
In comparison with Asia
Production (kg/person)
Asia
Sub Saharan Africa
Red and Pink are the importation of rice and wheat, respectively
Production (kg/person)
Millet
Sorghum
Yam(1/5)
Cassava
Maize
Wheat Import
Wheat Production
Rice Import
Rice Production
Because of balanced nutrition of rice, 150kg of milled rice can support both calory and nutrition for one person
African crops are diverse, even production potential of rice is higher than demand, rice is importing. Wheat has not enough potential in majority of SSA countries. Rice is also the highest quality cereals in terms of egg protein equivalent among the other 6 crops


Yield(kg/ha)
Various cereals' yields (FAOSTAT 2006)
No green revolution in Sub Sahara Africa
Asia
Cassava (1/8)
Yam (1/5)
Rice Paddy
Maize
Millet
Sorghum
Yield(kg/ha)
SubSahara Africa
Year
Year


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


IRRI
IR 8
Miracle
Rice
PETA
Indonesian
origin
DGWG
Taiwan
Dwarf


1930s
1990s
Left: traditional old variety
Right: Semi-dwarf high yielding variety (Sd1)



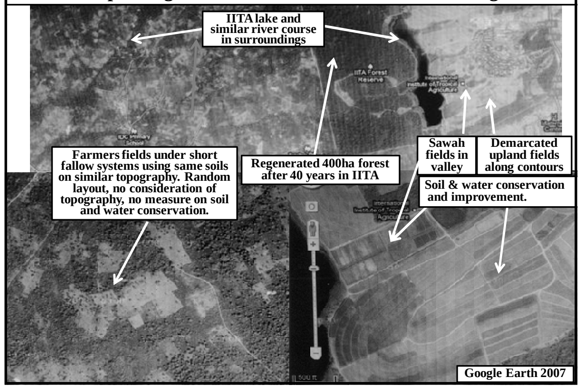
High Yielding Varieties for Green Revolution in Asia and Latin America have the same Gene, Sd 1. The Norin 10 was the first variety that expressed the Sd 1 character

Matsuoka 2004 Sd1=Semi-dwarf 1

After the dramatic success by CYMMET and IRRI in 1970s in Latin America and Asia, various HYVs were available in Sub Sahara Africa during last 40 years, 1970-2008.

However, the green revolution is yet realized in Sub Sahara Africa. Why ?

Sawah Hypothesis 1: Prerequisite condition to apply scientific technology is existing in 1000ha of "International Institutes of Tropical Agriculture, IITA", but not in surroundings

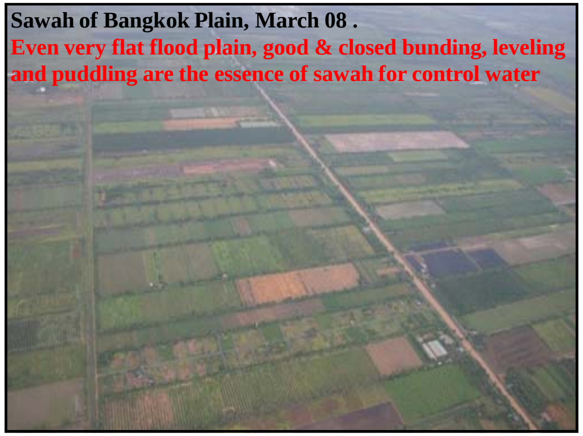


Sawah systems developed & managed by Chinese Farmers (Otsuka 2004)

Forest Destruction by Shifting Upland Paddy Cultivation in Guinea Highland: Upland rice can not be sustainable without sawah or soil conservation measures (Guinea highland, 2002)

Sawah of Bangkok Plain, March 08 .

Even very flat flood plain, good & closed bunding, leveling and puddling are the essence of sawah for control water



Sawah of Bangkok Plain, March 08 .
Even very flat flood plain, good & closed bunding, leveling and puddling are the essence of sawah for control water

Lowland paddy field at Sokawe, Kumasi, Ghana
Three Green Revolution technologies can't apply

Sokwae Sawah development
by CRI sawah team, June 2008

Soil and Wooden Weir, because of farmers' self-support management (Biemso No.1, JICA/CRI sawah project, 2000)

Canal construction by farmers' group work, (although the group work is not so easy smooth)

Biemso No.1, Mr. Suleiman's site in 2002, Puddled soil leveling using powertiller & wooden plank. (±5-10cm leveling is possible)

Sawah is ecotechnology based Multi-Functional constructed Wetland: Production, Environment, and Cultural landscape (JICA sawah project, 2001)

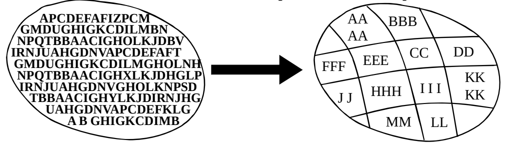
Once Sawah system was developed, yield can reach at least 4t/ha. If improved rice agronomy can practice, such as intermittent irrigation, or others like System Rice Intensification (SRI), yield can reach to 10t/ha (CRI sawah team, 2008)

Farmers' Paddy Fields: Diverse and mixed up environmental conditions: mixed farming systems, crops, varieties, and weeds. No clear field demarcations.

1. The improvement of field conditions are difficult. Water cannot be controlled, therefore no soil conservation possible.
2. Land right of the field has overlapping with diverse people and communities. No incentive to improve land.
3. Pure seed production and the post-harvest technology can not apply.

Sawah Fields: Lands are demarcated by bund based on topography, hydrology and soils, which makes diverse sawahs but homogeneous condition of each sawah.

1. Water is controlled. Soil is conserved. Therefore field conditions are improve through the accumulation of every year.
2. Land can be surveyed and registration become possible, then private ownership is promote, which makes incentives to improve land.
3. Pure seed production and qualified paddy production become possible for market.



Fertilizer, Irrigation, and high-yielding varieties(HYV) are not effective, therefore, Green Revolution is impossible.

Operational condition of the fields for Scientific technologies are satisfied, therefore, Green Revolution will be realized.

Fig 3. Sawah hypothesis (1): Farmers' Sawah should come first to realize Green Revolution. Farmers fields have to be classified and demarcated ecotechnologically. Then scientific technology can be applied.

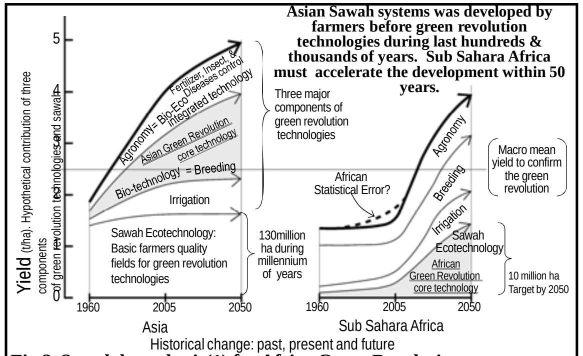


Fig.2. Sawah hypothesis(1) for Africa Green Revolution:
Hypothetical contribution of three green revolution technologies & sawah system development during 1960-2050. Bold lines during 1960-2005 are mean rice yield by FAOSTAT (2006). Bold lines during 2005-2050 are the estimation by the authors.

No proper English/French &local language in West Africa to describe eco-technological concept and term to improve farmers' rice fields, Sawah 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
Environment Ecotechnlogy	(Paddy) ?	Sawah	水田

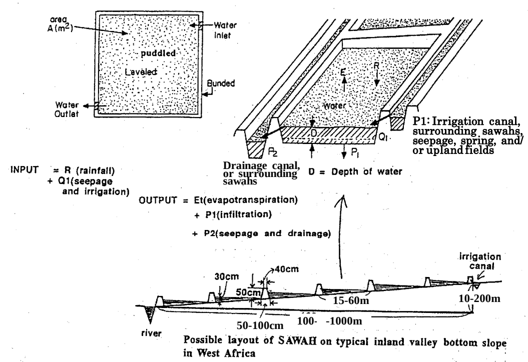


Figure 2. Sawah: A leveled, bunded, and puddled rice field with inlets and outlet to control water

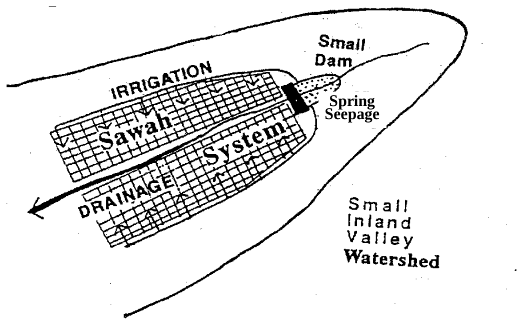
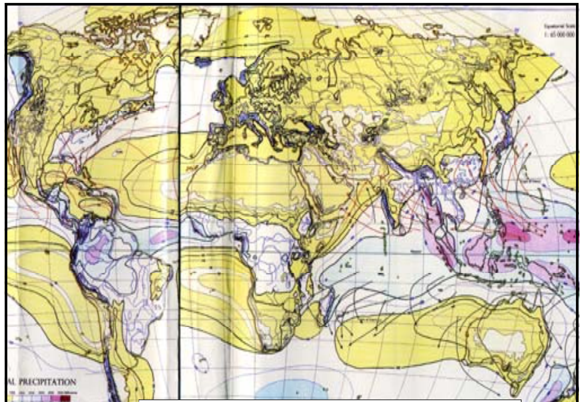


Figure 1. Sawah system with irrigation and drainage facilities for control of water in an inland valley watershed



Distribution of World Precipitation

Can watersheds of SSA sustain Sawah system? High rate of soil erosion and lowland sawah soil formation can be compensated by high rate of soil formation in Asia. However soil formation, soil erosion and hence lowland soil formation are very low (only 10-20%) in comparison with Asian watersheds

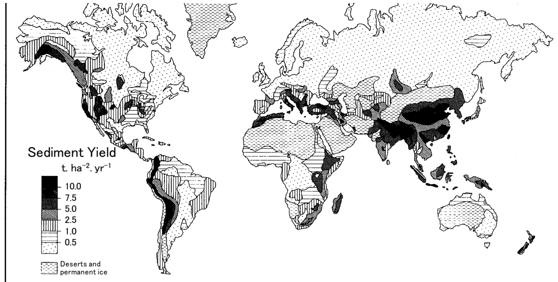
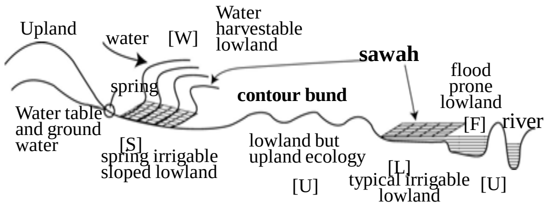


Fig.8. Rate of soils erosion in the world (Walling1983)



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

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

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

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%)

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

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

Multi Functionality of Sawah Systems

I. Intensive, diverse and sustainable nature of productivity

(1) Weed control
(2) Nitrogen fixation ecosystems: 20 to 200kgN/ha/year
(3) To increase Phosphate availability: concerted effect on N fixation
(4) pH neutralizng ecosystems: to increase micro nutrient availability
(5) Geological & irrigation fertilization: water, nutrients and topsoil from upland
(6) Various sawah based farming systems.
(7) Fish and rice, Goose and sawah, Birds and sawah, Forest and Sawah

II. To combat Global warming and other environmental problems

(1) Carbon sequestration through control of oxygen supply. Methane emission under submerged condition. Nitrous oxide emission under aerobic rice
(2) Watershed agroforestry, SATOYAMA, to generate forest at upland
(3) Sawah systems as to control flooding & soil erosion and to generate electricity
(4) Denitrification of nitrate polluted water

III. To create cultural landscape and social collaboration

(1) Terraced sawah as beautiful cultural landscape
(2) Fare water distribution systems for collaboration and fare society

Comparison between Biotechnology and Sawah Ecotechnology Options for Rice Production

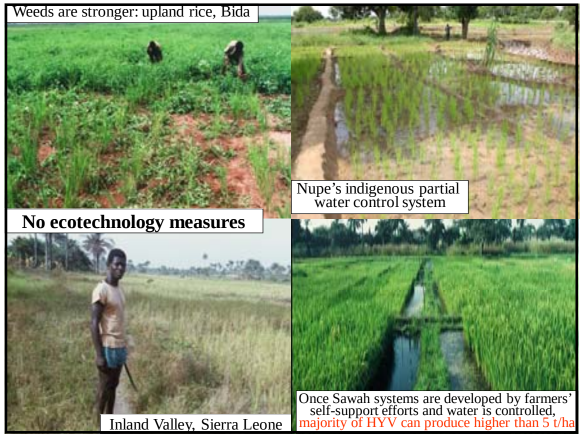
(1) **Water shortage**: **Genes for deep rooting、C4-nature、and Osmotic regulation.** Eco-technology of Sawah based soil and water management, bunding, leveling, puddling, and surface smoothing with various irrigations, Aerobic rice, System rice intensification

(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**: **Various 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.** Sawah based nutrition control. Fish, duck and rice in sawah systems



Weeds are stronger: upland rice, Bida

Nupe's indigenous partial water control system

No ecotechnology measures

Inland Valley, Sierra Leone

Once Sawah systems are developed by farmers' self-support efforts and water is controlled, majority of HYV can produce higher than 5 t/ha

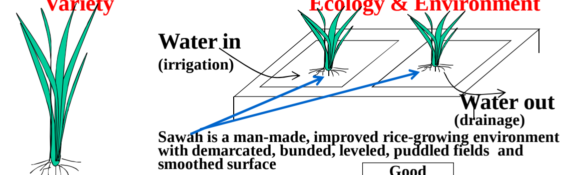
Table Mean gain yield of 23 rice cultivars in low land ecologies at low (LIL) and high input levels (HIL), Ashanti, Ghana (Ofori & Wakatsuki,2005) 2005)

	Entry No.	Cultivar	← ECOTECHNOLOGICAL YIELD IMPROVEMENT					
			Irrigated Sawah		Rainfed sawah		Upland like fields	
			HIL	LIL	HIL	LIL	HIL	LIL
			(t/ha)		(t/ha)		(t/ha)	
BIOTECHNOLOGICAL IMPROVEMENT	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	WITA 8	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	CT9737	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	CT9737-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
Mean (n=23)			7.2	3.8	3.8	2.0	1.7	0.4
Range			(4.0-8.2)	(2.8-4.4)	(2.8-4.5)	(1.3-2.8)	(0.9-2.3)	(0.3-0.6)
SD			1.51	0.81	0.81	0.45	0.44	0.12

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

Bio-technology and Eco-technology

Breeding to improve Variety **Sawah to improve Ecology & Environment**



Sawah is a man-made, improved rice-growing environment with demarcated, bunded, leveled, puddled fields and smoothed surface

Varieties could solve the main problems in Asia. Is this also true in SSA? No! , last 40years experiences

Good Yield ← Good Tillering & Grain ← Good Puddling Soft&low Bulk density topsoil ← Good Sawah

Good weed competition | Good rooting, nutrient supply & Water saving | Good Water control

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

Mr. Tawiah and his rice, growing on sawah about 4ha developed by himself, with CRI/SRI, and JIRCAS scientists, August 2009. This is original site of JICA/CRI sawah project in 1997-1999

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

Poor tillering and aggressive weed in non sawah field

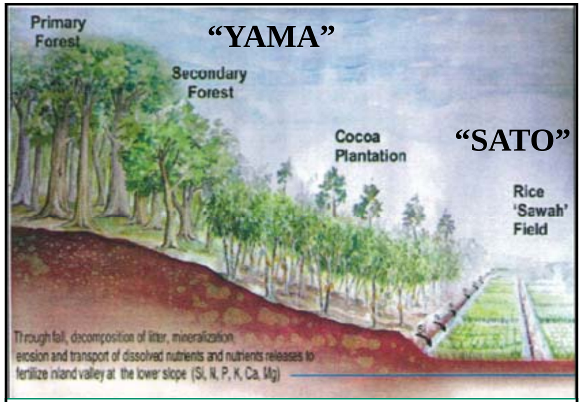


Figure 6. One Example of Africa SATO-YAMA Concept Map by Dr. Owusu, FoRIG, Ghana which is a watershed agro-forestry applicable to Cocoa belt region in West Africa.

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

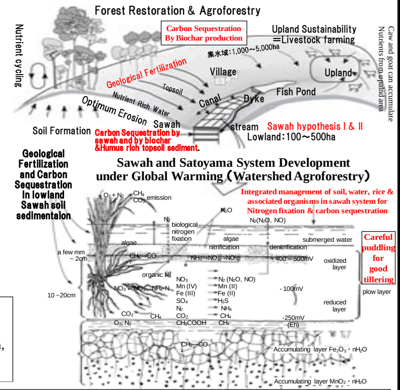
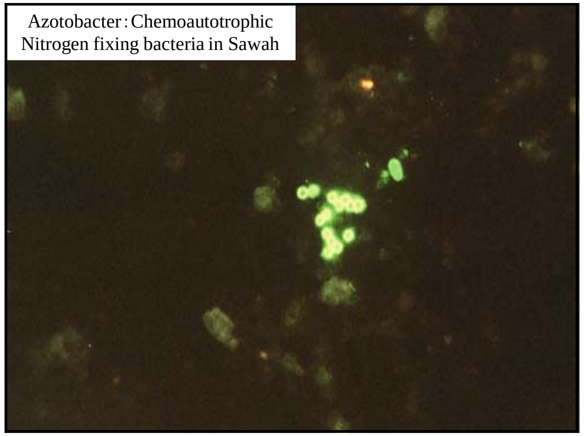


Fig. Sawah hypthesis (II) and creation of African SATOYAMA watershed systems to combat food crisis and global warming

Submerged sawah:
Multi functional ecosystems of various interaction between Rice, Algae, Fish, Goose, microbes, and others

Left :nitrogen fixing Azola

Azotobacter : Chemoautotrophic Nitrogen fixing bacteria in Sawah



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**)
Required area for sustainable1 ha cropping*	5 ha	:	1 ha

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

**In Case of No fertilization