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"SAWAH" ECO-TECHNOLOGY




PRINCIPLES AND PRACTICES

Wakatsuki T., Buri M. M. & Ademiluyi Y. S

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FOREWORD

In sub-Saharan Africa (SSA), even though there have been research concepts to improve natural resource management (NRM), there has been no clear research concept on how to improve natural resources such as soil and water conditions at the farmers field level. The "Sawah" eco-technology is one of such missing concepts to improve natural resources management in majority of African rice farms. It can accelerate improvements in effective natural resources management, minimize environmental degradation and increase soil productivity in majority of African conditions. In order to apply these scientific technologies, farmers' have to develop typically refined rice growing environments referred to as "Sawah" or develop similar alternatives which can conserve soil and control water. Essential components of such land development are: (i) demarcation by bunding based on topography, hydrology and soils, (ii) leveling and puddling to control and conserve soil and water, and (iii) water inlets and outlets. The above parameters are typical characteristics of "Sawah" fields. The essence for this is to avoid too much water deposited at one side of the field to the disadvantage of other parts of the field.

The “sawah” eco-technology can improve fertilizer and irrigation efficiency. Thus it can improve water shortage, poor nutrition especially for nitrogen and phosphorous supply, neutralize acidity as well as alkalinity, and improve micronutrient supply. With this, improved varieties can perform well to realize green revolution in Africa. The “Sawah” system of rice production therefore seeks to improve on lowland rice production by helping to effectively manage land, control water and nutrients to boost local rice production. If appropriate lowlands are selected, developed and soil and water managed properly, then the application of improved agronomic practices such as System of Rice Intensification (SRI) under the “Sawah” system, can result in paddy grain yields exceeding 10 t ha^{-1}. Use of the technology has increased rice production from about one ton per hectare under the current traditional system to over six tons per hectare at several locations across Ghana and Nigeria. It is also environmentally friendly and it minimizes erosion, reduces land degradation and increases nutrient-use-efficiency.

At the 1st International workshop on "Sawah" rice farming in SSA, participants were convinced that (i) the demand for rice will continue to rise in the immediate, medium and long term and that large amounts of foreign exchange will continue to be used on rice imports by countries of the sub-region, (ii) that Africa, and in particular West Africa, has large stretches of lowlands which can be used for rice production across most agro-ecological zones that can significantly reduce imports and create employment particularly for the youth, (iii) that there is the urgent need for the adoption of improved and sustainable technologies for the rapid expansion of local rice production in the sub-region, recommended that there was the need to build the capacity of extension workers and “Sawah” farmers by providing them with good training and working materials/documents which will offer Agricultural Ministries and other stakeholders in the rice industry of individual countries a better understanding of the technology and which can also be used to strengthen and/or expand farmer education on the eco-technology. This document is therefore in fulfillment of that recommendation. It provides the basis and principles of the "sawah" system. It also defines effective and efficient pathways for its application and adoption. Finally, the manual outlines field observations and experiences particularly in Ghana and Nigeria which can be shared by farmers, field extension staff and scientists not only within these countries but across other countries as well. This is a technology that has the greatest potential to galvanize rice farmers, minimize environmental degradation, improve productivity and accelerate the processes of the rice green revolution in Africa.

PROFILE OF AUTHORS

Toshiyuki WAKATSUKI is a Professor Emeritus who obtained his Ph. D in Agriculture in 1977 at the Kyoto University in Japan. He thought in several universities in Japan either as a full time lecturer or visiting Research Associate. His field of specialization is African "Sawah" development, Soil Science and Eco-technology while his major interests are implementation of "Sawah" eco-technology innovation to realize green revolution in Sub- Saharan Africa. His teaching experience spanned several years and covers the following: Emeritus Professor, Faculty of life and Environment Science, Shimane University (2008-present); Professor, Faculty of Agriculture, Kinki University (2004-March 2013); Professor, Faculty of life and Environment Science, Shimane University (1995-2003); Associate Professor., Faculty of life and Environmental Science, Shimane University (1981-1995); Research Associate, Faculty of Agriculture, Kyoto University (1979-1980).

T. Wakatsuki was not only a teacher but also a Researcher whose research career and experience also span over several decades, part of which covers the following: Project leader of MEXT/JSPS assisted grant-in-aid Specially Promoted Research on “Materialization of West African rice green revolution by "Sawah" eco-technology and the creation of African Satoyama systems” (2007-2011); Project leader of JSPS assisted Grant-In-Aid of Basic Scientific

Research (S) on "Watersheds Ecological Engineering for Sustainable Increase of Food Production and Restoration of Degraded Environment in West Africa" (2003-2007); Project leader of JSPS assisted Grant-In-Aid of Basic Scientific Research (A) on "Ultimate Decomposition Rates of Organic Waste and Purification function of Soil Ecosystems" (2001-2002); Project leader of JSPS assisted Grant-In-Aid of Basic Scientific Research (A) on "Land tenure and Agro-silvo-pastoral systems in West African small Inland valley watersheds" (1999-2001); Project leader of MOFA commissioned research on development assistance through FASID assisted research on "Comparative studies and evaluation on Asian collaborative "Sawah"-based Rice Development Projects in West Africa" (1998); Project leader on JICA/CSIR-CRI joint study project on "Integrated watershed management of Inland Valleys in Ghana and West Africa: Eco-technology Approach" (1997-2001); Project leader of MEXT assisted Grant-In-Aid of Scientific overseas research on "Indigenous farming adaptive "sawah" and agro-forestry systems' (1996-1997); Project coordinator of MEXT assisted Grant-In-Aid of Scientific overseas research on "Regeneration of Agro-Forest-Ecosystems in Sub-Saharan Africa" (1993-1995); Project leader of MEXT assisted Grant-In-Aid of Scientific research on "Rates of Rock Weathering and Soil Formation" (1992-1994); JICA expert at International Institute of Tropical Agriculture (IITA) on "West and Central Africa wide lowland rice soils and rice farming system survey" and "On farm research on the 'Sawah' system to intensify sustainable rice production at Bida, Nigeria" (1986-1989).

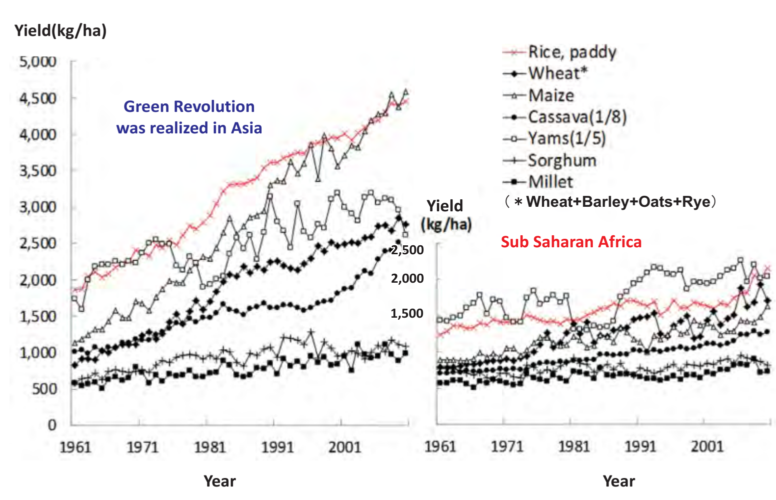
Mohammed Moro BURI is currently a Principal Research Scientist and Co-ordinator of the Ghana "Sawah" Project. He works for the Soil Research Institute (SRI) of the Council for Scientific and Industrial Research (CSIR), Ghana. He obtained his B. Sc. (Agriculture) degree from the Kwame Nkrumah University of Science and Technology, Ghana and M.Sc. (Natural Resource Science) from the Shimane University in Japan. He obtained a Ph. D. in Bioenvironmental Science from the Tottori University also in Japan in 1999. Dr. Buri has conducted extensive research with a variety of interdisciplinary teams on soil resource management, water management, environmental related problems and crop (rice, maize, cassava, yam, potato, and cowpea) production across the different agro-ecological zones in the Ghana and beyond. His research areas of interest include resource management (soil/water), soil fertility, plant nutrition and general agronomy. He has worked and continues to work with several International Organizations (AfricaRice, IITA, IWMI, JIRCAS, and JICA); Universities in Japan (Kinki Univ., Shimane Univ. Tsukuba Univ. United Nations Univ.); the Ministry of Food and Agriculture, Ghana and sister Institutes of the Council for Scientific and Industrial Research (CSIR) also in Ghana. Dr. Buri has been a major contributor to developing and demonstrating the "sawah" eco-technology on rice production in Ghana. He has made a significant contribution to training young scientists from Nigeria on sustainable management of inland valleys under the UNU-ISP (Tokyo) Training Program. He was the leader of the team that published the first book on the "Sawah" system of rice production and a backbone of the team that organized the first international workshop on Sawah Eco-technology and Rice Farming in Sub-Saharan Africa. With several years of experience on "sawah" system development and training of field technical staff and farmers, Dr Buri has assisted in "sawah" technology transfer to Togo and Benin. He provided consultancy services towards the effective, efficient and practical execution of the "Sawah", Market Access, and Rice Technologies for Inland Valleys (SMART-IV) Project in Togo and Benin which is being executed by Africa Rice. Nationally, he is a member of the team working in collaboration with Ministry of Food and Agriculture, on scaling out of the "Sawah" system for rice production across Ghana.

Ademiluyi Yinka SEGUN, a royal from the family of Ademakinwa Ademiluyi, had his basic education at Ibadan and Ikirun. He earned a Bachelor degree in Agricultural Engineering from the University of Ilorin and M. Sc. in the same field from the University of Ibadan, both in Nigeria. He obtained a Ph.D. in Agriculture from Kinki University, Japan. His tireless efforts and studies on the use of medium and intermediate technologies for field operations drew the attention of the Federal Government of Nigeria through the Ministry of Agriculture (where he is serving currently) to nominate him as a consultant on the use of Draught Animal Power (DAP) for Agricultural Production in Nigeria. He was trained at Beijing, Chinese Academy of Agricultural Mechanization Sciences (CAAMS) on the operation and maintenance of Agricultural Machinery in China where he developed an unparalleled interest in Single Axle Tractor (Power Tiller). He brought his experience to bear on "Sawah" Eco-technology for Rice Farming (SERIF) project where he played leading role as the Nigeria National Coordinator. Since becoming a National Coordinator, he has worked to scale up the "Sawah" eco-technology to six geo-political zones of Nigeria. Working in collaboration with World Bank Fadama III Project and Commercial Agricultural Development Program (CADP), over 2000 farmers have adopted "Sawah" eco-technology for rice production.

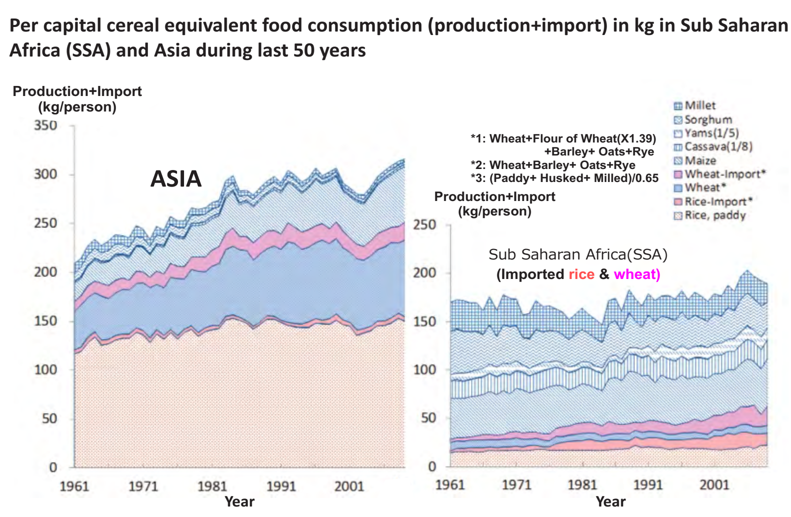
CHAPTER 1

INTRODUCTION

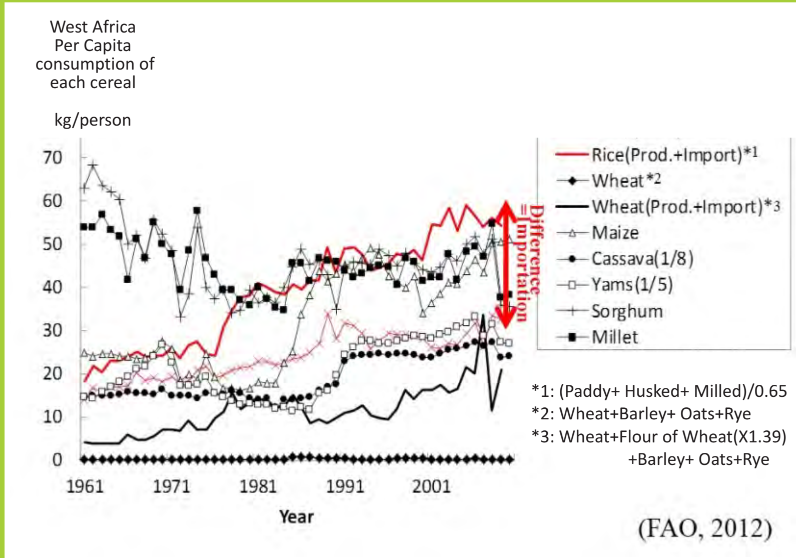
An understanding of the current global trend of activities that affect the rice industry is key to identifying major constraints based on site and the laying of solid foundations towards solving or mitigating the effects of such constraints, in order for any effective change and impact to be made.



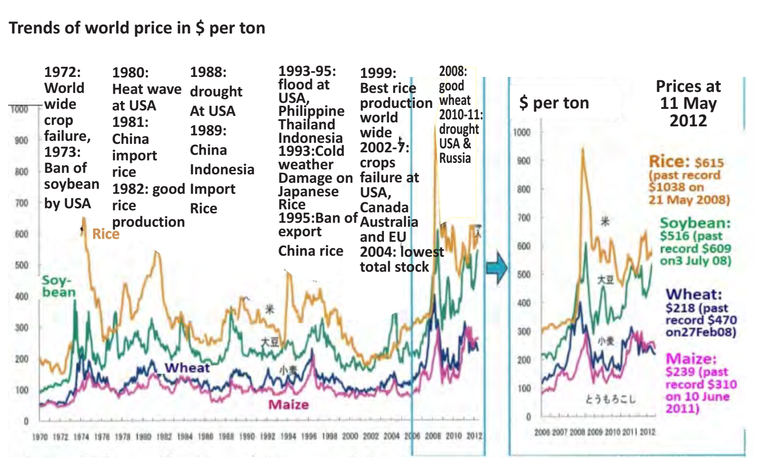
Comparative yield trends of five major cereals, Yam and Cassava between Asia and Sub Saharan Africa (SSA) during 1961-2010 show **No green revolution in SSA (FAO 2012).** Data of Yam and Cassava were divided by 5 and 8 respectively to calculate cereals equivalent.



Both SSA and Asia produced about 200kg of per capita cereal food equivalent in 1960s. However, 50 years later, that of Asia increased to above 300kg, while SSA remained stagnant at less than 200 kg. Both cassava(108%) & yam(167%) increased. While both millet (73%) & sorghum(70%) decreased, maize (120%) & rice(140%) increased. Rice consumption sharply increased(186%). Hence, its importation of 383% was similar to wheat (428%). SSA , however, has a high potential of rice production



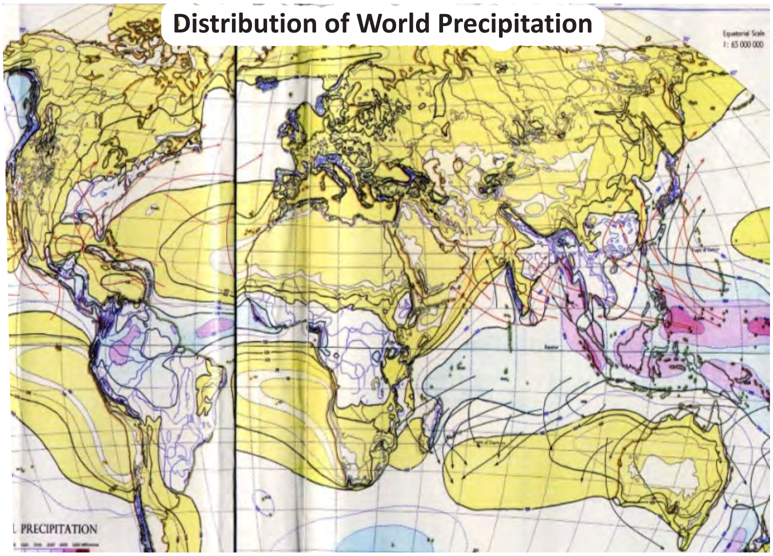
Per Capital consumption of Paddy in West Africa increased abruptly from 21 to 56 kg and importation uptl from 5 kg to 24k during 1961-2010. Recent steep rise of paddy price induced social unrest. However West Africa has a huge potential of paddy production and even exportation to Asia in near future



Note: Prices of wheat, Maize, and Soybean are prices at both the first and the last Friday of each month. Rice price is at both the first and the last Wednesday of each month.

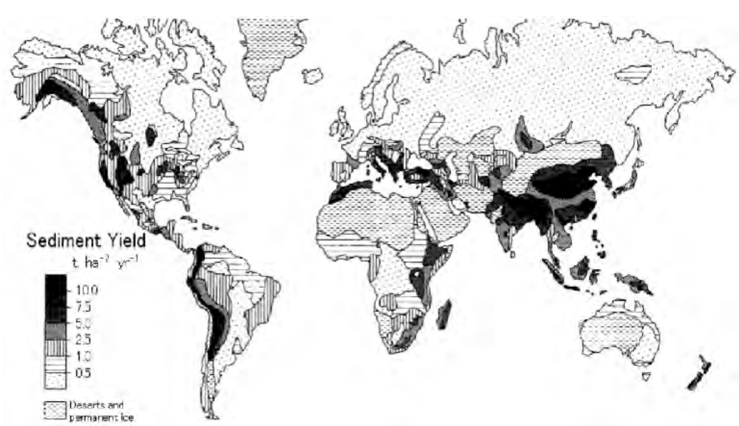
Trends of world trading prices of rice at Thai (milled 2nd class FOB) and of soybean, wheat and maize at Chicago commodity exchange during 1961-2012. *(Source - Ministry of Agriculture, Forestry and Fishery, Japan).* Note : Prices of wheat, maize, and soybean are prices at both the first and the last Friday of each month. Rice price is at both the first and the last Wednesday of each month

Distribution of World Precipitation



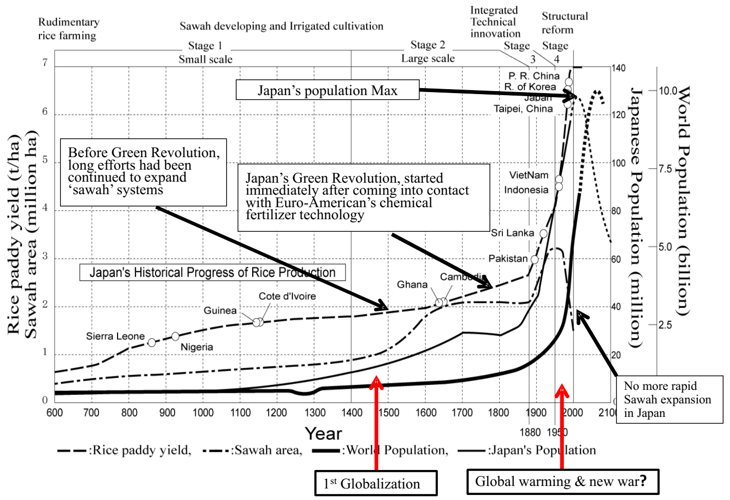
Water (quality and quantity) is very essential for effective and sustainable crop production. Water scarcity therefore calls for adoption of effective and efficient utilization methods

Rate of soils erosion in the world (Walling1983)



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

Population, rice yields & "sawah" area of historical path in Japan in comparison with Asia & Africa (Takase & Kano,1969, modified)

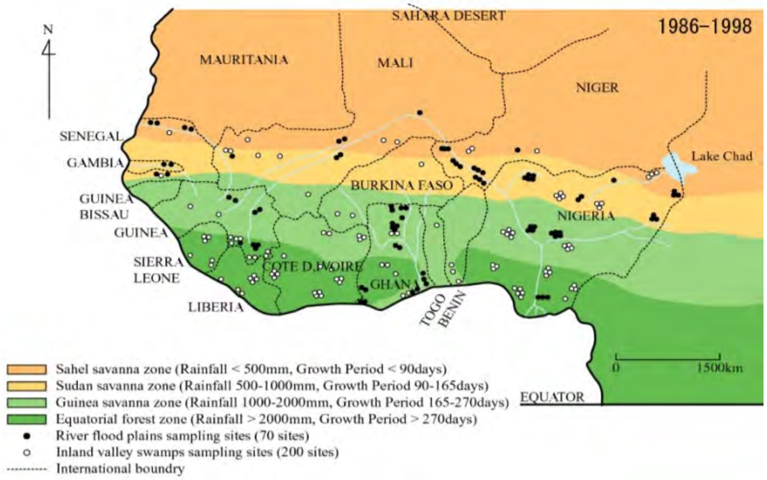


Japanese Experiences has shown that farmers' "sawah" fields are the most important infrastructure to be developed under the green revolution. Hence the development of farmers' fields is the first key step under the green revolution.

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%)

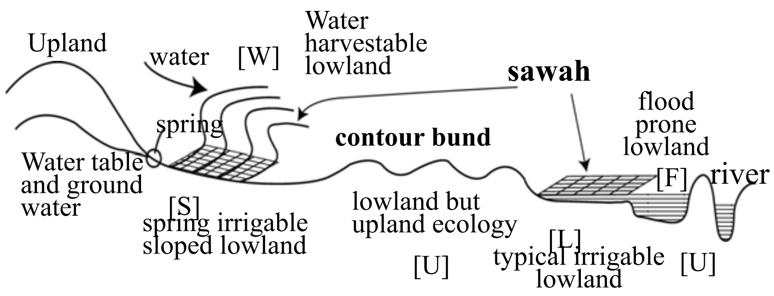
In SSA, estimated total maximum "sawah" area is 20 million hectors. Even though priority is given to inland valleys because of easier water control, some flood plains can also be given the same high priority. Examples are Sokoto & Kebbi where personal pump irrigated "sawah" is efficient



West Africa map showing selected sampling sites of lowland soils where detailed studies on the characteristics of both Inland valleys and flood plains across the sub-region have been studied (*Buri, Issaka and Wakatsuki et al)*

Source – Buri et al, 2010

Lowlands (mainly inland valleys and flood plains) in Sub Saharan Africa are composed of heterogeneous soils that require different soil and water management options. The development of site specific management options will ensure their sustainable use.



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

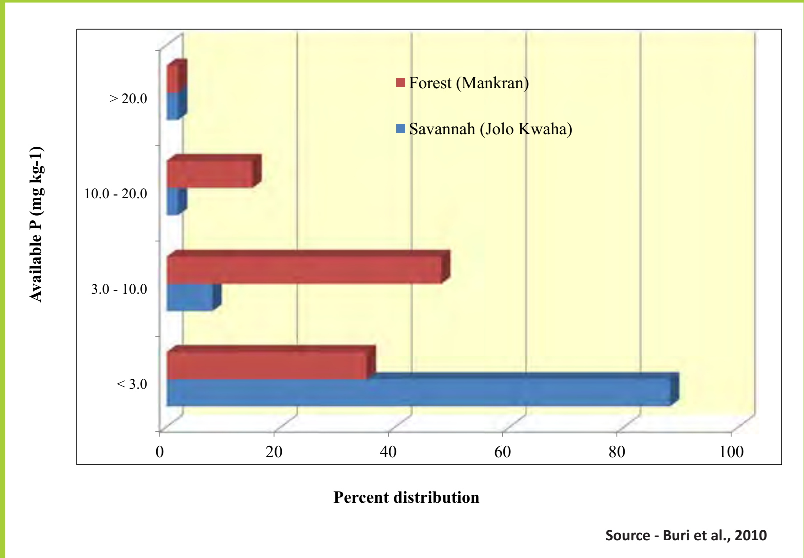
Irrigation options: Sawah to sawah/contour bund water harvesting, spring, dyke, river, pump, peripheral canal, interceptor canal, tank

As a result of variability in ecology, vegetation and rainfall, SSA has very diverse nature of lowlands that require Large Scale Action Research and On-the-Job training on Site Specific "Sawah" Development and "Sawah" Based Rice Farming

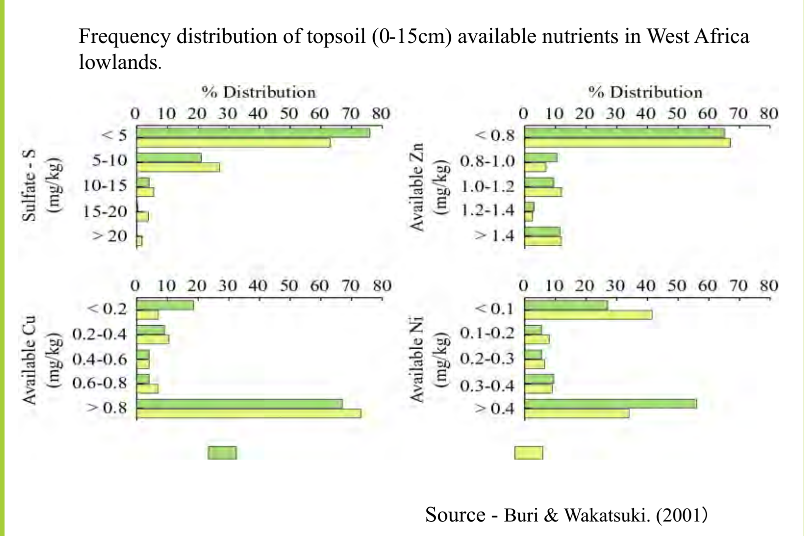
Mean values of fertility properties of inland valleys (IVS) and flood plains (FLP) of West Africa in comparison with lowland top-soils of tropical Asia and Japan

Location	Total C (%)	Total N (%)	Available P (mgkg^{-1})	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
Japan	3.3	0.29	57	9.3	0.4	2.8	12.9	49	21	61

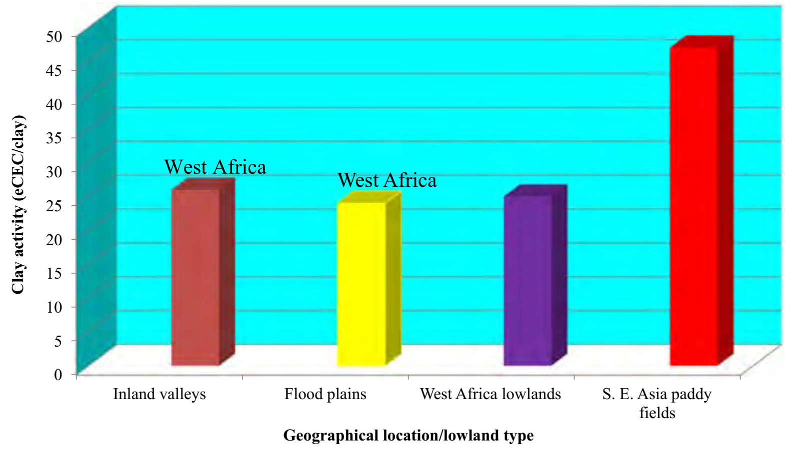
Studies have shown that soils of lowlands of SSA (particularly West Africa) are low in plant nutrients required for obtaining optimum crop yields. Lowland soils of the sub-region when compared to other similar areas are relative deficient in soil nutrients.



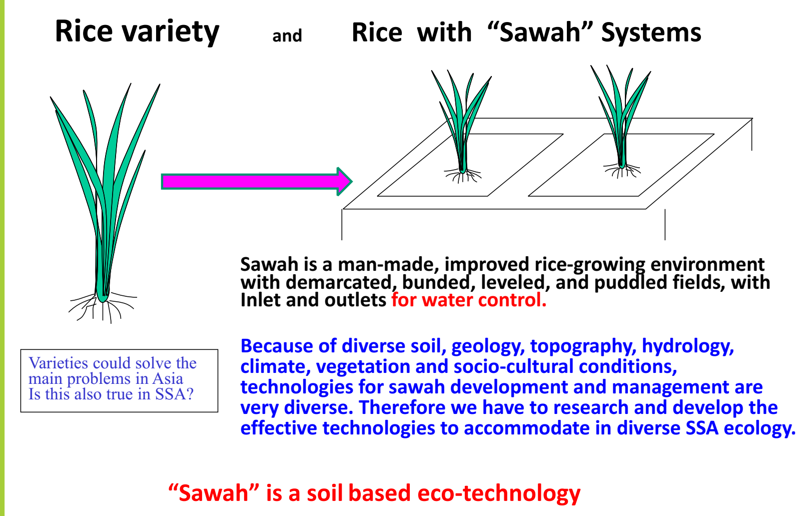
Available P distribution in Ghanaian Soils. Soil phosphorus is a major limiting nutrient to crop production in SSA not only within the lowlands but also in the uplands as well.



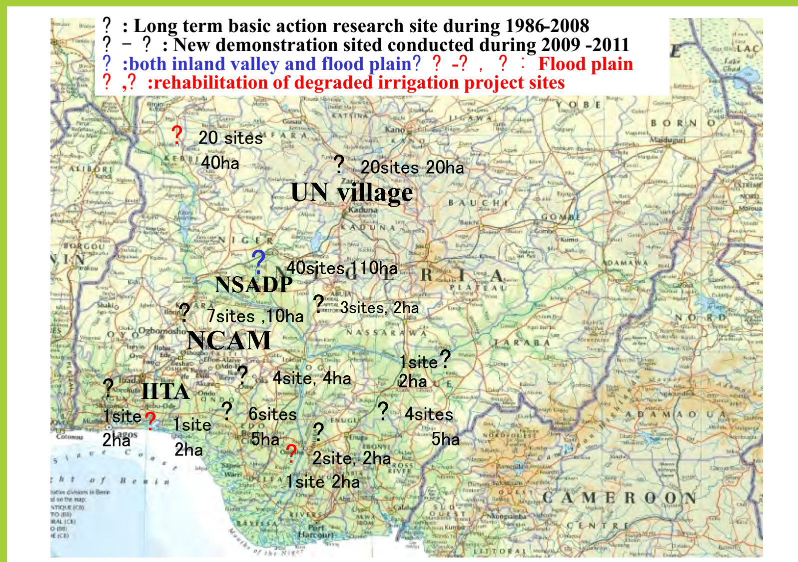
Lowland soils of the sub-region are very deficient in most secondary and micronutrients notably Sulfur and Zinc which are very critical for rice nutrition and hence grain yield.



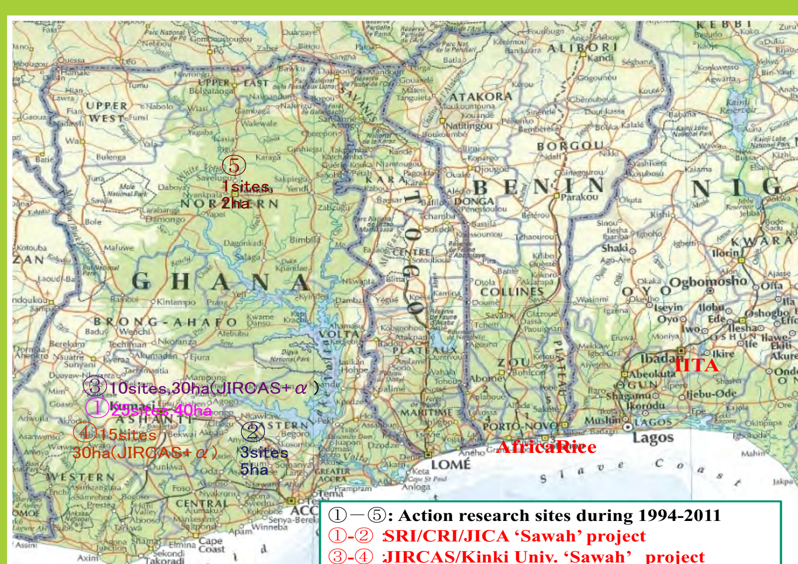
Clay activity is a good indication of how active soils are in terms of nutrient supply. Lowland soils of SSA are low in clay activity due to high weathering and the dominance of low activity clay minerals



Under the prevailing condition as spelt out earlier, there is the urgent need therefore to provide an improved environment (eco-technology) if the full potential of improved rice varieties (biotechnology) are to be realized. Higher yielding rice varieties require an improved growing environment ("Sawah" systems) to give off their high yield potentials. In effect, there must be a balance in bio-technology and eco-technology for effective and sustained rice production



Map of Nigeria showing areas where action research and on-the-job training has been conducted on "Sawah" System Development. So far action research and demonstration have been conducted at 100 sites covering 200ha in Nigeria including both inland valley and flood plains



Map of Ghana showing areas where action research and on-the-job training has been conducted on "Sawah" System Development. Many farmers have been given on-the-job training on "sawah" system development in the country. Currently "sawah" rice yields of 6-8 t ha-1 are very common. In addition, demonstrations and on-the-job training have been successfully conducted for technical staff of the SMART IV Project of AfricaRice

CHAPTER 2

VARIOUS TRADITIONAL RICE FARMING SYSTEMS IN SUB-SAHARAN AFRICA

Various traditional farming systems that exist across Sub Saharan Africa are outlined. These systems need to be studied and improved upon through the introduction of modern and easy to adopt technologies such as "Sawah", for effective soil, nutrient and water management.

Traditional forms of land preparation for rice cultivation differ from location to location, among different people. Skilled land preparation for rice, Bida in Nigeria

Burying surface organic matter to accelerate decomposition under traditional systems, however, water management is poor

In some areas due to thick vegetation, land is brushed and completely burnt destroying total organic matter

Total burning of fields prevents organic matter accumulation which support rice growth. Where burning is unavoidable, partially burning is recommended

Seeding directly on fields without proper land preparation results in poor growth growth and hence yields.

Some methods of land preparation do not favour rice cultivation, particularly under very severe water limitations. UN Millennium village of Pampaida, Zaria, Sudan Savanna zone. Rice soil become hardened during prolonged dry season

Such traditional form of land preparation have no water control measures in place and surface flowing water is mostly under utilized.

Crop establishment and the use of inputs such as fertilizers would not be effective and efficient where soil and water management methods are non-existence.

Weeds finally take up such rice fields particularly under upland conditions. Example at Mokwa in Nigeria:

Rice fields that have no water control measures are proned to severe soil erosion. Example of an upland field at Mokwa in Nigeria.

The three Green Revolution Technologies can't apply under such lowland paddy fields

Land preparation is also influenced by cropping systems practices Mounts are constructed for upland crops after which rice comes as second crop

In certain parts of northern Ghana, rice and sorghum are sometimes cropped together especially around Bawku area in the Upper East region

In some parts of central Nigeria, particularly around Bida, Upland NERICA is intercropped with Sorghum

In some parts of Nigeria, root and tuber crops (cassava, yam) are grown with rice especially at Bende.

Irrigated Lowland Paddy Field (Rudimentary Sawah). No Integration of Fulbe Grazing with Nupe Rice Farming. Animal traction and/or small machinery is necessary for Sawah cultivation

The highest diversity traditional system of cultivation in Bende, Nigeria, where rice and many others crops are simultaneously grown together

In the savanna agro-ecological zones of Ghana, (e.g. Bawku), rice and vegetable growing valleys are walled to serve as protection against animal (cow, sheep, goats, etc) destruction.

Water availability and management are very essential for effective rice production.
Under traditional system, water management is a critical and key factor that requires attention

Farmers need to be trained to harvest free flowing water for rice cultivation in the abundant valleys of Guinea (e.g. Kissidougou)

Ridge planting in a flood plain, Bida, Nigeria. Such field are easily overtaken by weeds resulting in very low yields.

Under traditional systems, mixed cropping where several varieties can be seen growing on a the same field are very common (e.g. Kaduna in Nigeria where glaberrima and sativa rice are mixed).

A variety of different traditional methods of rice cultivation exist across Sub-saharan Africa. An example of Oryza Glaberrima at Mopti in Mali

Under virgin lands and natural favourable conditions, traditional methods can be rewarding but such areas are now very rare to find.

After harvest, in order to maintain fertility and re-cycle nutrients, Farmers allow animals to graze on rice fields. Cattle are fed with rice straw and dung dropped during grazing enriches the soil nutrient content.

Irrigated rice but no Sawah technology, Bida, Nigeria

Poor tillering and aggressive weed easily take over non-sawah field

Such poor crop performance and low harvest from traditional fields, cannot ensure or gurantee food availability and/or reduce hunger

Farmers' Irrigation canal and rudimentary 'sawah' in Nigeria

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.

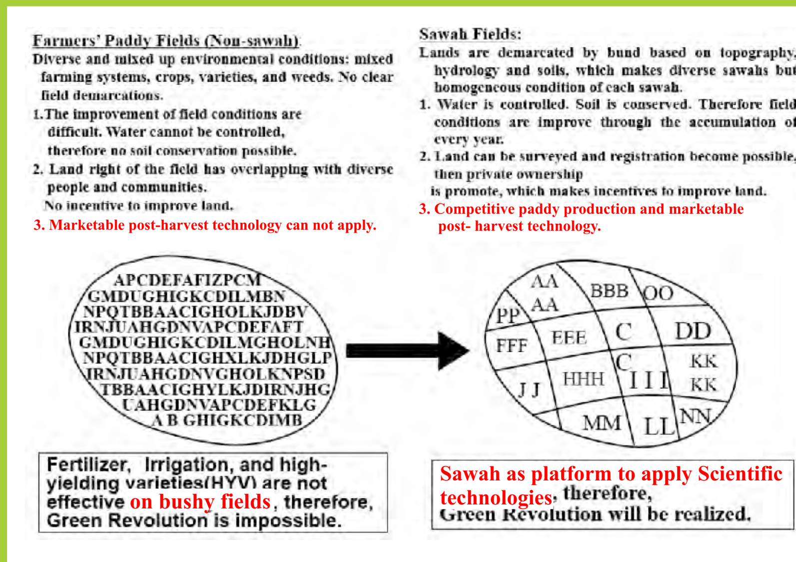
Those three technologies are applicable on experimental fields.
However, are they also applied in African farmers' fields?
Are there any missing factors that need to be identified and looked at ?

THE WAY FORWARD

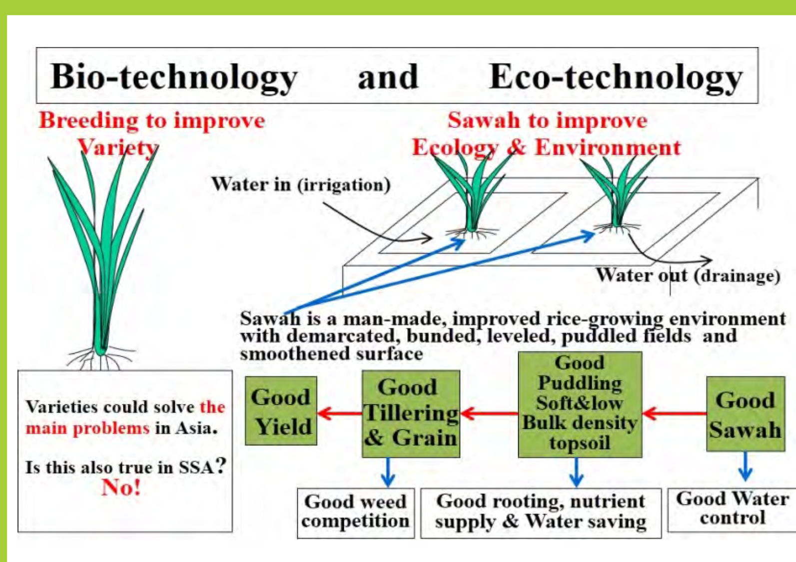
In order for the three core technologies , which are based on Biotechnology, to be successful, they must be made to operate in an improved environment (Eco-technology). In other words, there must be a balance between biotechnology and eco-technology.

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.

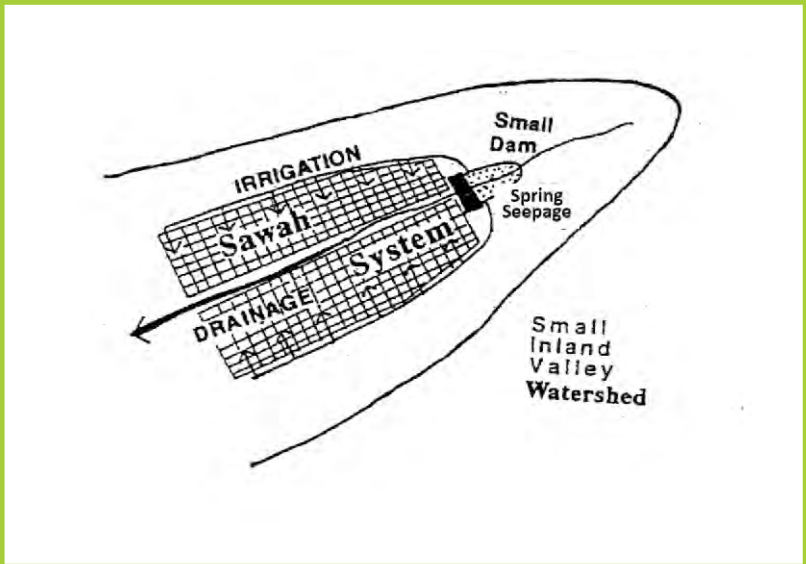
1. **High Yielding Varieties (HYV)**
2. **Soil, nutrients and pest management (Soil conservation, Fertilizers, Agrochemicals, and Integrated PM)**
3. **Water management (Irrigation and Drainage)**



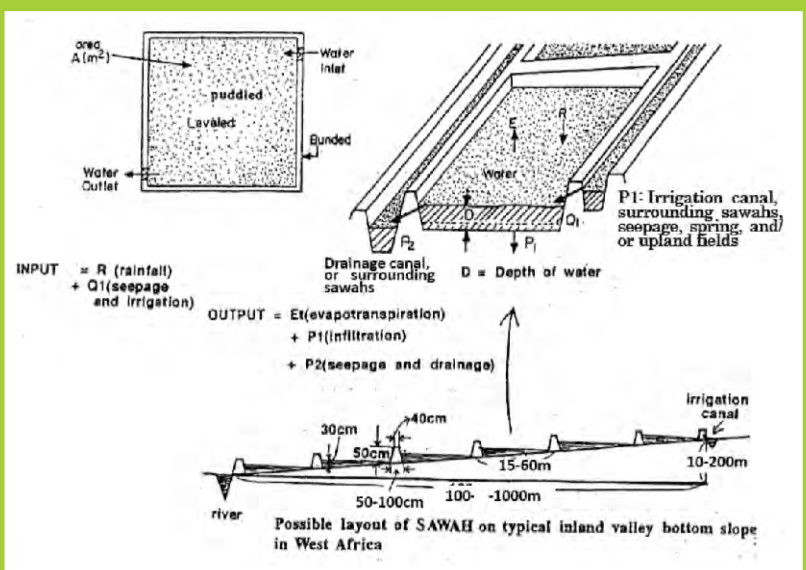
Sawah hypothesis (1): Farmers fields have to be classified and demarcated eco-technologically before any scientific technology can be effectively applied.



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

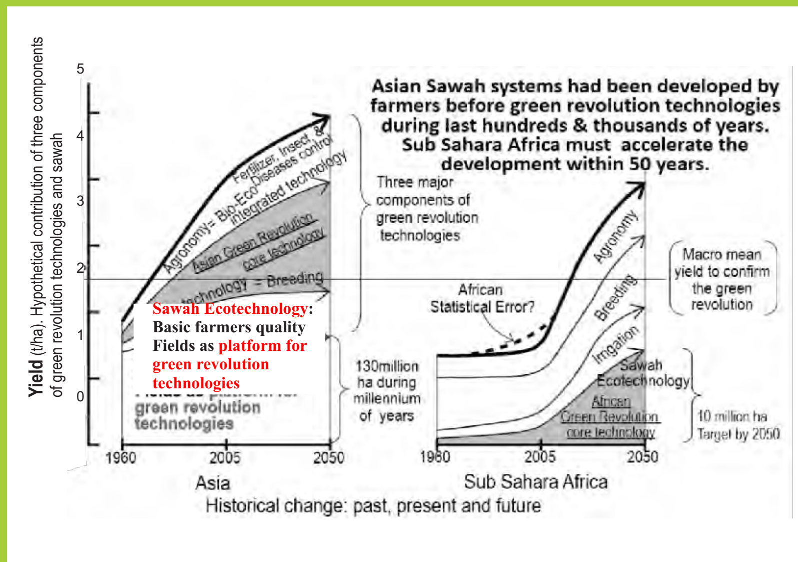
Effective combination and balance between Biotechnology and Eco-technology is key to achieving desired results

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



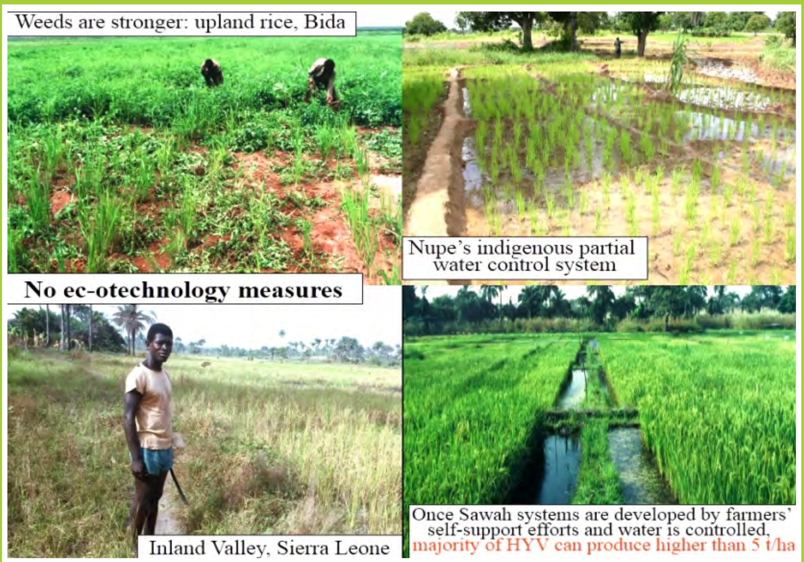
<u>Estimated yields under Sawah hypothesis(1) for Africa Green Revolution:</u> Hypothetical contribution of three green revolution technologies & sawah system development during 1960-2050. Bold lines during 1960-2005 are mean rice yield by FAOSTAT (2006). Bold lines during 2005-2050 are those estimated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

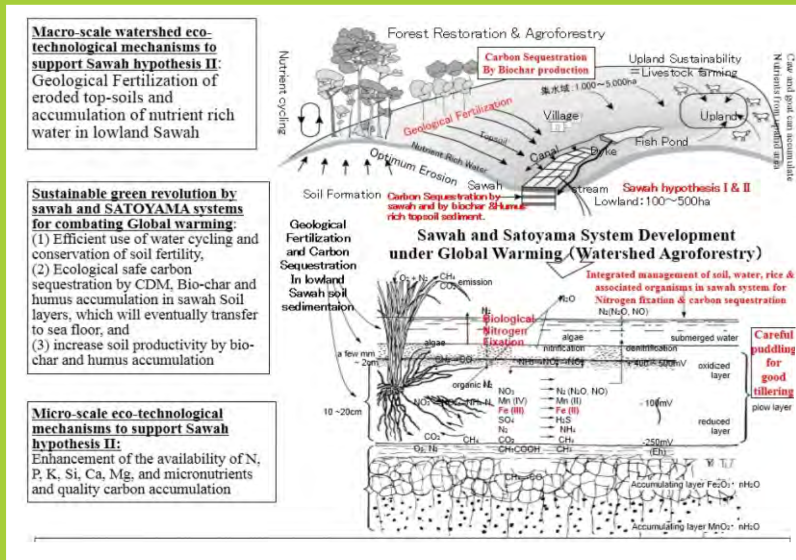
Field demonstration on "Sawah" and traditional (non-sawah) rice at Pampaida, UN millennium village in Zaria, Nigeria

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		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

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'

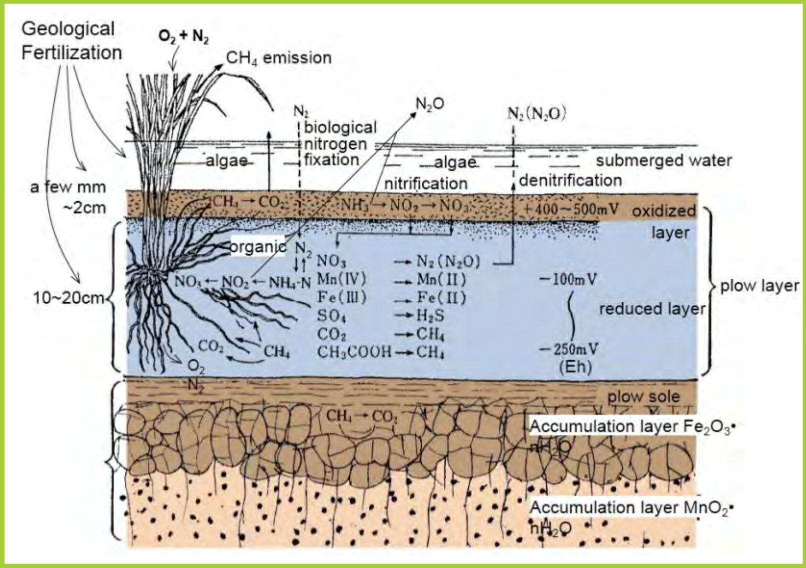
B. To combat Global warming and other environmental problems

(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

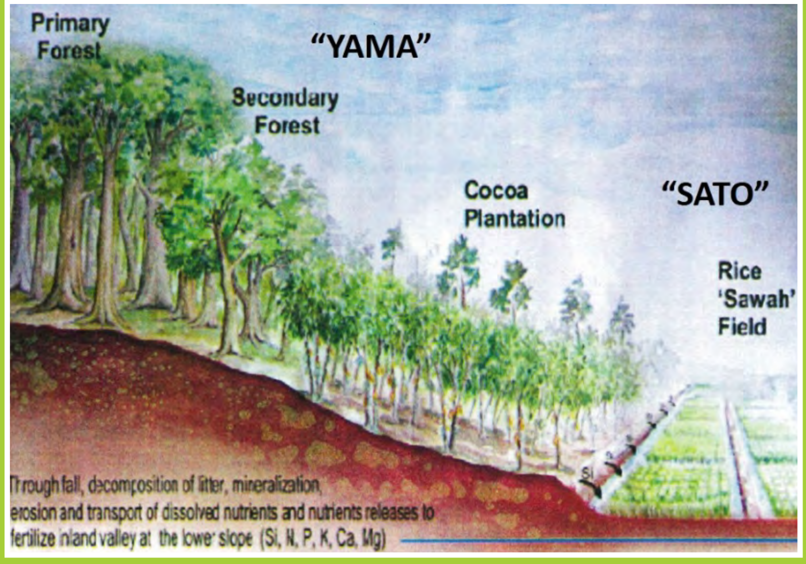
C. To create cultural landscape and social collaboration

(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

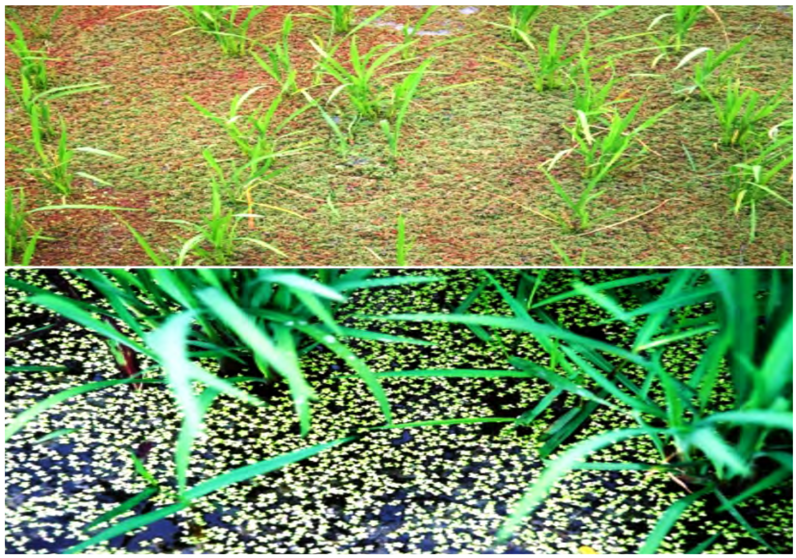


Africa SATO-YAMA Concept in Ghana which is a watershed agro-forestry applicable to Cocoa belt region in West Africa.

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)

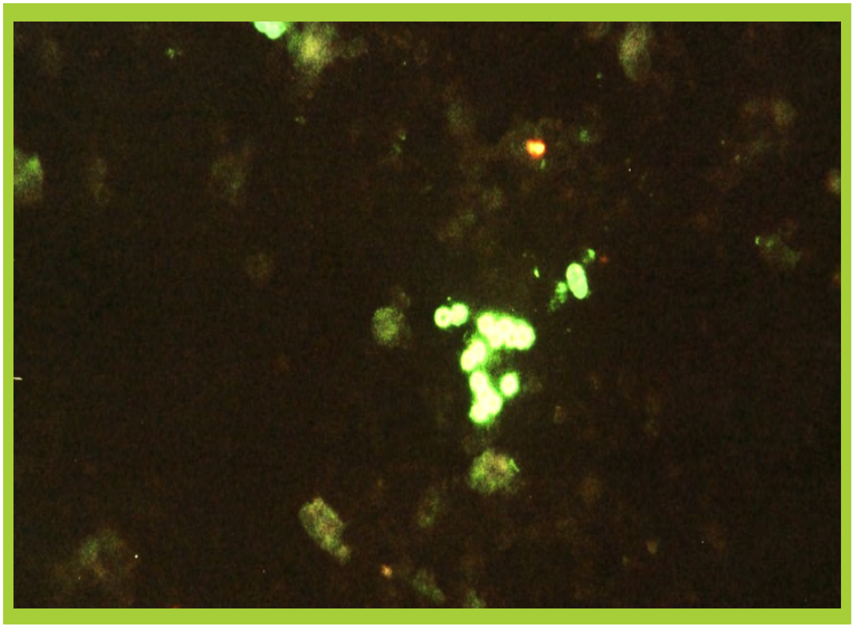
Cocoa fields/forest on upland or upper slopes can significantly contribute to sustain lowland rice production if carefully managed.

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

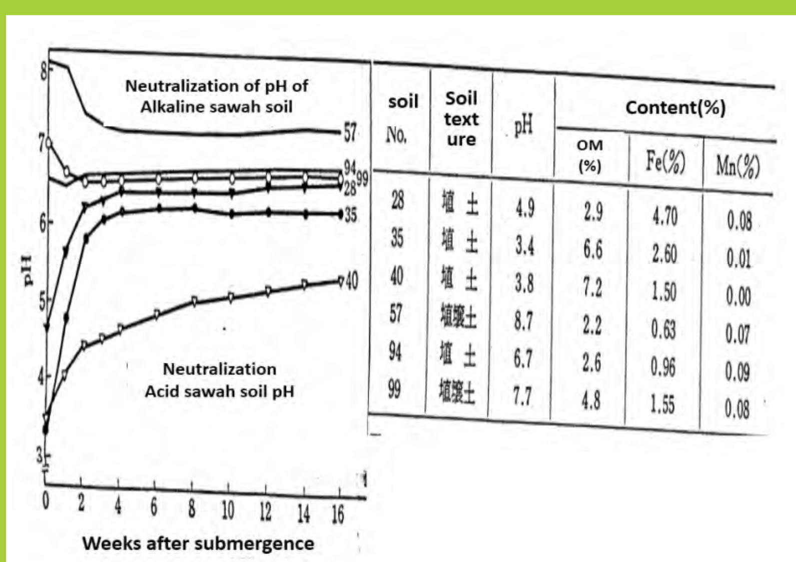


(a) Submerged sawah: Multi functional ecosystems of various interaction between Rice, Algae, Fish, Goose, microbes, and others:

(b) Nitrogen fixing Azola

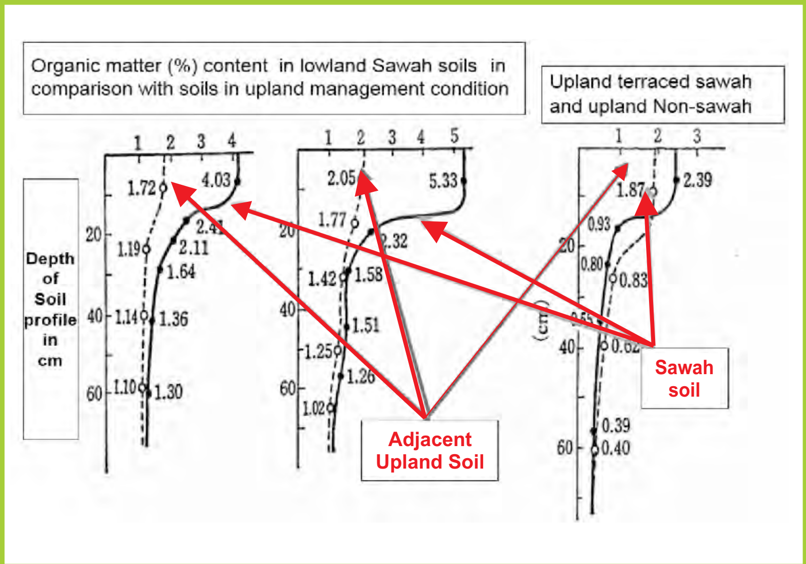


Azotobacter : Chemoautotrophic Nitrogen fixing bacteria in Sawah (Photograph : SSSA Slide collection)

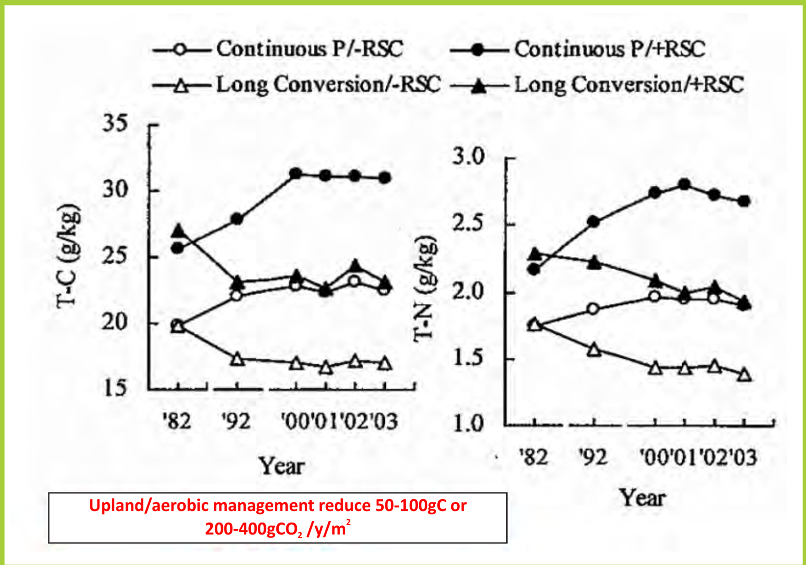


soil No.	Soil texture	pH	Content(%)		
			OM (%)	Fe(%)	Mn(%)
28	埴 土	4.9	2.9	4.70	0.08
35	埴 土	3.4	6.6	2.60	0.01
40	埴 土	3.8	7.2	1.50	0.00
57	埴壌土	8.7	2.2	0.63	0.07
94	埴 土	6.7	2.6	0.96	0.09
99	埴壌土	7.7	4.8	1.55	0.08

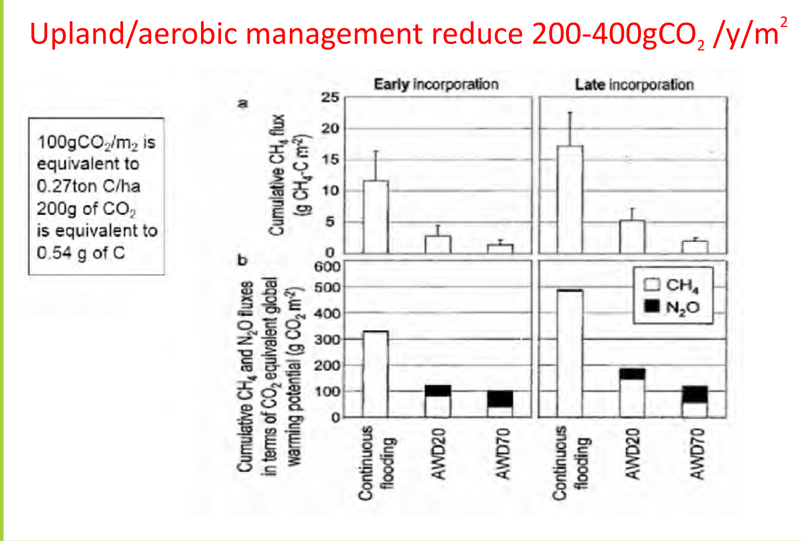
Sawah soil neutralization through submergence (Ponnamperuma 1976)



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)



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.

CHAPTER 4

SITE SELECTION AND “SAWAH” SYSTEM DESIGN

Site selection for Sawah system development is very vital and plays a key role in effective Sawah establishment for effective and sustained rice production. Careful consideration of site selection is thoughtfully advised

Site Selection Skills

>>>

Identifying suitable lowlands (valleys, flood plains etc.) for sawah system development is a key step. Several factors may be considered during site selected but these would vary depending on prevailing conditions and circumstances.

Most common factors to consider but not limited to include the following:

a. Water sources & quality: (>10 L/s, > 5 months/year) Stream/River, Spring, Seepage, Flood, Rain-fed

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

c. Socio-economics: Strong will, market access, road access in case of demonstration, land tenure, secured rent

NB:

(i) Collaboration between farmers, scientists, engineers, and extension staff is very essential at demonstration stage

(ii) Farmers know best, local and site specific hydrological conditions of any area in which they operate. This is very critical and very important for site selection

SKILLS FOR SITE SELECTION CON'T

1. Ongoing and potential lowland rice areas are larger than 10ha within walking distance of a core site. The core site can include various sub- sites with 0.5-10ha or more rice area.

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. Intensive hearing from rice farmers on the local hydrological conditions for past 10-15 years is important.

SKILLS FOR 'SAWAH' SYSTEM DESIGN

1. *Sawah* layout and total potential area, shape and size of 'sawah', water intake and distribution are critical factors. Common examples of water sources and distribution methods include:
   (i) Spring and from 'sawah' to 'sawah',
   (ii) spring and diversion canal,
   (iii) Stream/seepage, (iv) Simple dyke and diversion canal,
   (v) Fish pond, dam, lake, Weir and Canal and (vi) Pump irrigation
2. Interceptor canal, Contour bund system
3. Flood control by drainage or dam
4. Drought control by pond/water-harvest
5. Soil movement and quality of leveling
6. Bund layout and quality

NB:
Successful examples of Sawah system design suitable for the various ecologies include:
(1) Type of oasis in floodplain (Sudan savanna zone)
(2) Pump irrigation system (all climatic zone)
(3) Irrigation with dyke on small river (Guinea savanna zone, forest/transition zone, forest zone)

SURVEY AND MAPPING

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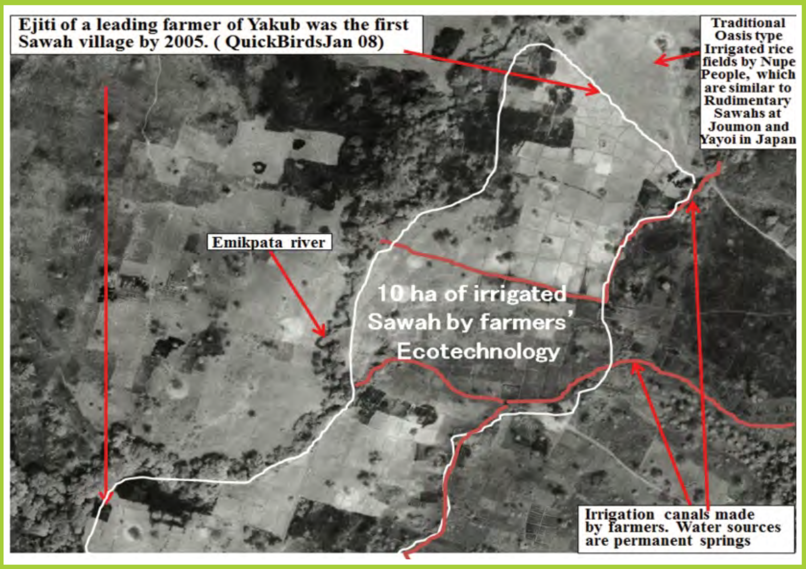
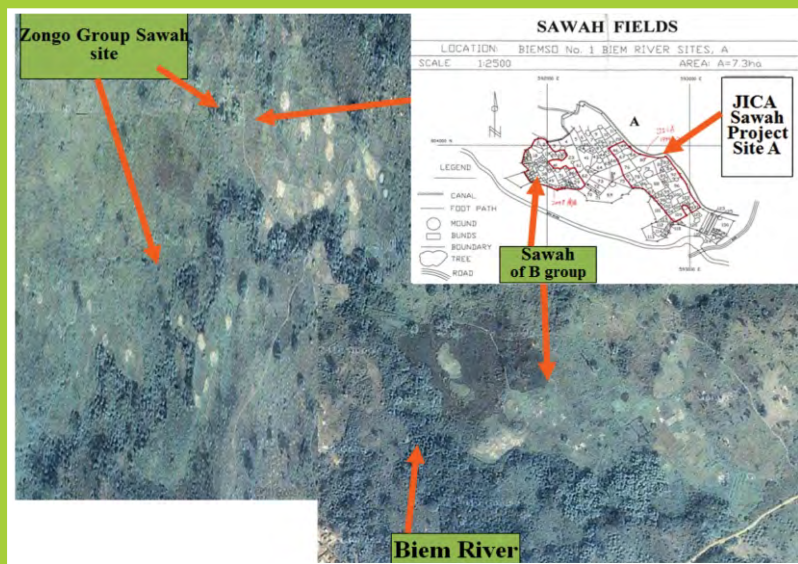
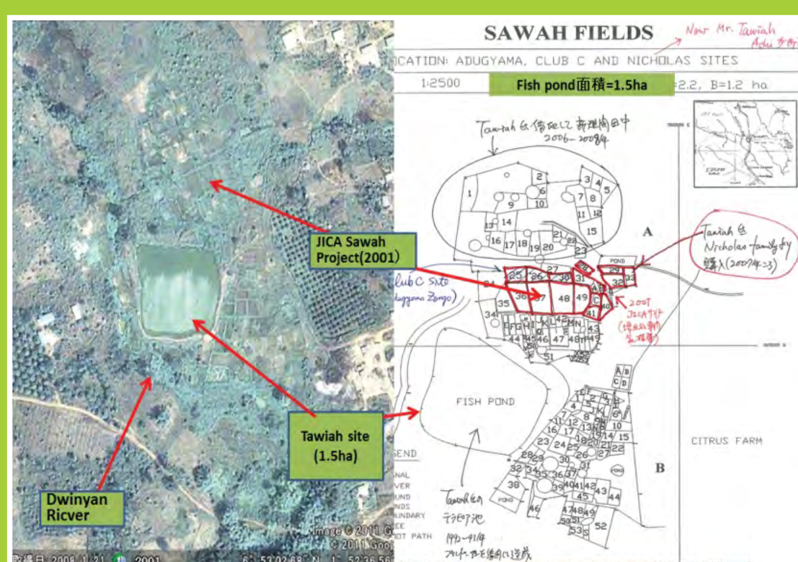
Existing satellite maps or surveys if available can helps to early identify or locate watershed water and water sources



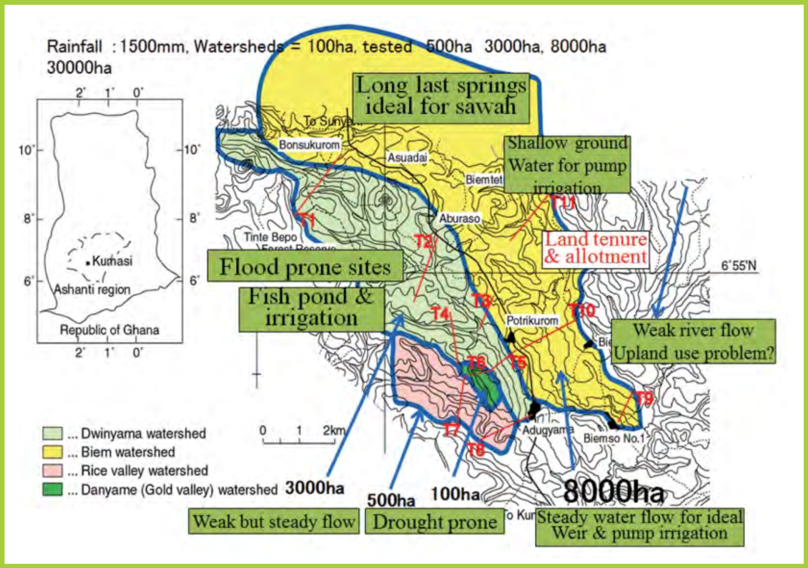
Quick Bird Image of the Ejiti Sawah Village, Bida, Nigeria. Permanent spring water sources identified along the Emikpata river



A satellite map of the Mankran watershed in Ashanti. Ghana showing suitable sites along the Biem river that have been developed into Sawah systems



A sitelite map of the Mankran watershed in Ashanti. Ghana showing suitable sites along the Dwinyam river that have been developed into Sawah system.



Mankran watershed showing different valley types/forms. Farmer based Site Specific Sawah Development and Management through On-The-Job Training are key (Sawah project phase I) in Ghana

Expanded photo of numerous small Oasis type pump irrigated fields in Nigeria.

Sokoto-Birnin Kebbi flood plain in Nigeria, Google 2007

It may be good (but not a necessity) to have a topo-survey of a site

It may be necessary to physically walk through the area to acertain prevailing conditions on the ground

Where a proper survey has to be done, transect lines will be cut and citing poles used

Simple survey tools may be used to establish co-ordinates and proper geographical location of site

The type of system design for any particular valley is greatly influenced by ;

1. **The type of water source (spring, weir & canal, etc) and**

2. **The physical nature of the valley (wet, dry, wide, narrow, etc).**

Restoration measure to connect spring water and Sawah by irrigation canal and syphon pipes at Adugyama, Mr. Tawiah's site. August 2011. This site was destroyed by IVRDP through poor knowledge of Sawah system development.

Mr. Tawiah trained another farmer to develop 3ha of sawah using small spring water source at Adugyama in Ghana. Only local farmers know much about such water sources.

A strong spring source can irrigate large areas of land in a season as in Dwinyama, Ghana

Water source could be a small stream with several springs along both banks. Such combination can provide enough water for sawah rice cultivation in Ghana.

Rice growing in a narrow but long valley that relies on a small stream supported by several spring sources

Natural ponds that have a high recharging capacity can be useful sources of water

Al contained in spring water can, however, result in poor rice growth as experienced in Bida, Nigeria.

Photo. 3-25. Compaction to create impermeable layer on the front of dyke, March 2000

Photo. 3-23. Excavation of river bottom and jute bags

Photo. 3-26. Dyke was covered with sand bags after compaction of permeable layer

Photo. 3-17. Flooding over dyke

A dyke can be constructed over stream and water harvested for sawah rice cultivation. (e.g. JICA/CSIR Sawah project in Ghana)

Sand bag and Wooden Weir, construction through farmers' self-support management in Ghana (1999)

Sand bag weir by farmers and SRI Sawah team, Aug.2009, Asuodei, Ghana

Canal construction by participating farmers indicates the commitments of farmers towards Sawah System Development.

Bigger water sources such as rivers can be partially intercepted and water harvested for use as in Nigeria.

Fadama III Sawah Demonstration site, 40km south from Gwagwalada along Abuja Lokoja road, (Upper - 25 Feb 2011, Lower - 2 May 2010).

Flood plain and pump

>>>

Flood plains are relatively flat areas where variable water harvesting methods needs to be adapted.

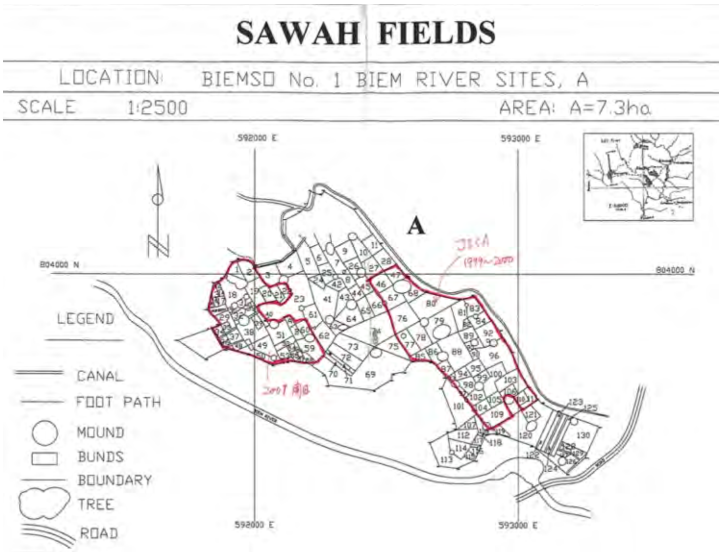
Small pond may be constructed by farmers, when necessary for water to irrigate (e. g. Kodadwen, Ghana)

Small dams constructed for water storage in the dry regions can be used to irrigate rice and source of water for animals

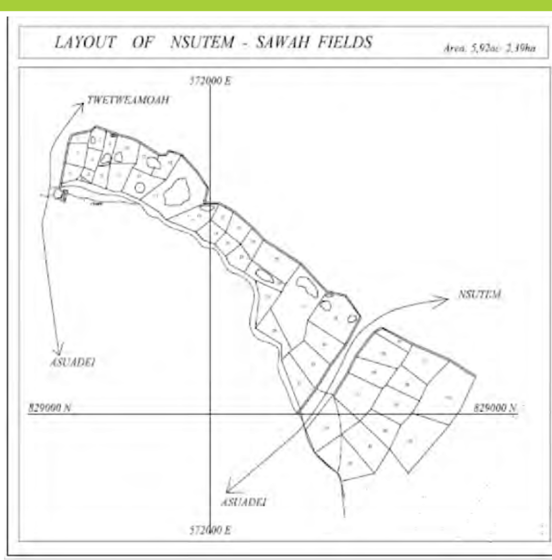
A pump lifting water from a pond onto a rice field at a site in Nigeria

Oasis type pump irrigated rice and vegetable fields under poor water use efficiency and weedy rice field before Sawah technology was introduced at Kebbi, Nigeria

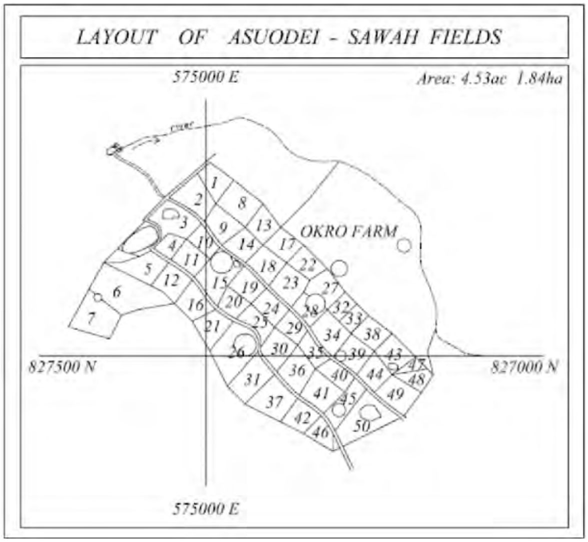
EXAMPLES OF SAWAH FIELD LAYOUTS AS INFLUENCED BY LOWLAND TYPE, WIDTH OF LOWLAND AND EXISTING PHYSICAL CONDITIONS



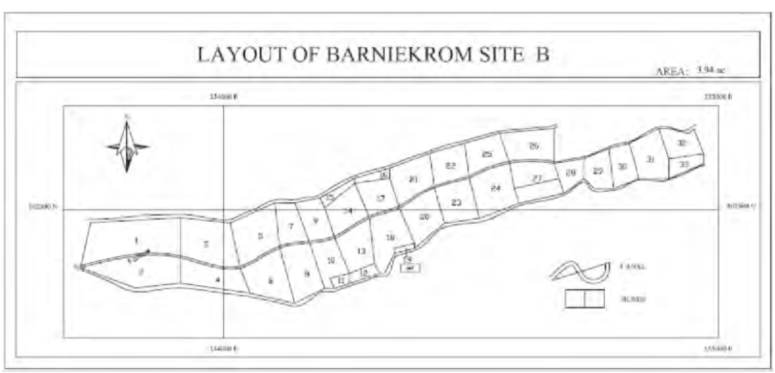
Layout of several fields along a meandering valley of the Biem river in Ghana



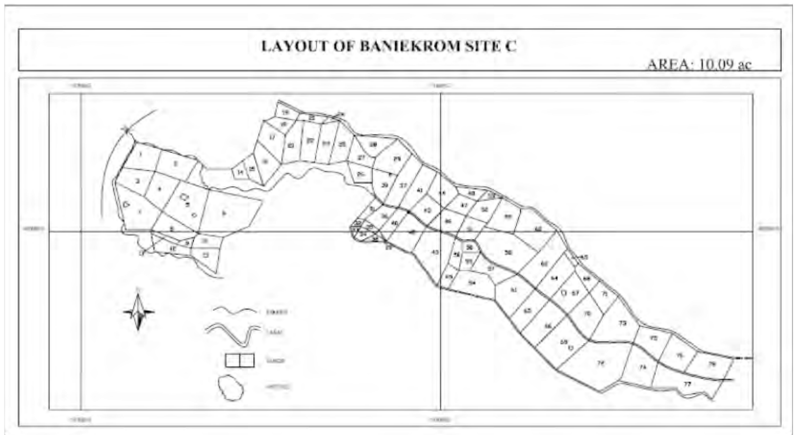
Field layout of a valley that harvest water from bridges on roads that cut across Several portions of the valley



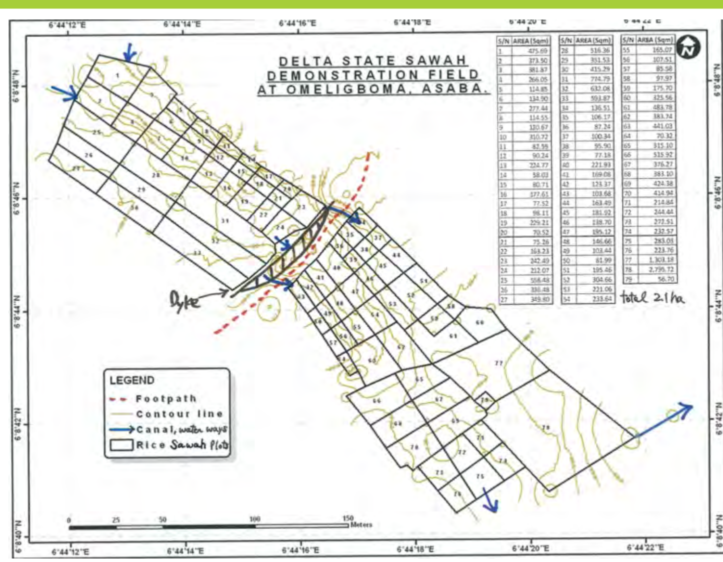
Field layout of a short but relatively wide valley that lies off the main water Source (river/stream) at Asuodei in Ghana



Upper portion of field layout of a long and narrow valley in Baniekrom In the Ashanti region of Ghana



Field layout for the lower portion of a long but narrow valley at Baniekrom in Ashanti region of Ghana



Sawah demonstration field (flood plain) at Asaba in the Delta State of Nigeria

Ebonyi state sawah demontration field (a wide flood plain) in Nigeria

Rehabilitation of degraded irrigation system

Sawah technology can renovate abandoned pump irrigation fields (eg. Lagos State in Nigeria)

Other but costly conventional irrigated development system involving expensive materials are not cost effective and difficult to manage by farmers

A large and abundant dam that is not beneficial to the farmer. Such development project are not sustainable and have no direct benefit to farmers.

Large irrigation sites where farmer water management and water use-efficiency are very poor