CHAPTER 3

‘SAWAH’ HYPOTHESIS 1 & 2: MULTI-FUNCTIONALITY OF ‘SAWAH

“Sawah” Eco-technology operates on certain principles and assumptions, some of which one outlined in this chapter. Advantages of the system compared to traditional systems are also mentioned.

WHAT IS THE CORE TECHNOLOGY FOR AFRICAN RICE GREEN REVOLUTION?

Three already known core technologies for green revolution are

(1) High Yielding Varieties (HYV)

(2) Soil, fertilizer and pest management (Fertilizers and Pesticides)

(3) Irrigation and drainage

After the dramatic success by CYMMET and IRRI in 1970s in Latin America and Asia, various HYVs have been made available to Sub Sahara Africa since 1970-2012.

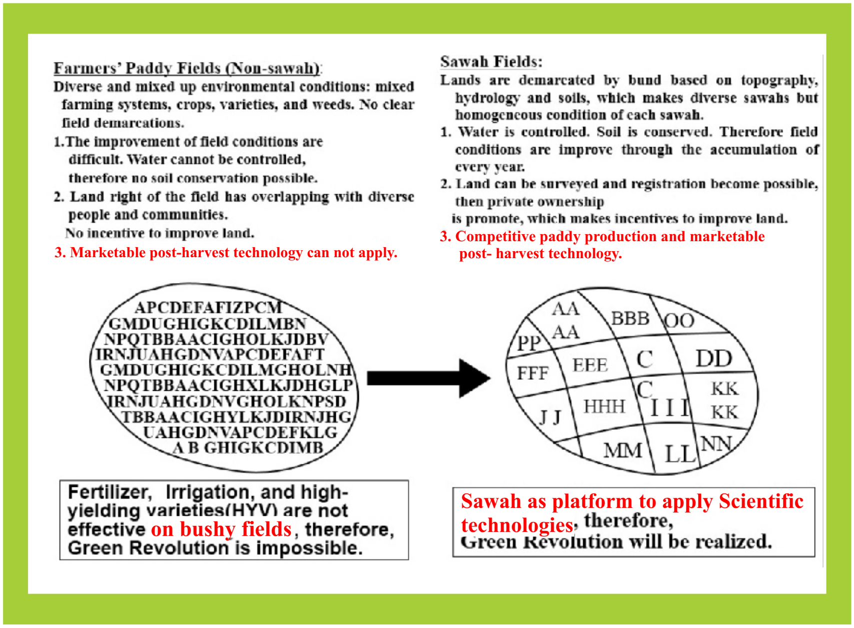
Those three technologies are applicable on experimental fields.
However, are they also applied in African farmers' fields?
Are there any missing factors that need to be identified and looked at ?

THE WAY FORWARD

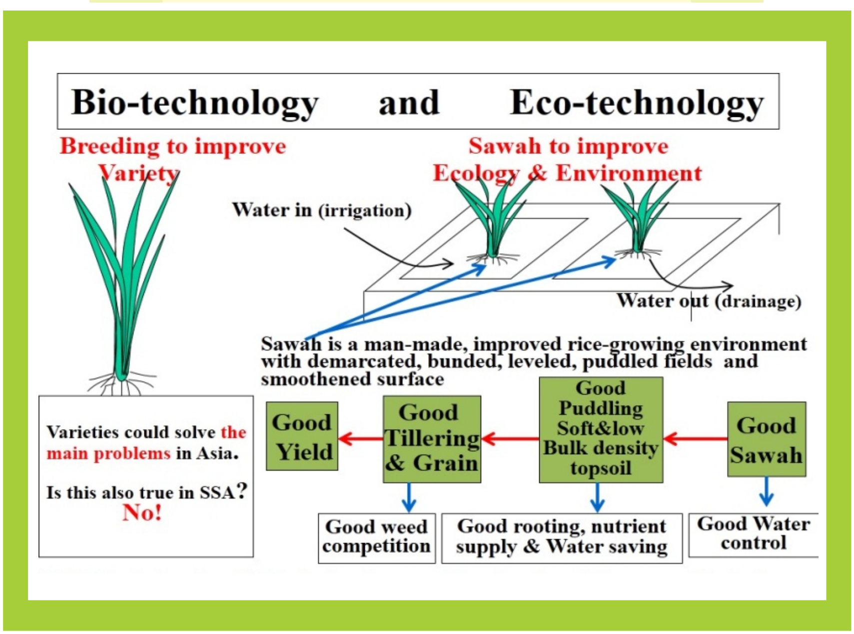
In order for the three core technologies , which are based on Biotechnology, to be successful, they must be made to operate in an improved environment (Eco-technology). In other words, there must be a balance between biotechnology and eco-technology.

An eco-technology such as 'Sawah' should serve as the Platform for the effective operation and implementation of the three (3) scientific technologies listed below.

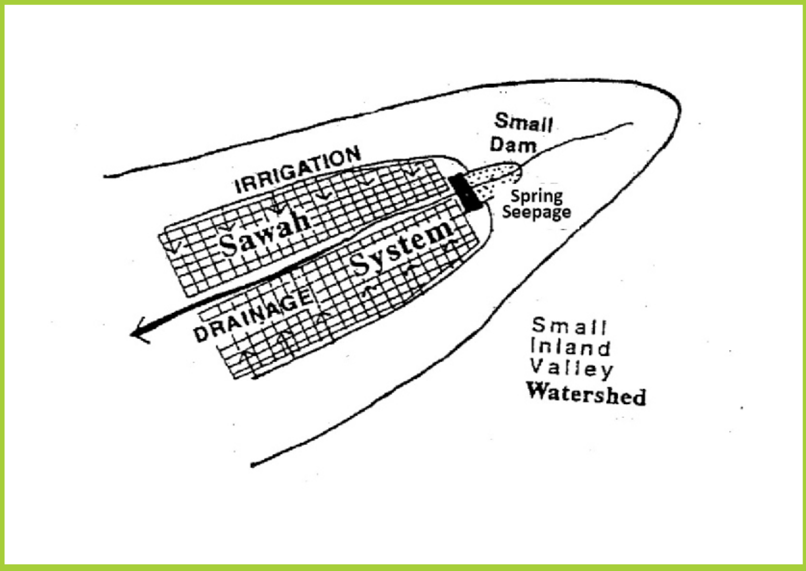
1. **High Yielding Varieties (HYV)**
2. **Soil, nutrients and pest management (Soil conservation, Fertilizers, Agrochemicals, and Integrated PM)**
3. **Water management (Irrigation and Drainage)**



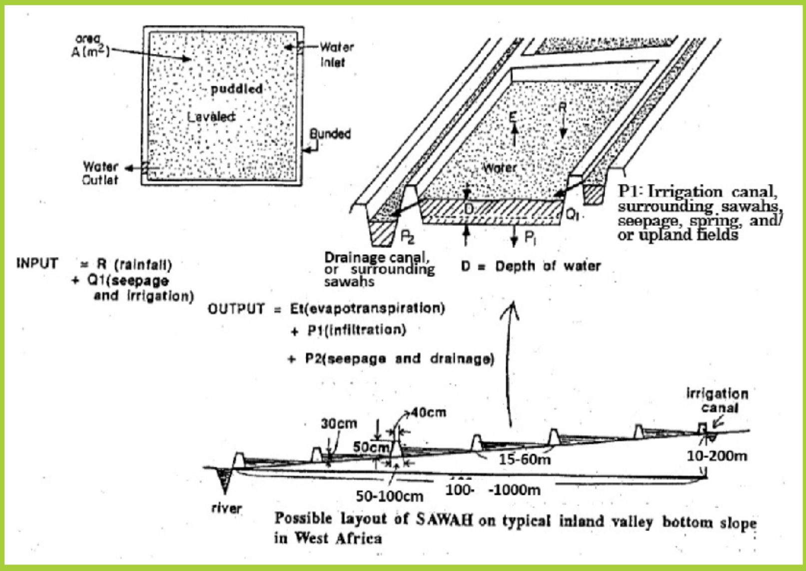
Sawah hypothesis (1): Farmers fields have to be classified and demarcated eco-technologically before any scientific technology can be effectively applied.



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



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



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

BIOTECHNOLOGY AND SAWAH ECO-TECHNOLOGY OPTIONS FOR SUSTAINABLE RICE PRODUCTION: IMPORTANCE OF BALANCED APPROACH

(1) Water shortage and Flood damage
Bitoech: Genes of deep rooting, C4-nature, Osmotic and flood tolerance
Ecotech: Sawah based water harvest in watersheds. Bunding, leveling, puddling, with various irrigation and drainage. Flood control systems, aerobic rice.

(2) Poor nutrition, acidity and alkalinity
Biotech: Gene of N fixation, P and various micronutrient transporters.
Ecotech: Sawah based method to increase N fixation and P, Si, K, and Zn etc. availabilities. Geological fertilization and watershed agroforestry (Satoyama systems). Mixed, organic and natural farmings

(3) Weed, Pest and disease control
Biotech: Genes of various resistance, rapid growth, C4 nature
Ecotech: Sawah based weed management through water control and line transplanting. Good leveling. Sawah based silica and other nutrients supply to enhance immune mechanisms of rice. Sawah based mixed cropping, Sawah based duck, fish and rice and other rice farming.

(4) Global Warming
Biotech: Ultra high yield varieties
Ecotech: Carbon sequestration by Sawah systems through the control of oxygen supply, use of Biochar, and organic farming. System rice intensification and other ultra high yield agrsnomic practices

(5) Food quality and Biodiversity
Biotech: Golden rice, other vitamine rice gene
Ecotech: Fish, duck and rice in sawah systems. Satoyama agroforestry systems

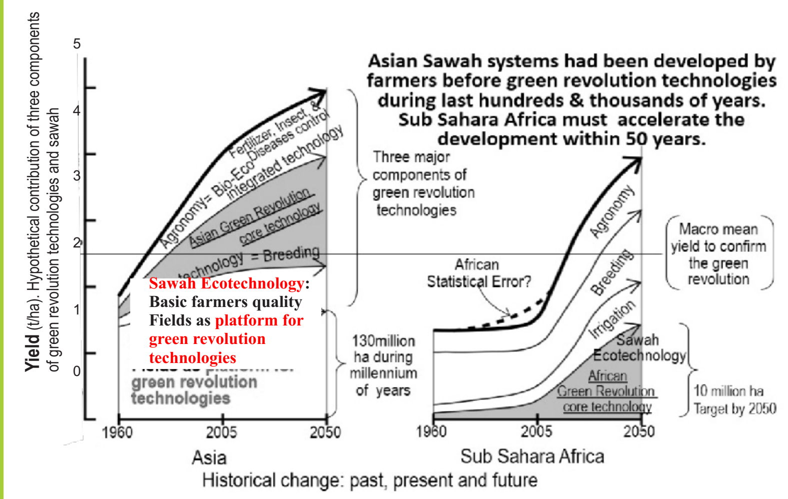
Effective combination and balance between Biotechnology and Eco-technology is key to achieving desired results

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 Eco–technlogy	(Paddy)?	Sawah	水田

'Sawah' malayo-Indonesian word / term



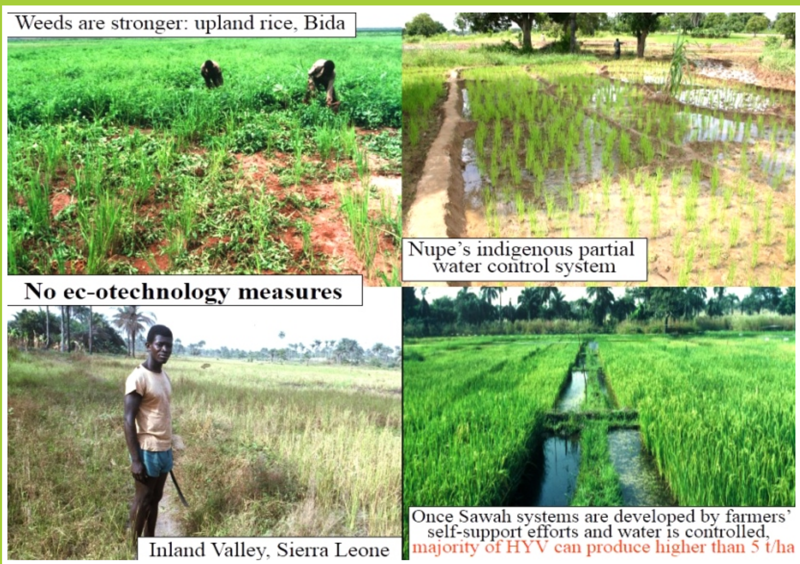
<u>Estimated yields under Sawah hypothesis(1) for Africa Green Revolution:</u> Hypothetical contribution of three green revolution technologies & sawah system development during 1960-2050. Bold lines during 1960-2005 are mean rice yield by FAOSTAT (2006). Bold lines during 2005-2050 are those estimated by the authors.

Even with very flat flood plains, good and closed bunding, leveling and puddling are necessary (the essence of sawah is for good water control)

Sawahs of Madagascar have thousands years of history with the migration of "old" Indonesians. Sawah systems form the base for "System of Rice Intensification (SRI)"

The Three Green Revolution technologies cannot be applied under such lowland paddy field such as Sokwae site in Kumasi, Ghana.

Once "Sawah" system is developed, such as the Sokwae site shown earlier, yields can reach at least 4t ha^{-1}. With improved rice agronomy, yields of up to 10t ha^{-1} and above are possible.



(a)Weeds are stronger: upland rice, Bida (b) Nupe's indigenous partial water control system,
(c) open valley systems in Sierra Leone. Under such conditions No ec-otechnology measures are put in place.
(d) Once Sawah systems are developed by farmers' self-support efforts and water is controlled, majority of HYV can produce higher than 5 t/ha

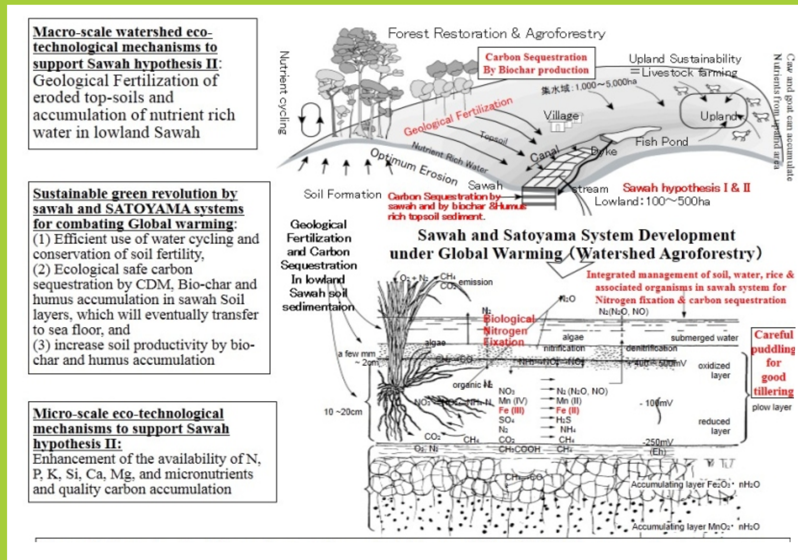
Field demonstration on "Sawah" and traditional (non-sawah) rice at Pampaida, UN millennium village in Zaria, Nigeria

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

	Entry No.	Cultivar	← ECOTECHNOLOGICAL YIELD IMPROVEMENT: Irrigated Sawah HIL (t/ha)	Irrigated Sawah LIL (t/ha)	Rainfed sawah HIL (t/ha)	Rainfed sawah LIL (t/ha)	Upland like fields HIL (t/ha)	Upland like fields LIL (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

Yield must be higher than 4t/ha because of cost of green revolution technology,

In order for "sawah" to be profitable and sustainable, grain yield must be higher than 4t/ha



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

Multi Functionality of 'Sawah' Systems

A. Intensive, diverse and sustainable nature of productivity

(i) Weed control
(ii) Nitrogen fixation ecosystems: 20 to 200kgN/ha/year
(iii) Increased Phosphate availability: concerted effect on N fixation
(iv) pH neutralizng ecosystems: to increase micro nutrient availability
(v) Geological and irrigation fertilization: through water, nutrients and topsoil from upland
(vi) Various 'sawah' based farming systems.
(vii) Fish and rice, Goose and 'sawah', Birds and 'sawah', Forest and 'Sawah'

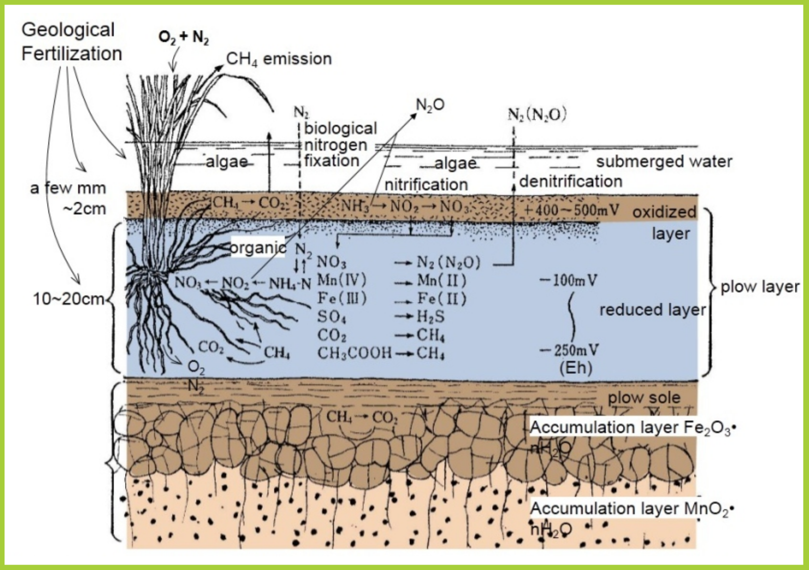
B. To combat Global warming and other environmental problems

(I) Carbon sequestration through control of oxygen supply, methane emission under submerged condition. and nitrous oxide emission under aerobic rice
(ii) Watershed agroforestry, SATOYAMA, to generate forest at upland
(iii) 'Sawah' systems as to control flooding & soil erosion and to generate electricity
(iv) Denitrification of nitrate polluted water

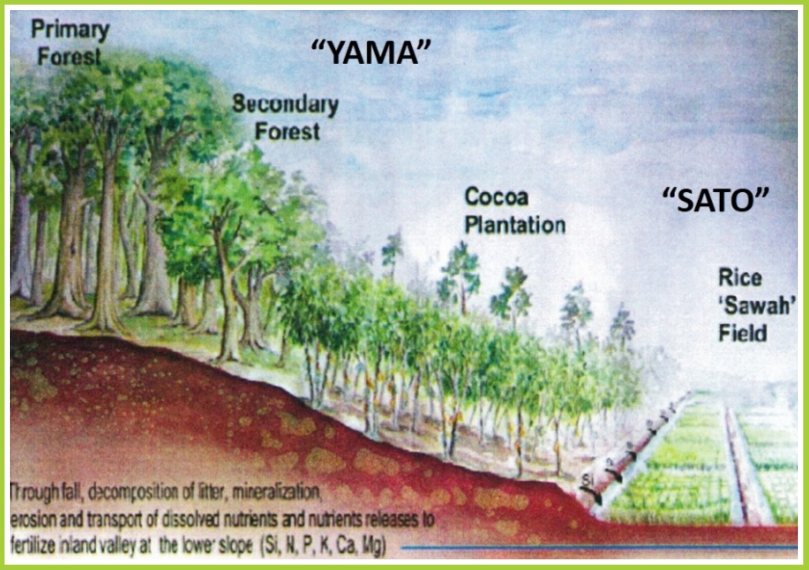
C. To create cultural landscape and social collaboration

(i) Terraced 'sawah' as beautiful cultural landscape
(ii) Fare water distribution systems for collaboration and fare society

Natural benefits of the sawah systems are multi-dimensional cutting across several areas/fields under natural operation



Sawah system: functional constructed wetland: Morphology of sawah soil profile and various redox reactions to increase soil fertility

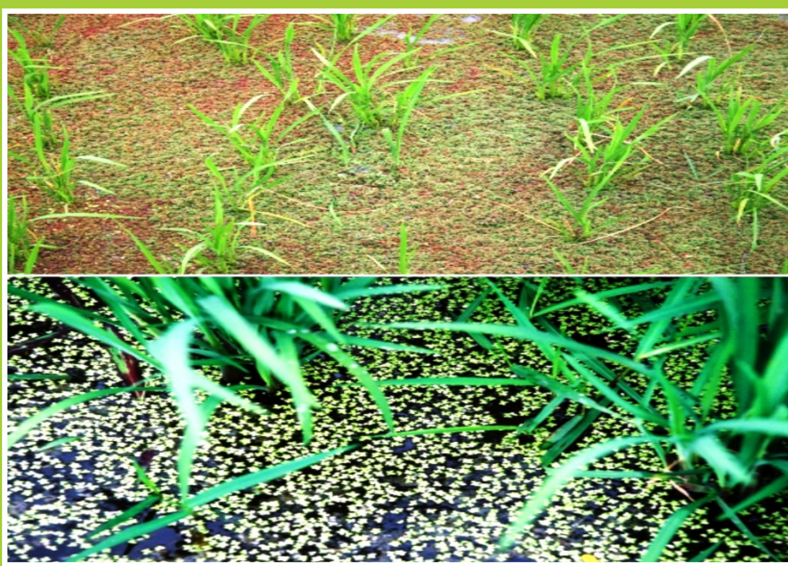


Africa SATO-YAMA Concept in Ghana which is a watershed agro-forestry applicable to Cocoa belt region in West Africa.

In the forest agro-ecology, inland valleys can benefit enormously from operations that take place on the upland/upper slopes (e. g. Tawiah Site, Terarced sawah and cocoa at Adugyama near Kumasi in Ashanti region of Ghana)

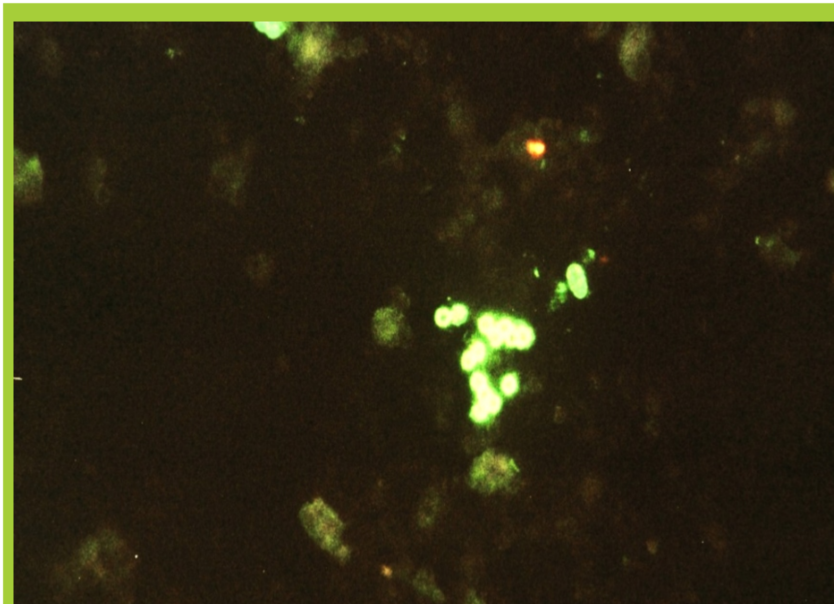
Cocoa fields/forest on upland or upper slopes can significantly contribute to sustain lowland rice production if carefully managed.

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

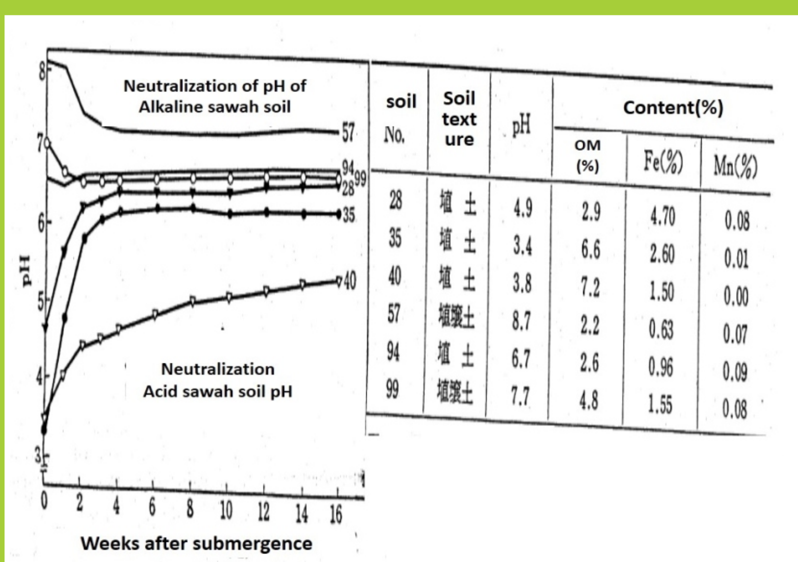


(a) **Submerged sawah: Multi functional ecosystems of various interaction between Rice, Algae, Fish, Goose, microbes, and others:**

(b) **Nitrogen fixing Azola**

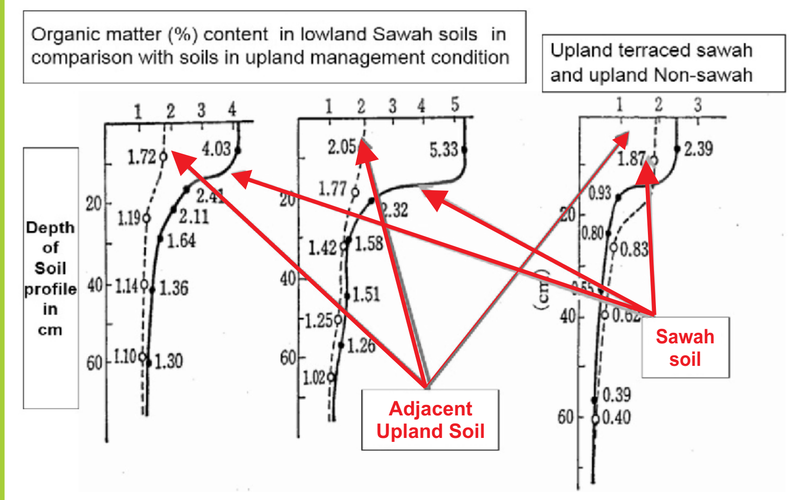


Azotobacter : Chemoautotrophic Nitrogen fixing bacteria in Sawah (Photograph : SSSA Slide collection)

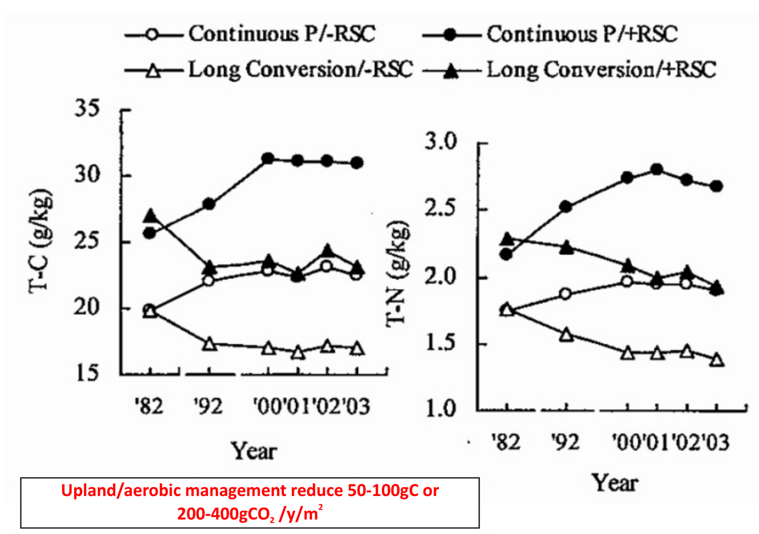


soil No.	Soil texture	pH	Content(%)		
			OM (%)	Fe(%)	Mn(%)
28	埴 土	4.9	2.9	4.70	0.08
35	埴 土	3.4	6.6	2.60	0.01
40	埴 土	3.8	7.2	1.50	0.00
57	埴壌土	8.7	2.2	0.63	0.07
94	埴 土	6.7	2.6	0.96	0.09
99	埴壌土	7.7	4.8	1.55	0.08

Sawah soil neutralization through submergence (Ponnamperuma 1976)



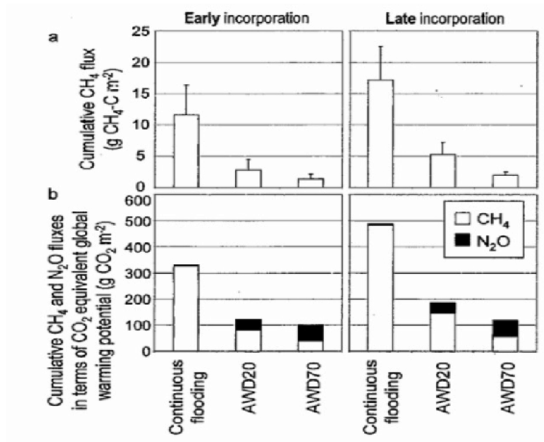
Organic matter (%) in Sawah soils in comparison with soils in upland management (Mitsuchi 1970, 1974)



Changes in total C and N contents of the soil in long term upland conversion systems: P = paddy; RSC = rice straw compost (Upland/aerobic management reduce 50-100gC or 200-400gCO_2 /y/m^2)

Upland/aerobic management reduce 200-400gCO_2 /y/m^2

100gCO_2/m_2 is equivalent to 0.27ton C/ha
200g of CO_2 is equivalent to 0.54 g of C



Comulative CH_4 flux (a) and comulative CH_4 and N_2O fluxes in terms of CO_2 equivalent global warming potential (b) during rice cropping period (January 29, 2007 transplanting, and harvested in May 8, 2007).The conventional cropping period in the dry season in the region. Bars indicate SE (only for a) (n= 3)

In 2003, Dr. Darmawan collected sawah soils from the same sites where Prof Kyuma surveyed in 1970 and analyzed for changes in soil characteristices

Table 3 Changes in total carbon and total nitrogen (Mg ha^{-1}) content in the 0–20 cm and 0–100 cm soil layers in seedfarms and non-seedfarms from 1970 to 2003 in Java, Indonesia

	Seedfarm				Non-Seedfarm			
	0–20 cm		0–100 cm		0–20 cm		0–100 cm	
	1970	2003	1970	2003	1970	2003	1970	2003
Total carbon (Mg ha^{-1})								
n	18	18	18	18	22	22	22	22
Mean	34.50	39.24	92.68	112.83	29.77	41.37	79.60	114.86
Standard deviation	9.95	9.70	39.47	40.91	10.88	15.12	28.07	40.50
Mean change		4.74		20.15		11.60		35.26
% change		13.7		21.7		39.0		44.3
t-test		*		***		***		***
Total nitrogen (Mg ha^{-1})								
n	18	18	18	18	22	22	22	22
Mean	3.16	3.95	9.34	12.03	2.94	3.98	8.93	11.44
Standard deviation	1.07	0.89	4.01	4.10	1.15	1.24	3.16	3.30
Mean change		0.79		2.69		1.04		2.51
% change		25.0		28.8		35.4		28.1
t-test		**		***		***		***

n, number of sampling sites. *$P < 0.05$; **$P < 0.01$; ***$P < 0.001$.

Environmental conservation, soil nutrient rebuilding and re-cycling are prominent features of the "Sawah" system. Nutrient monitoring in under sawah in Indonesia, showed that both soil Carbon and Nitrogen increased by over 30% during the period 1970-2003.

Changes (%) in topsoil (0-30cm) fertility levels (2001 – 2008)

Parameter	Adugyama	Biemso	Mean
Total carbon	3.5	3.0	3.25
Total Nitrogen	- 3.4	- 4.0	- 3.7
Available Phosphorus	10	- 30	- 10
Exchangeable K	32	35	33.5
Exchangeable Ca	37	15	26
Exchangeable Mg	10	12	11

Buri et al., 2010

Similar results of nutrients accumulation were also observed in Ghana

Productivity of 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

Sawah Hypothesis(II): This postulates that the Sustainable Productivity of one hacter of lowland “Sawah” is over 10 times higher than one hacter upland field. Hence, for environmental conservation, preservation and to minimize further land degradation and promote sustainable production, “sawah” emphasis on intensification rather than extensification

Prof. Kyuma collected soil samples from selected sawah fields in 1970 in Java, Indonesia, and revisited the sites in 2003 where rice has been grown for over 30yrs with yields of over 10t ha^{-1}

Sawah systems may be damaged by natural disasters but can manage draught and flooding through its Multi-functionalities. A typical scene on field in Nigeria.