Sawah Technology (3PPt)Principles: Sawah Hypothesis (1) for scientific foundation of technology evolution and Sawah Hypothesis (2) for sustainability through multi-functionality of Sawah systems in watershed agroforestry (Africa SATOYAMA System)

Why variety, fertilizer and irrigation technologies can not work in farmers' rice field in Africa?

Non-Sawah upland paddy field Guinea, Aug.03

Degraded non-Sawah lowland Paddy field, Sierra Leone, Jan. 1989

Sawah Hypothesis 1 : Farmers rice fields have to be classified and demarcated based on topography, soil and hydrology. Scientific technologies can not be applied in bushy fields.

Sawah was developed using hundreds years by Chinese Farmers (Otsuka 2004)

Sawah development at savanna floodplain performed paddy yield 7t/ha at Kebbi state, Nigeria (May 2011)

Sawah

- Paddy
- Irrigation and Drainage
- Sawah Evolution
- Bio-Technology
- Eco-Technology
- Sawah System Evolution

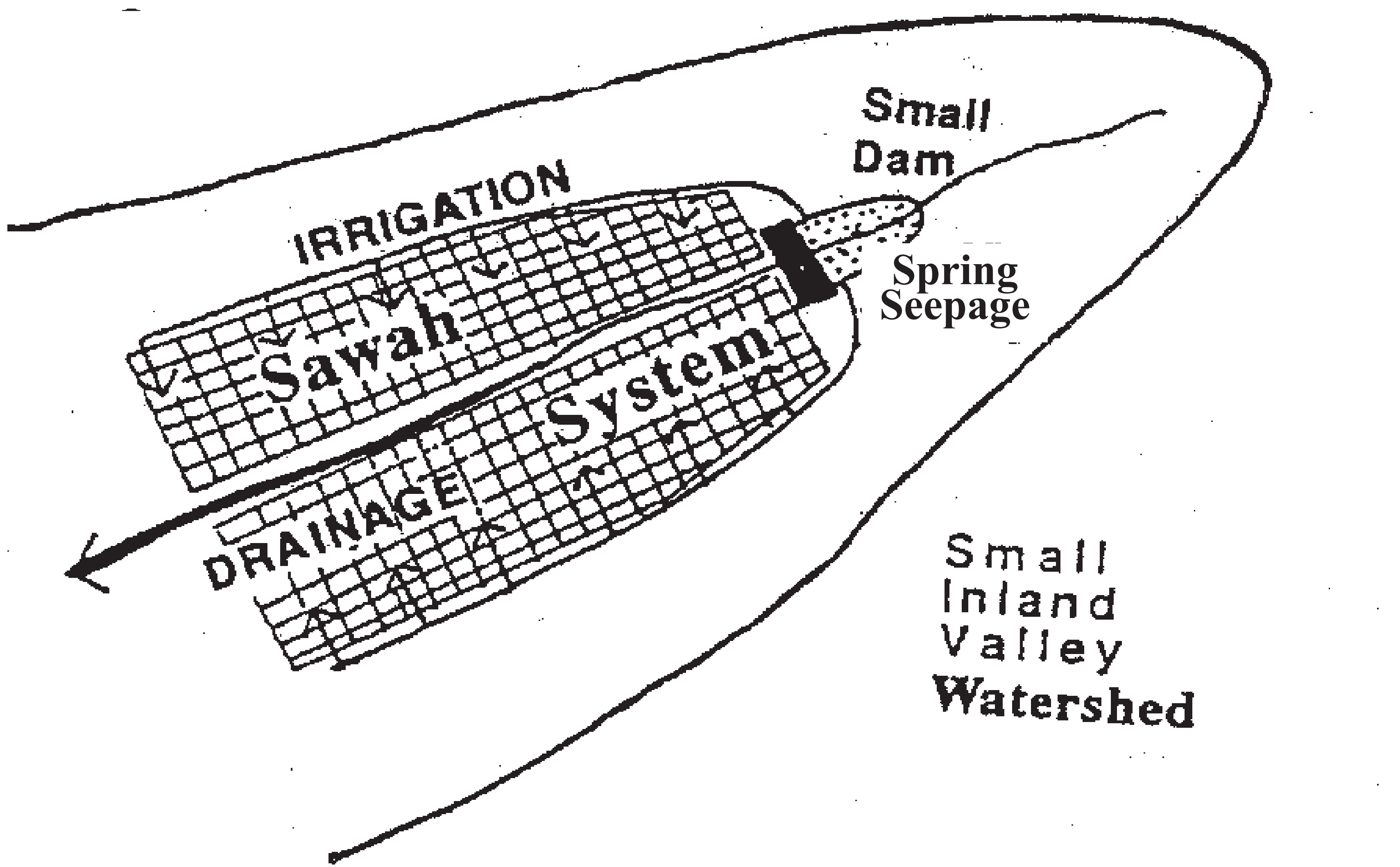
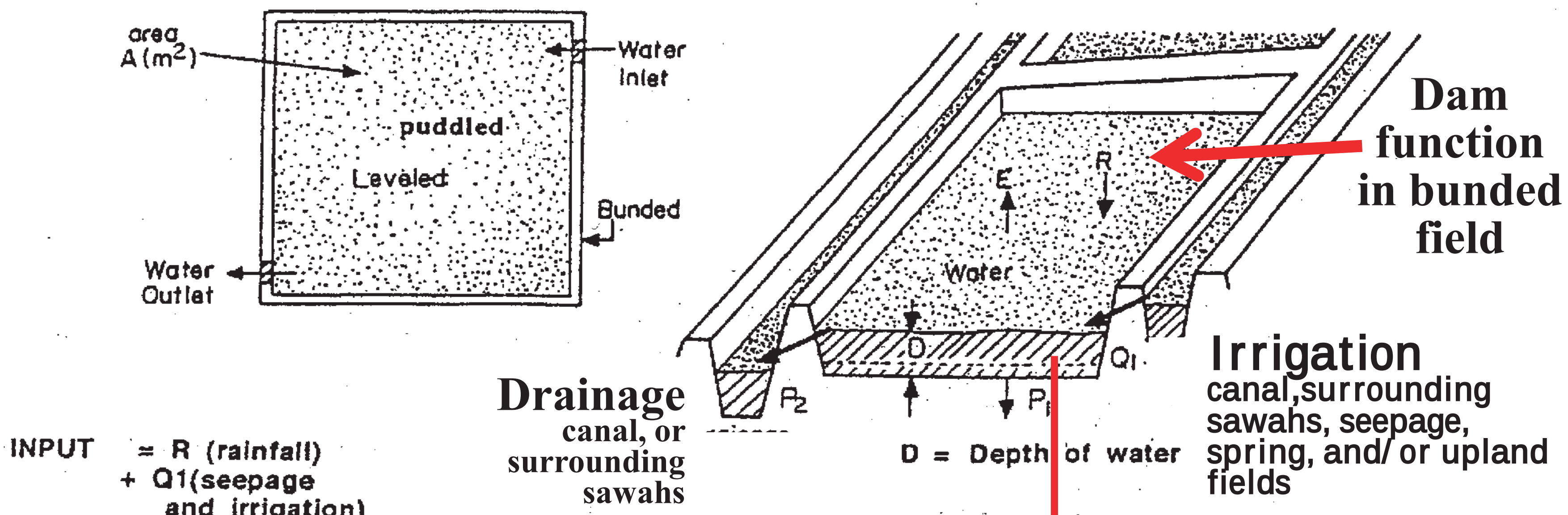
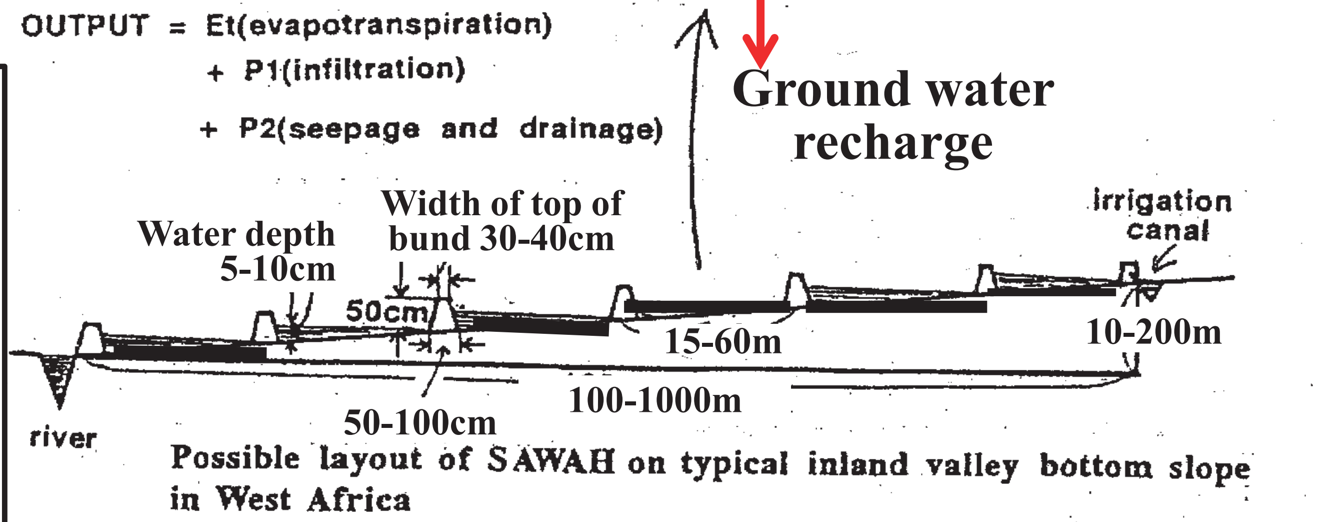


Figure 1. Sawah system with irrigation and drainage facilities for control of water in an inland valley watershed

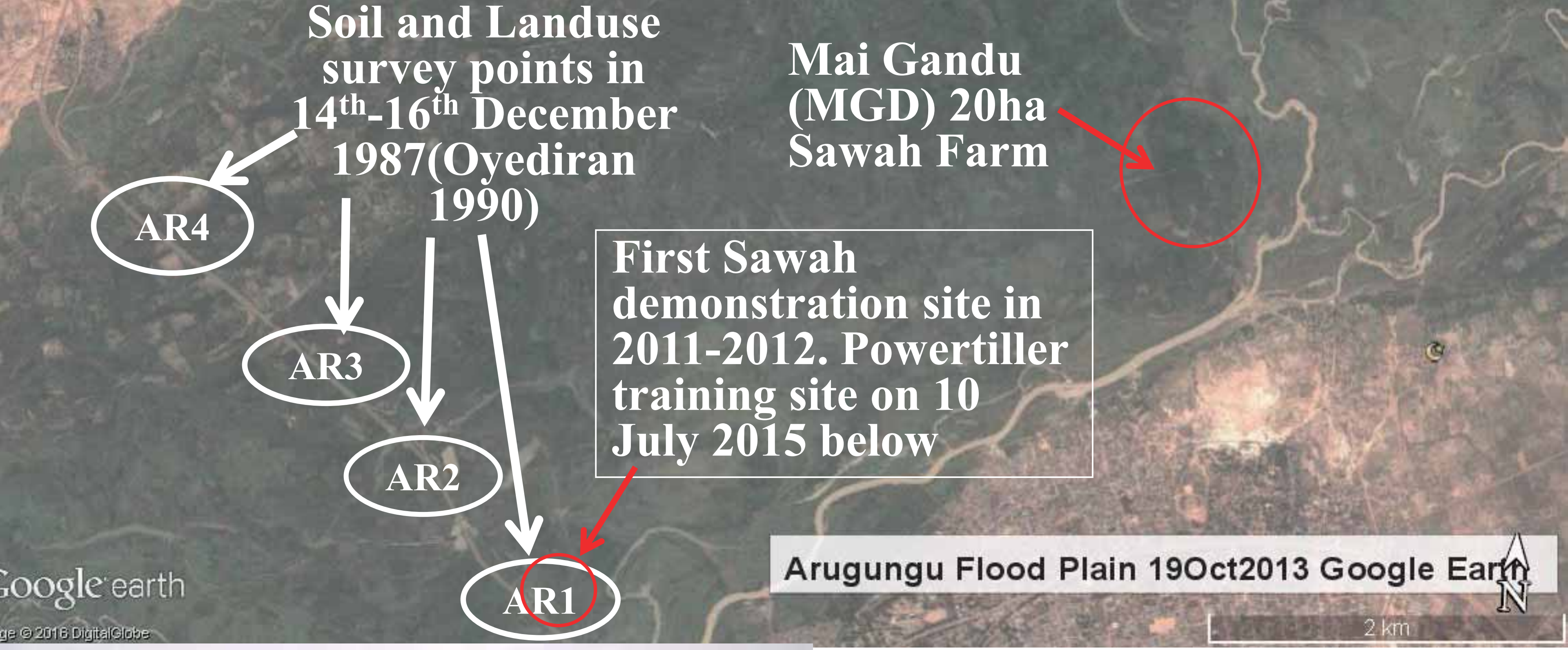
Quality of Sawah determines the performance of various agronomic practices . The quality of a sawah can be determined mainly by the quality of leveling. If height difference in a plot of Sawah is within 5cm, excellent, within 10cm, good, within 20cm marginal to get the targeted yield 4t/ha, if more than 30cm, paddy yield will be less than 3t/hahe.





Quality of a Sawah was determined by the quality of leveling and bunding.
Puddling, irrigation, drainage, and ground water recharge practices can also improve water cycling

Figure 2. Sawah: A bunded, leveled, and puddled rice field with inlet of irrigation and outlet to drainage, thus control water and weeds as well as manage nutrients



Photograph 4. Arugung in 1987 and 2015. Starting site of Kebbi rice revolution through sawah system evolution through sawah technology

6 Stages of Sawah System Evolution (I)

Green Revolution is possible only after the 4th Evolutional Stage

1st (L) stage : Lowland non sawah rice cultivation, Inland Valley, Sierra Leone, 1987

Evolutionary Satge 1 or 0 (Upland rice and Fonio cultivation at Guinea)

2nd stage: Irrigated micro rudimentary sawah. 3rd stage: ridge planted rice in Inland valley, Nupe, Nigeria

Micro sawah plots (Evolutionary Stage 2) Archaelogical site. 2400-2500 years BP, Japan (Photo by T. Komori, 2011, http://tsu-com.515.my.coocan.jp/H23.11.12.NakanishiIseki.html).

6 Stages of Sawah System Evolution（II）

4th Stage: Standard sawah plots with leveling quality of ±5cm using animal plowing, Indonesia. This has the longest history in Asia

5th stage : Standard sawah plots with leveling quality of±5cm. Bush inland valley was developed by farmer using powertiller

6th Stage: Advanced and large sawah plot of >1ha with leveling quality of ±2.5cm using laser leveler tractor (Kubota Co)

Transplanting on the 6th stage sawah. Direct sawing is possible with high performance

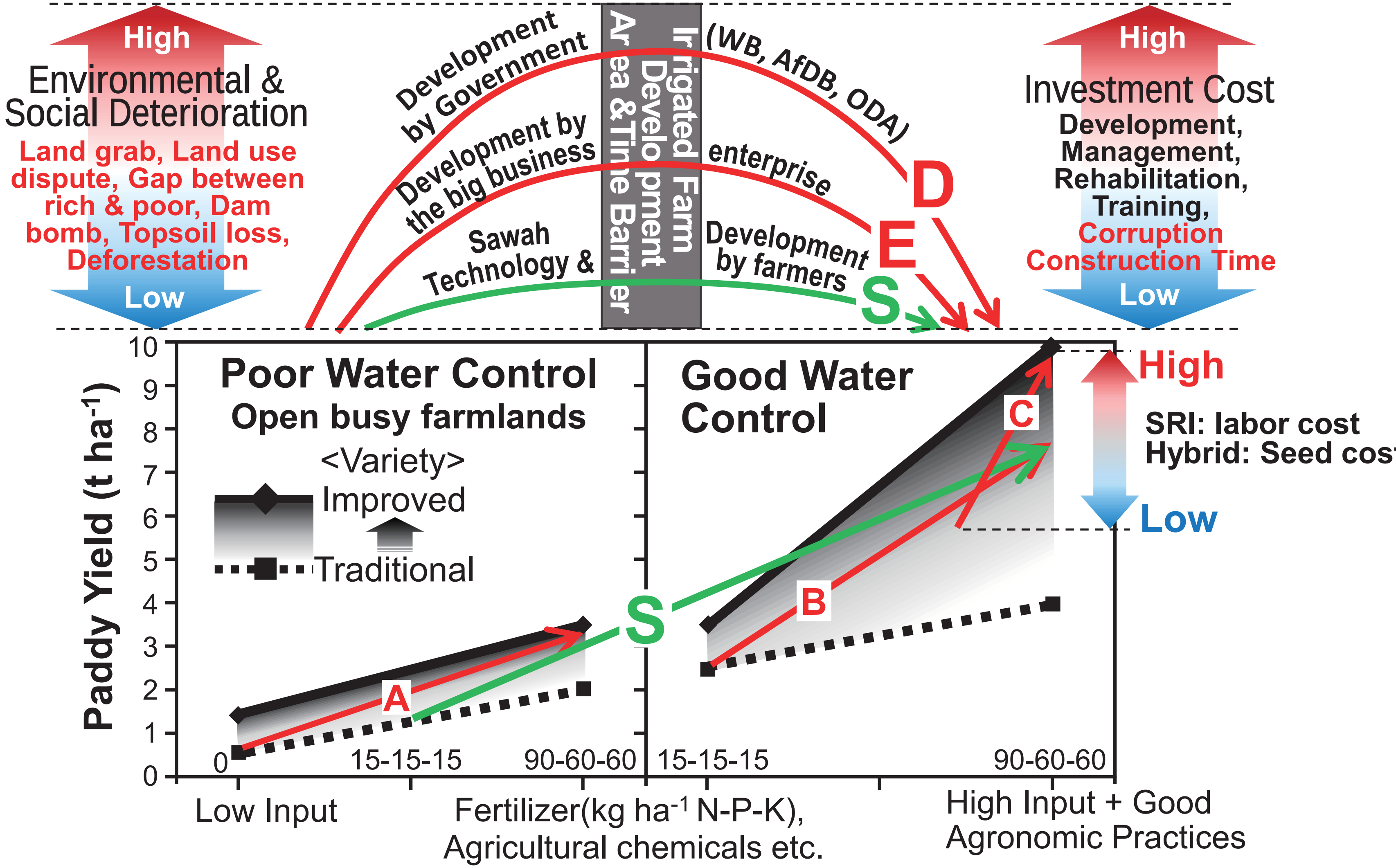


Figure. Six Strategies to Increase Paddy Yield and Production in SSA

A type strategy: Upland **NERICA** technology
B type strategy: **Asian Green Revolution technology**
C type strategy: **System Rice Intensification**
D type strategy: **Contractor based ODA** irrigation/drainage development
E type strategy: Irrigation by **private big business enterprises**
S type strategy: Sawah technology with sustainable mechanization

Irrigated but micro rudimentary sawah plots at Northern Nigeria
Because of difficulty of water control, paddy yield is less than 3t/ha

Sawah Hypothesis 1

- British Enclosure for Agricultural Revolution, Modern Science, Industrial Revolution
- Sawah and Enclosure
- Sawah as Foundation for Science

Disadvantages of the old system

People have to walk over your strips to reach theirs

Field left fallow

No hedges or fences

Difficult to take advantage of new farming techniques

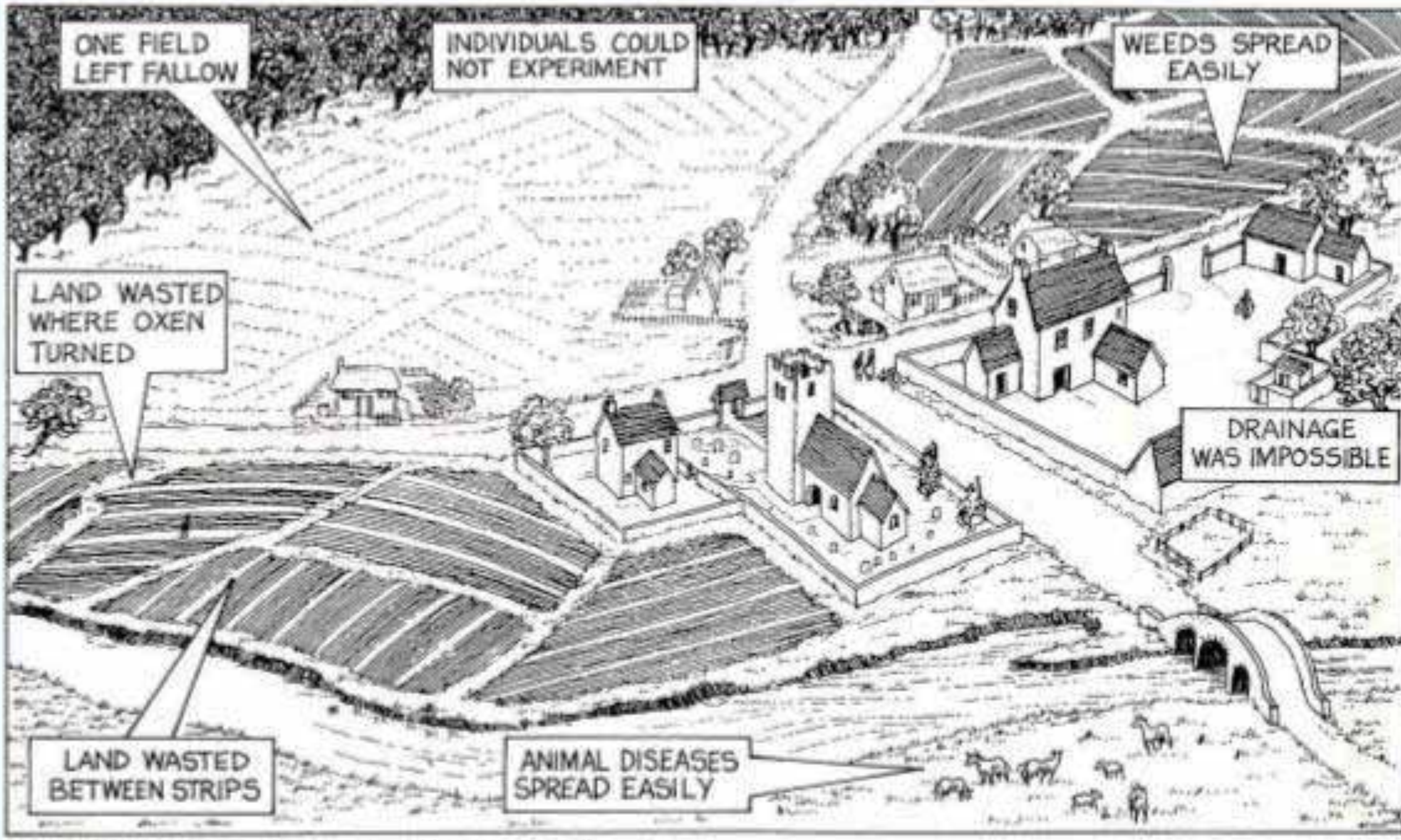
No proper drainage

Because land in different fields takes time to get to each field

Animals can trample crops and spread disease

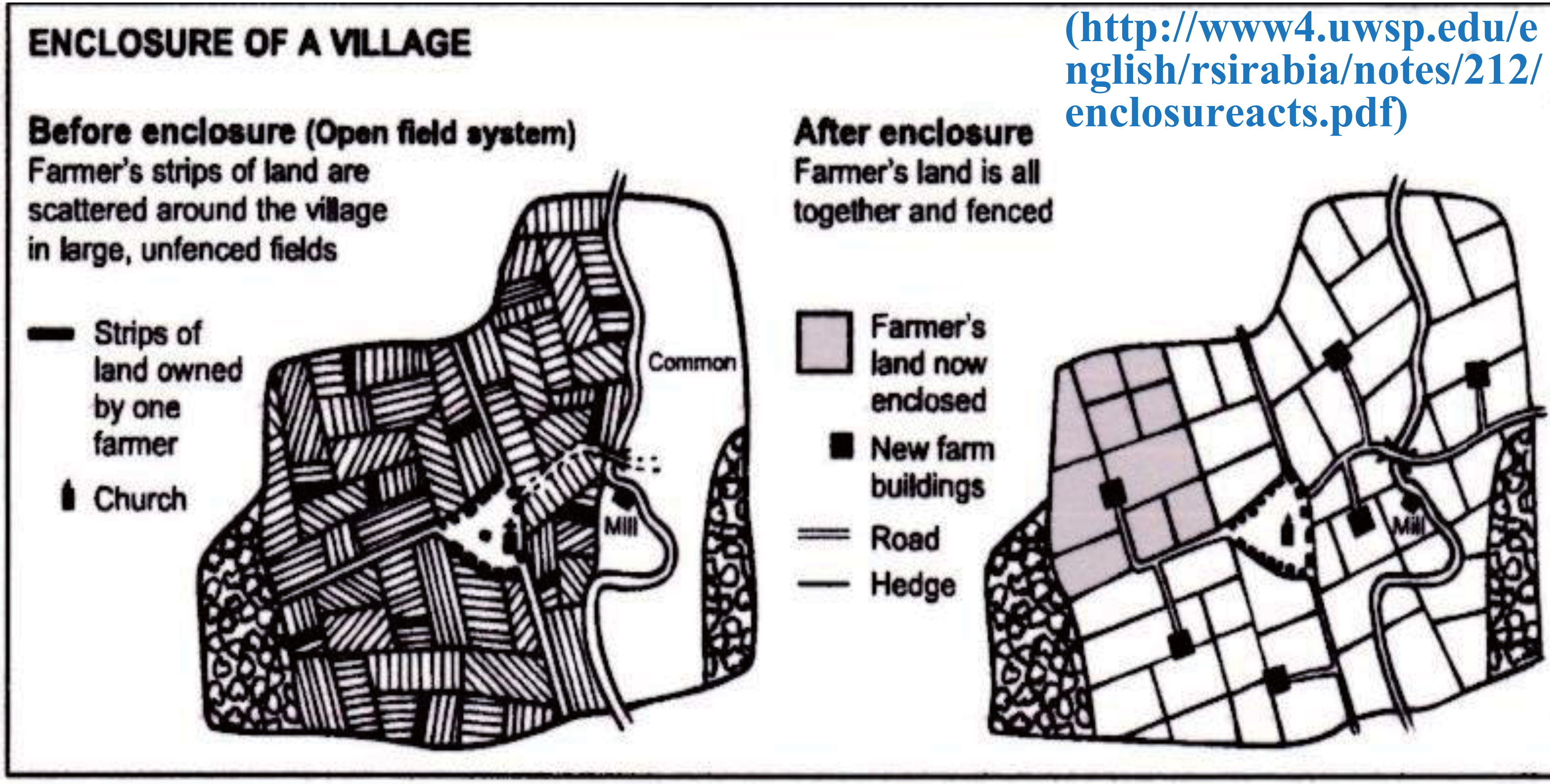
http://www.slideshare.net/maggiesalgado/agricultural-revolution-13173417

- Farmers could not take advantage of all these new ideas in the open field system



An open field village, showing the problems of strip farming.

http://www.slideshare.net/maggiesalgado/agricultural-revolution-33117637



(http://www4.uwsp.edu/english/rsirabia/notes/212/enclosureacts.pdf)

Enclosure → Changes in Agriculture → Selective Breeding; Four Crops Rotation; Chemical Fertilizers; Mechanization

http://www.slideshare.net/maggiesalgado/agricultural-revolution-33117637

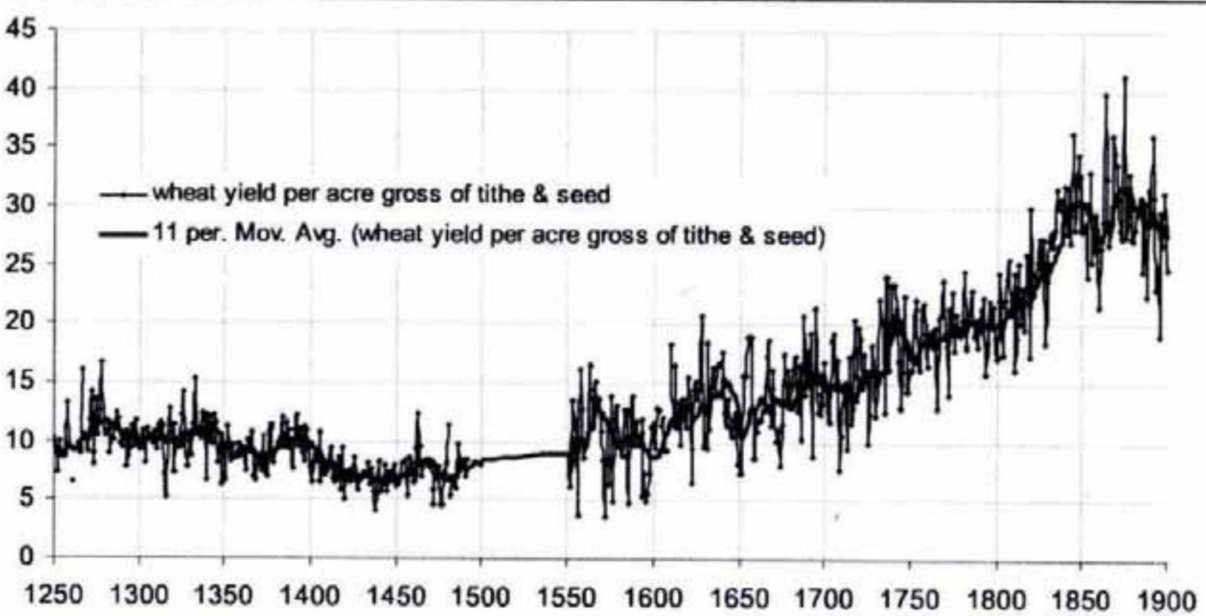
So the open land was enclosed

(http://www.slideshare.net/maggiesalgado/agricultural-revolution-33117637)

The land was divided into separate farms and enclosed by hedges or walls

English Agricultural output and labour productivity, 1250-1850: Some preliminary estimate by A. Apostolider, S. Broadberry, B. Campbell, M. Overton, B. van Leeuwen, 26 Nov 2008 (http://www.basvanleeuwen.net/bestanden/agriclongrun1250to1850.pdf)

FIGURE 4: Weighted national average wheat yields per acre, gross of tithe and seed (bushels)



Enclosure in UK during 15-18th centuries Created Basic platform for scientific technology, Agricultural Revolution, then Industrial revolution

	A. Yield per acre gross of seed (bushels)					B. Seed sown per acre (bushels)				
	Wheat	Rye	Barley	Oats	Pulses	Wheat	Rye	Barley	Oats	Pulses
1250-1299	11.27	13.73	14.41	10.91	8.93	2.56	3.02	4.16	3.67	2.90
1300-1349	10.77	13.31	13.36	10.21	8.77	2.53	2.95	3.90	3.61	2.63
1350-1399	9.96	12.00	13.67	11.12	8.43	2.49	2.79	3.92	3.63	2.57
1400-1449	8.28	13.01	12.20	9.52	7.71	2.39	2.55	3.75	2.97	2.30
1450-1499	8.94	16.75	12.74	8.42	6.57	2.45	2.79	4.18	2.48	2.08
1550-1599	10.38	11.71	12.40	11.87	10.62	2.50	2.50	4.00	4.00	3.00
1600-1649	12.95	18.78	15.16	14.97	11.62	2.50	2.50	4.00	4.00	3.00
1650-1699	13.86	16.69	16.48	14.82	11.39	2.50	2.50	4.00	4.00	3.00
1700-1749	16.36	17.32	19.38	16.27	13.23	2.57	2.50	4.30	4.00	3.00
1750-1799	19.54	20.37	25.38	24.90	17.19	2.27	2.50	3.50	4.00	3.00
1800-1849	25.56	22.02	29.70	32.37	20.35	2.41	2.50	3.80	4.00	2.50
1850-1899	29.19	28.68	27.08	35.36	18.80	2.50	2.50	3.27	4.00	2.50

Scientific technology, Sawah Hypothesis(1), and Enclosure

1. Scientific technology is defined as the whole of knowledges, experiences, skills and practices which can be systematically and reasonably classified and categorized, thus which can be transferred between human beings through learning, education and training. Enclosure was land demarcation, classification and rezoning practices.
2. Modern Western world has only been materialized through the establishment of modern sciences (S. Nakayama, H. Butterfield). It may not be a rare coincidence that active period of contributors to establish modern science, such as Nicolaus Copernicus (1472-1543), Johannes Kepler (1571-1630), Galileo Galilei (1564-1642), René Descartes (1596-1650), Robert Boyle (1627-91), Isaac Newton (1642-1727), Antoine-Laurent de Lavoisier (1743-94), James Watt (1736-1819) and Justus Freiherr von Liebig (1803-73) had been overlapped with the period of Enclosure.
3. Medieval manors were characterized with a set of open fields and rural community. The period of the modernization progresses were also the ages of enclosure, that is the arable lands were enclosed with stone walls, bunds, or hedges, then reclaimed the enclosed land. The first enclosure mainly on the 16th century was called that "Sheep eat men (Thomas More's Utopia)", because the landowner evicted the tenant farmers to expand pastureland for sheep rising. Whereas the second enclosure around 1700-1850 dramatically increased agricultural production.
4. As shown in M. Salgado(2012, http://www.slideshare.net/maggiesalgado/agricultural-revolution-13173417), the enclosed farmlands enabled reasonable land use plan and infrastructure development such as drainage improvement, the reduction of the waste land, conservation of land degradations originated from cultivation, pests and weed management, promotion of selective breeding, new farming techniques and the mechanization. Furthermore, various scientific farming techniques were innovated (evolved) through field experiments which were only became possible in enclosed lands.
5. However, since the enclosures and infrastructure development needed investments, the rich capitalists who were able to carry out enclosure became increasingly rich and the tenant and the small farmers that were not able to enclose decreased agriculture income, lost their land and became wage labors at urban areas. Consequently, the gap between rich and poor was increased. The wage labors were important for the Industrial Revolution.

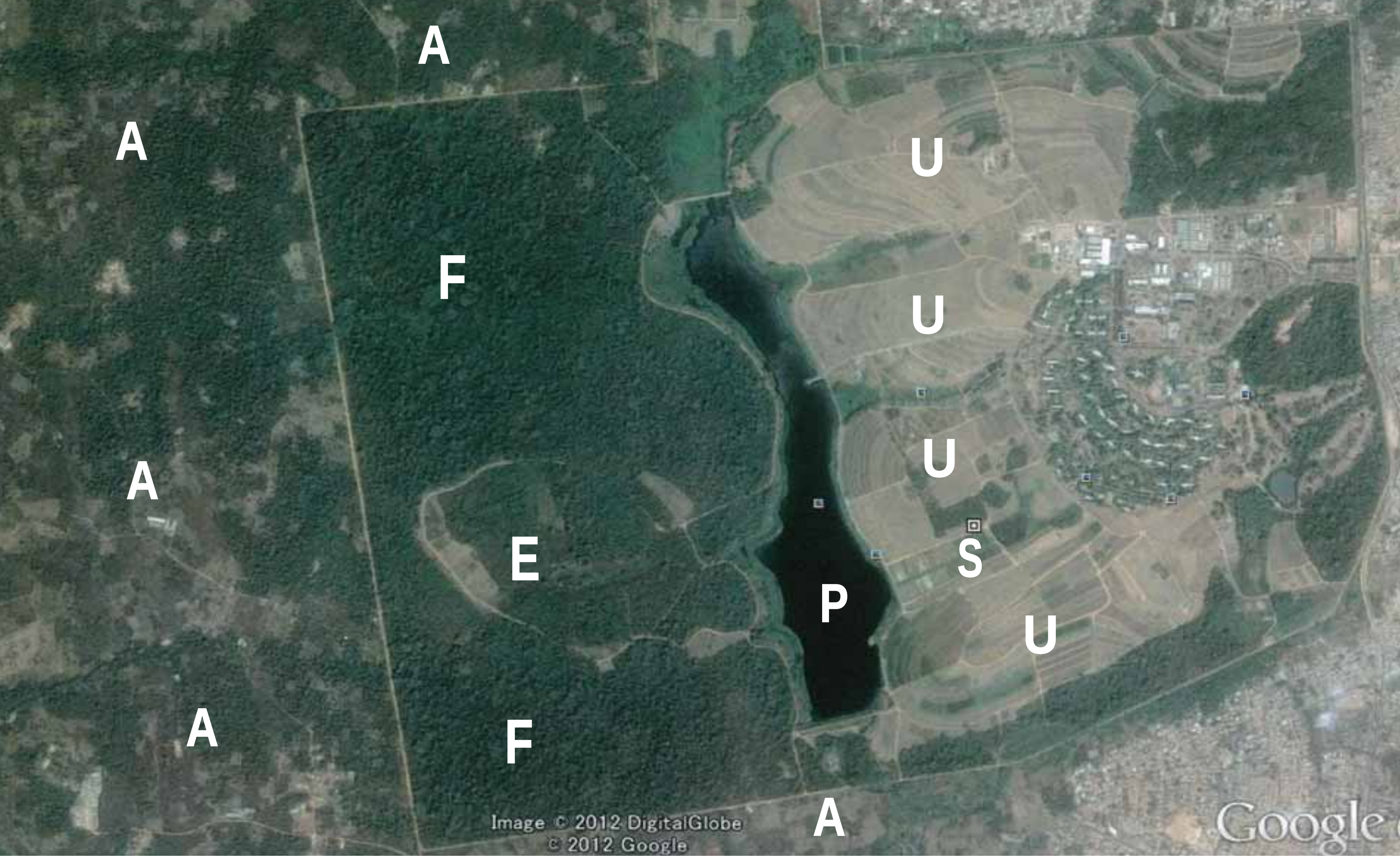


Fig.6. Sawah Hypothesis (1). Prerequisite platform to apply green revolution technologies exist in fenced 1000ha of IITA's research fields, but no such infrastructures farmers' fields. A: Farmers fields with the same soils, topography and hydrology. U: demarcated upland fields along contours. S: Sawah fields at valley bottom. P: Pond for irrigation. F: Regenerated forest, E: Erosion experiment site by Prof. R. Lal and his team in 1970-80s

Non-Sawah upland paddy field Guinea, Aug.03

Sawah was developed using hundreds years by Chinese Farmers (Otsuka 2004)

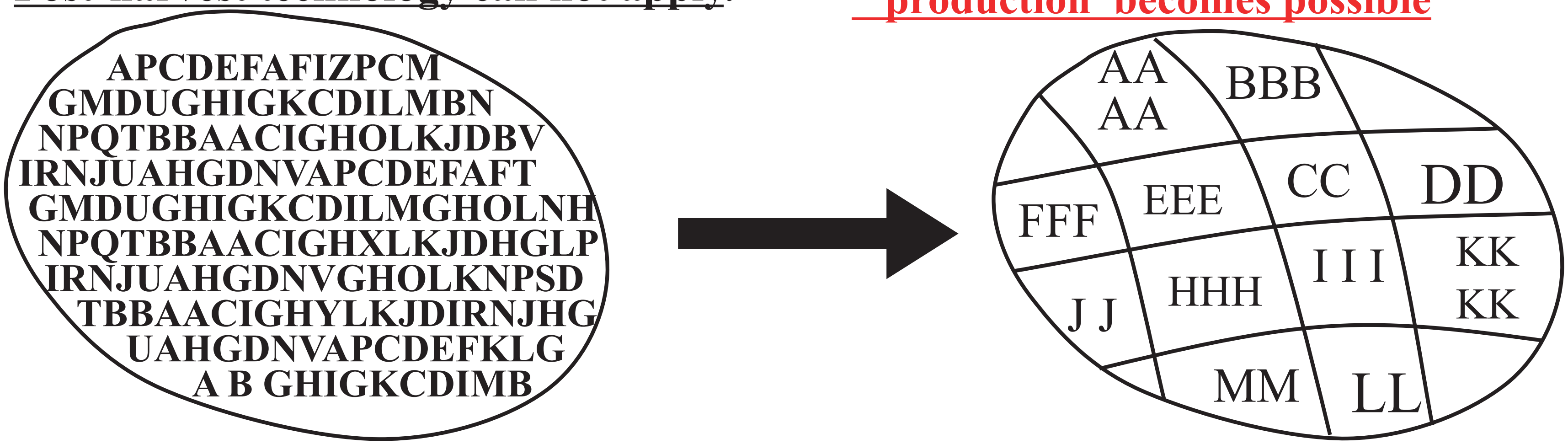
Sawah system development by Sawah Technology

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. Conflicts with nomads and fishermen No incentive to improve land.
3. 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 can be 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 promoted, which makes incentives to improve land.
3. Market competitive standardized paddy production becomes possible



Green revolution (GR) technologies of fertilizer, irrigation, and high-yielding varieties (HYV) are not effective in the bushy open fields

Sawah is similar to British enclosured land, which realized Agricultural revolution. This is foundation for scientific technologies of GR

Fig 5. Sawah hypothesis (1): Farmers' Sawah should come the first to realize Green Revolution. Farmers fields have to be classified and demarcated ecotechnologically. Then scientific technologies can be applied effectively.

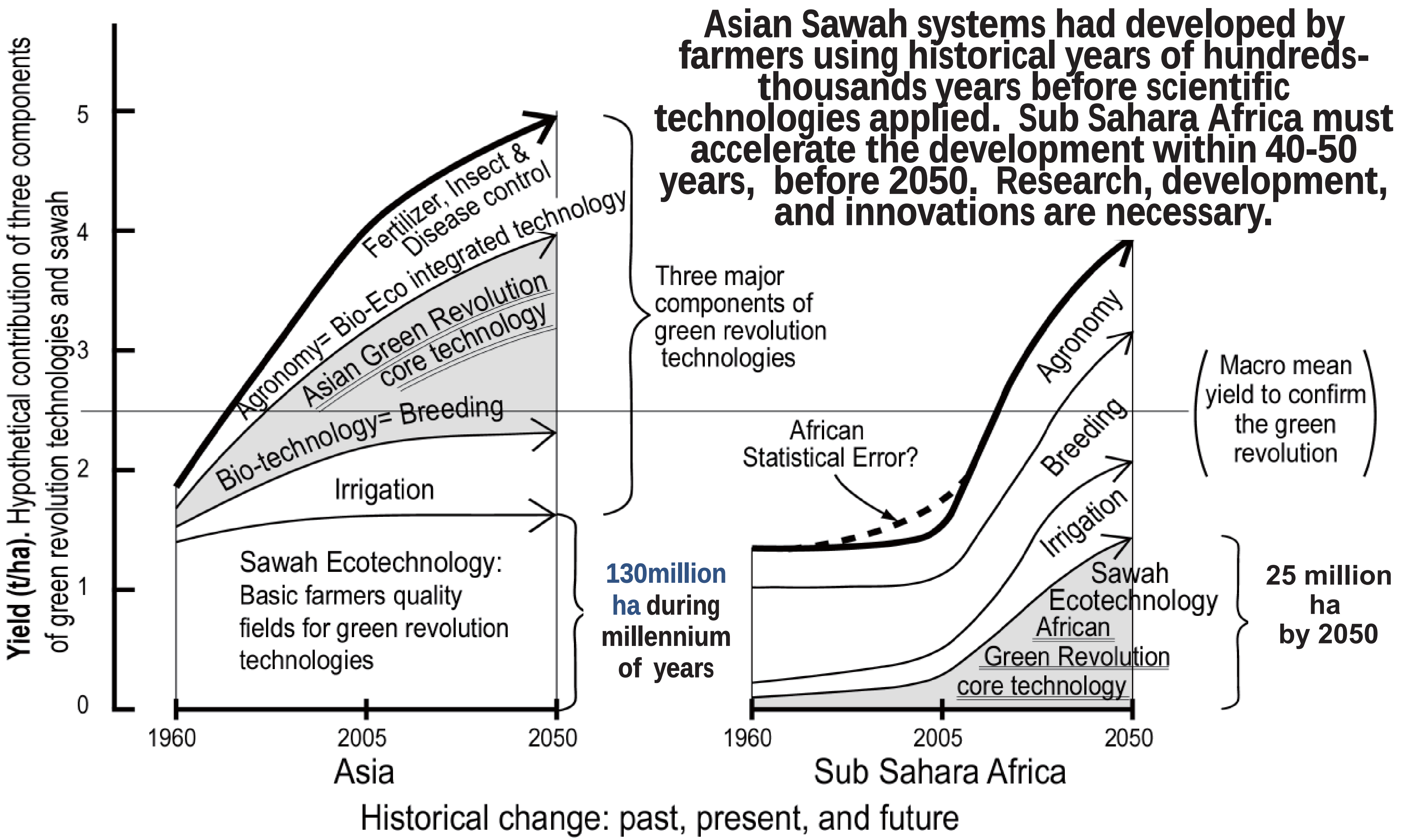


Fig. 7 : Sawah hypothesis (1) for Africa Green Revolution:

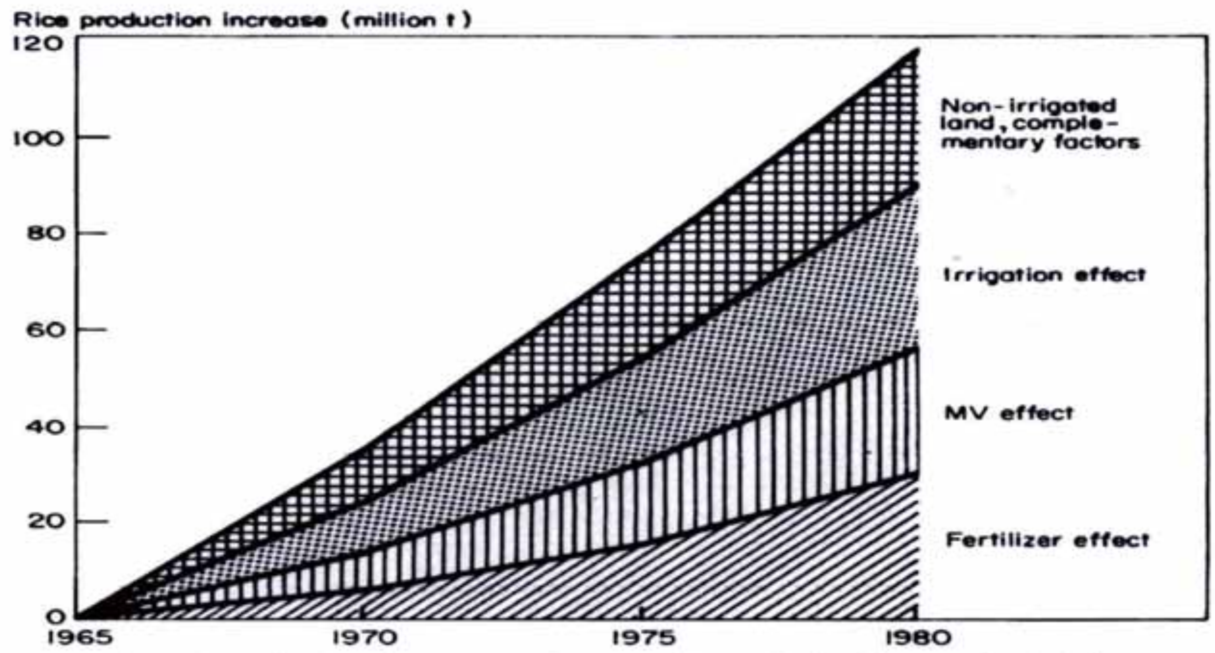
hypothetical contribution of three green revolution technologies & sawah system development during 1960-2050. Bold lines during 1960-2005 are mean rice yield by FAOSTAT 2006. Bold lines during 2005-2050 are the estimation by the authors.

Table 10. Contribution of specified factors to rice production increases achieved from 1965 to 1980.

Year	Contribution of factors				
	MV effect	Fertilizer effect	Irrigation effect	Other factors (residual)	Total observed growth in output[a]
	Output increases (thousand t paddy)				
Burma	647	353	685	167	1,852
Bangladesh	420	1,284	1,091	2,759	5,554
China	13,231	11,507	16,153	9,609	50,500
India	7,998	10,867	11,209	5,078	35,152
Indonesia	3,162	2,680	2,773	4,998	13,613
Philippines	849	1,009	801	615	3,274
Sri Lanka	241	215	262	316	1,034[b]
Thailand	822	682	865	4,031	6,400
Total of above	27,370	28,597	33,839	27,573	117,379
	Value (US$ million)[c]				
	4,516	4,718	5,583	4,549	19,367

[a]Difference between 1980 and 1965 production (USDA FG38-80). [b]A 3-year average was used for 1965 because 1965 yields were unusually low. [c]Paddy was valued at $165/t.

Herdt RW and Capule C. 1983. Adoption, spread, and production impact of modern rice varieties, 1-54, http://books.irri.org/getpdf.htm?book=9711040832



5. Estimated contribution of 4 separate factors to rice production increases in 8 Asian countries, 1965-80.

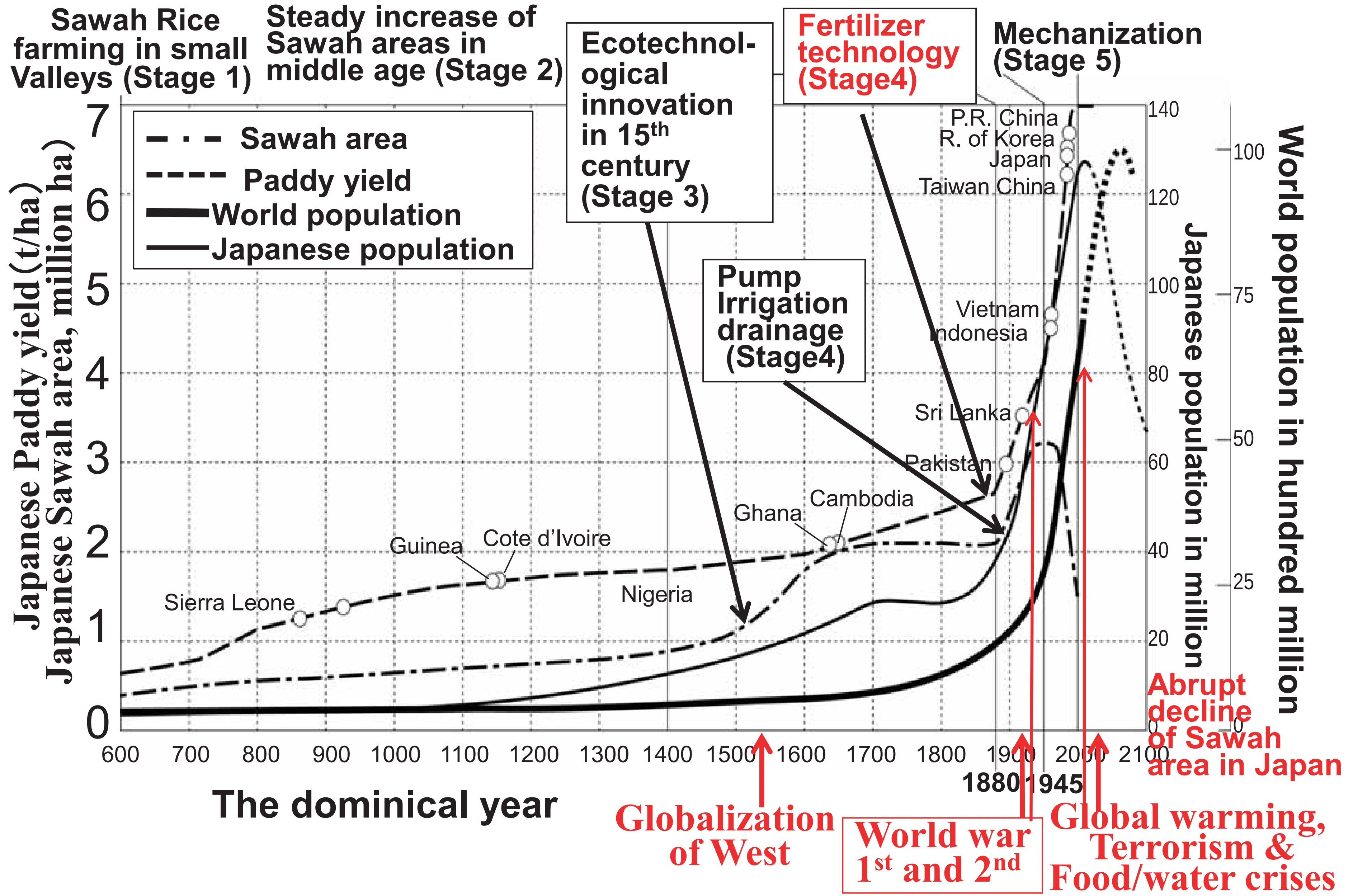


Figure 8a. Historical path of Japanese and world population, Sawah area, and paddy yield in comparison with Asia and Africa at 2001/2005 of FAOSTAT data. (Takase & Kawano 1969, Honma 1998, JICA 2003, Kito 2007, Wakatsuki 2013b)

Sawah Hypothesis 2

- Intensive Sustainability through both Macro and micro scale ecological and eco-technological mechanisms
- Watershed Agroforestry as Africa SATOYAMA System against global warming, bio-diversity loss and hydrological cycling problems
- Multi-functionality of Sawah System

Table 2. Sawah hypothesis (2) : Sustainable Productivity of high quality 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

Macro-scale watershed eco-technological mechanisms to support Sawah hypothesis 2: 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 water cycling and conservation of soil fertility, (2) Ecologically safe carbon sequestration by afforestation, 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 2: Enhancement of the availability of N, P, K, Si, Ca, Mg, and micronutrients by puddling and water management. Quality organic carbon accumulation to sustain soil fertility.

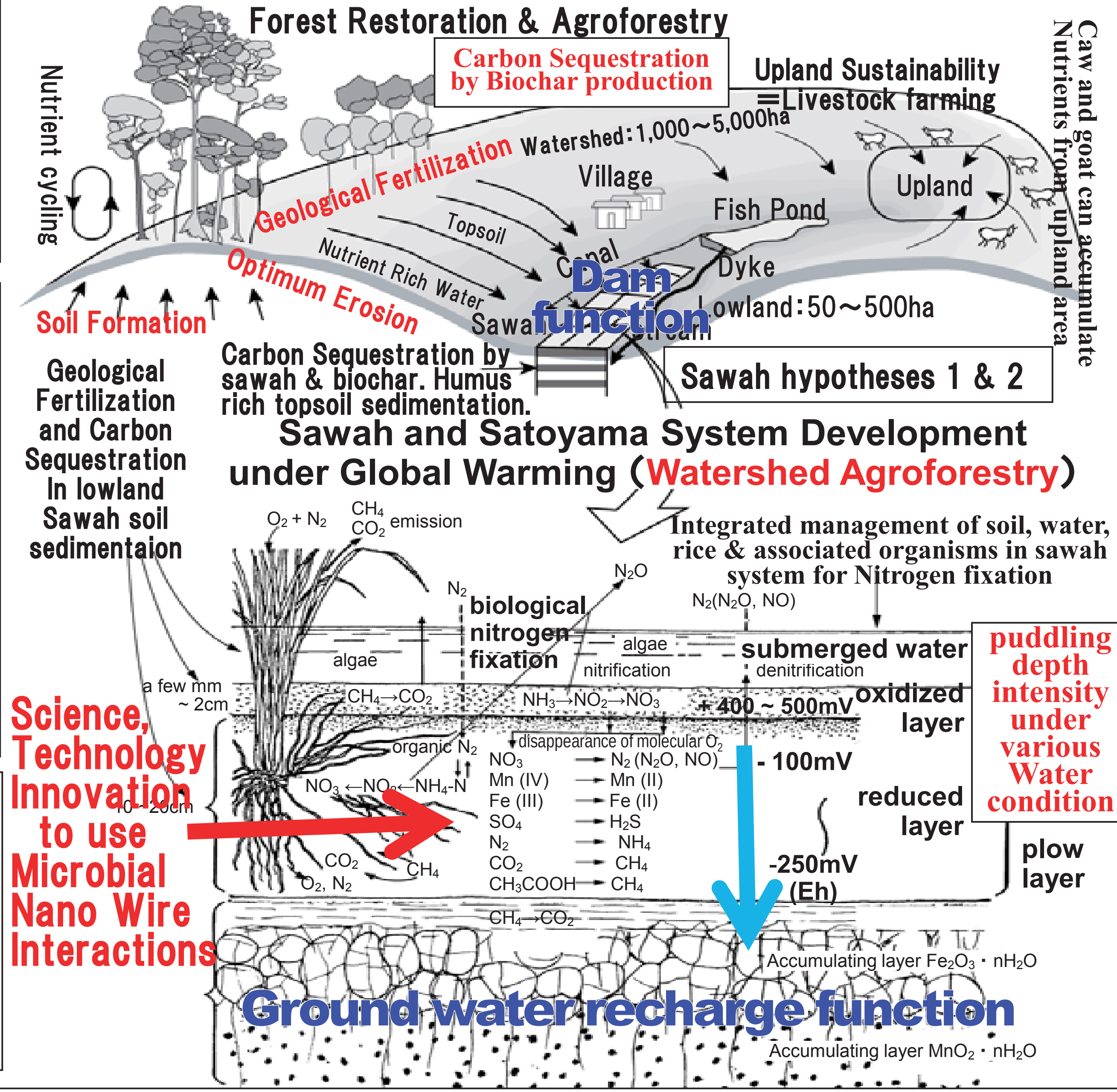
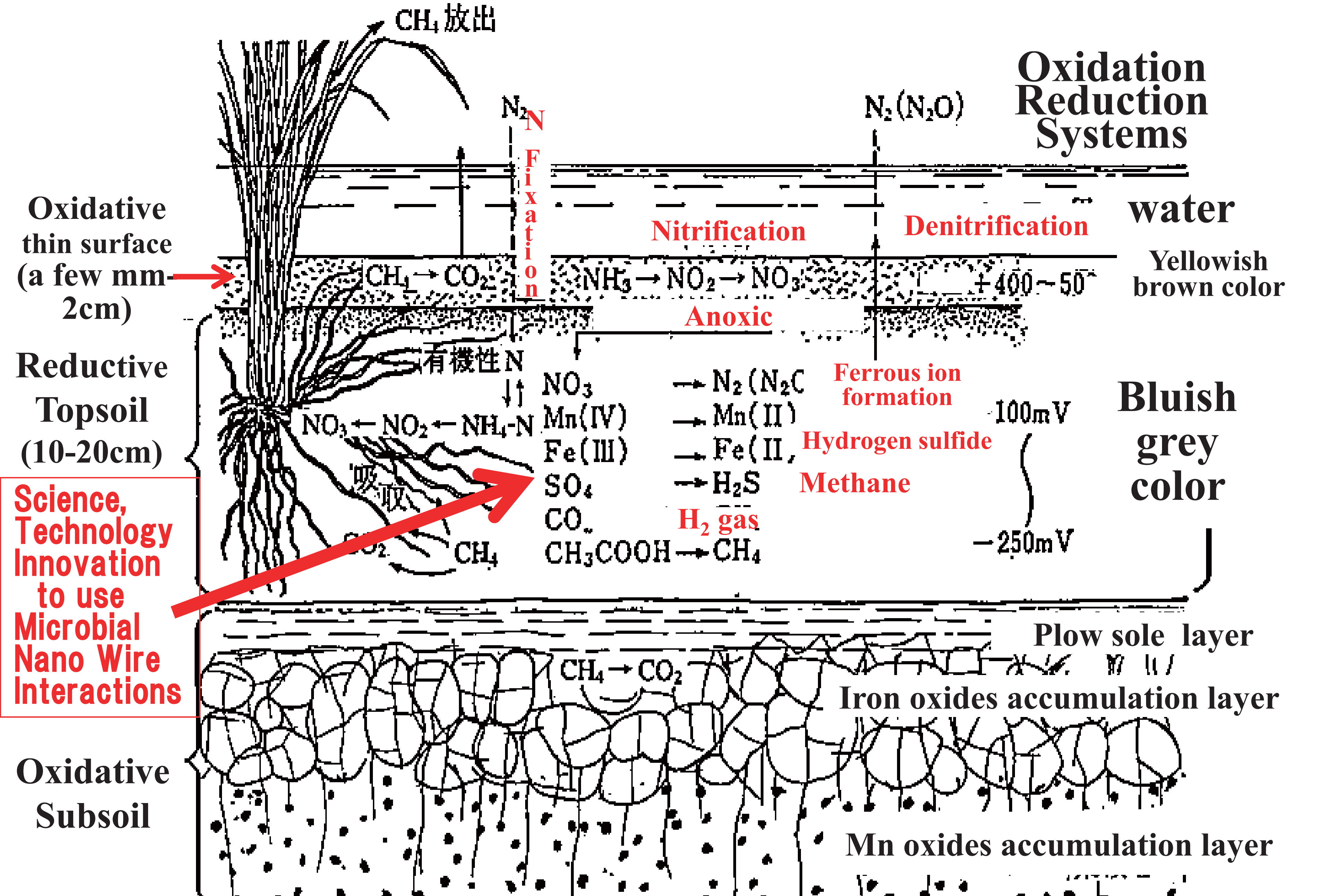


Fig 9. Sawah hypothesis (2) of multi-functionality & creation of African SATOYAMA (or Watershed Agroforestry) systems to combat food crisis and global warming.



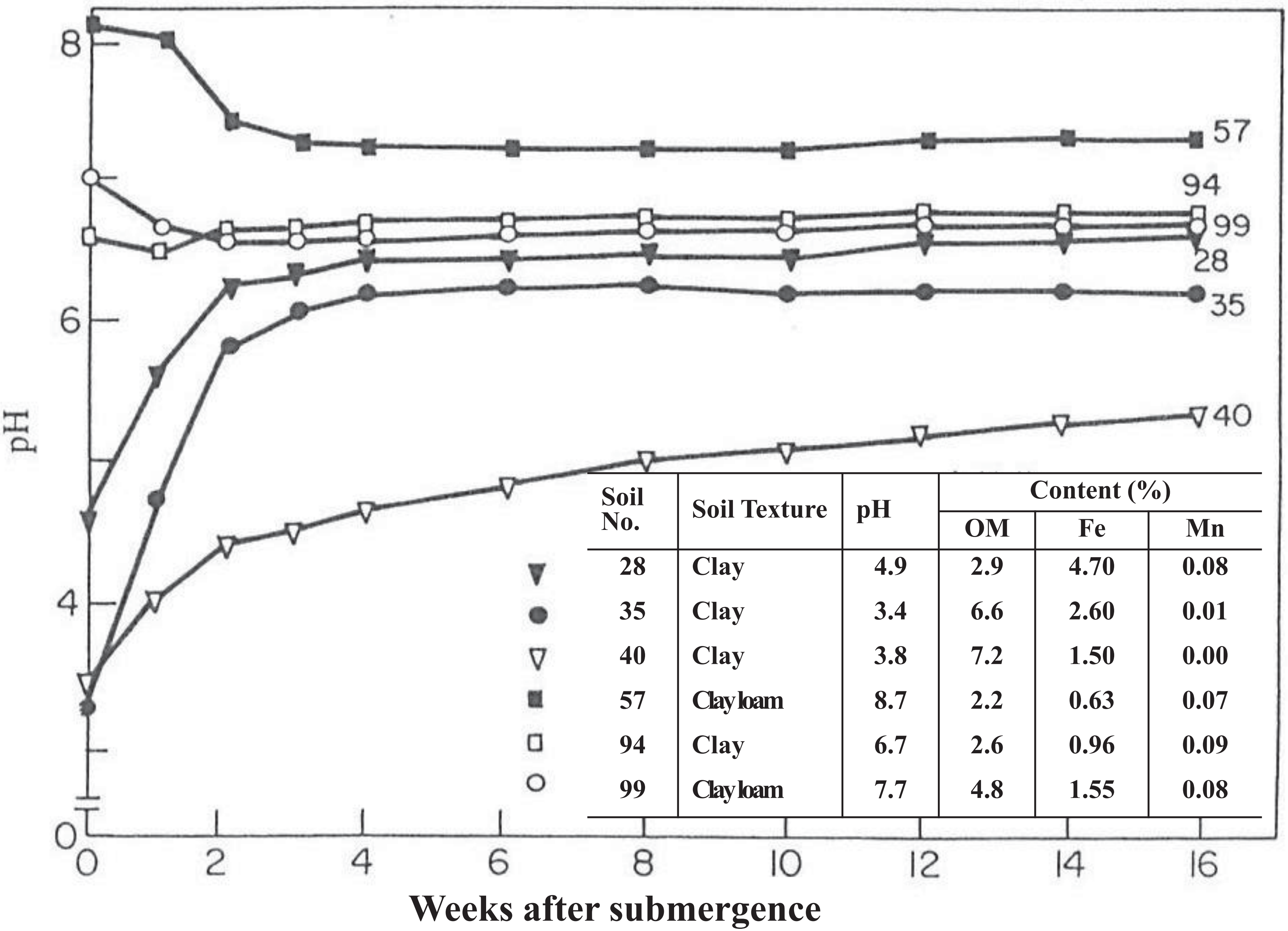
Typical Sawah soil profile development under controlled submerged condition

Wada 1984, Minami 1994, Wakatsuki 1997

Weed in SAWAH*

	Soil moisture	Weed (g/m^2) Total	C-3	C-4
Upland	30-60%	58	6	52
Moist	80-90%	31	3	28
Sawah	flooding (6 cm depth)	10	9	1

*M. ARAI & I. TANAKA, 1972

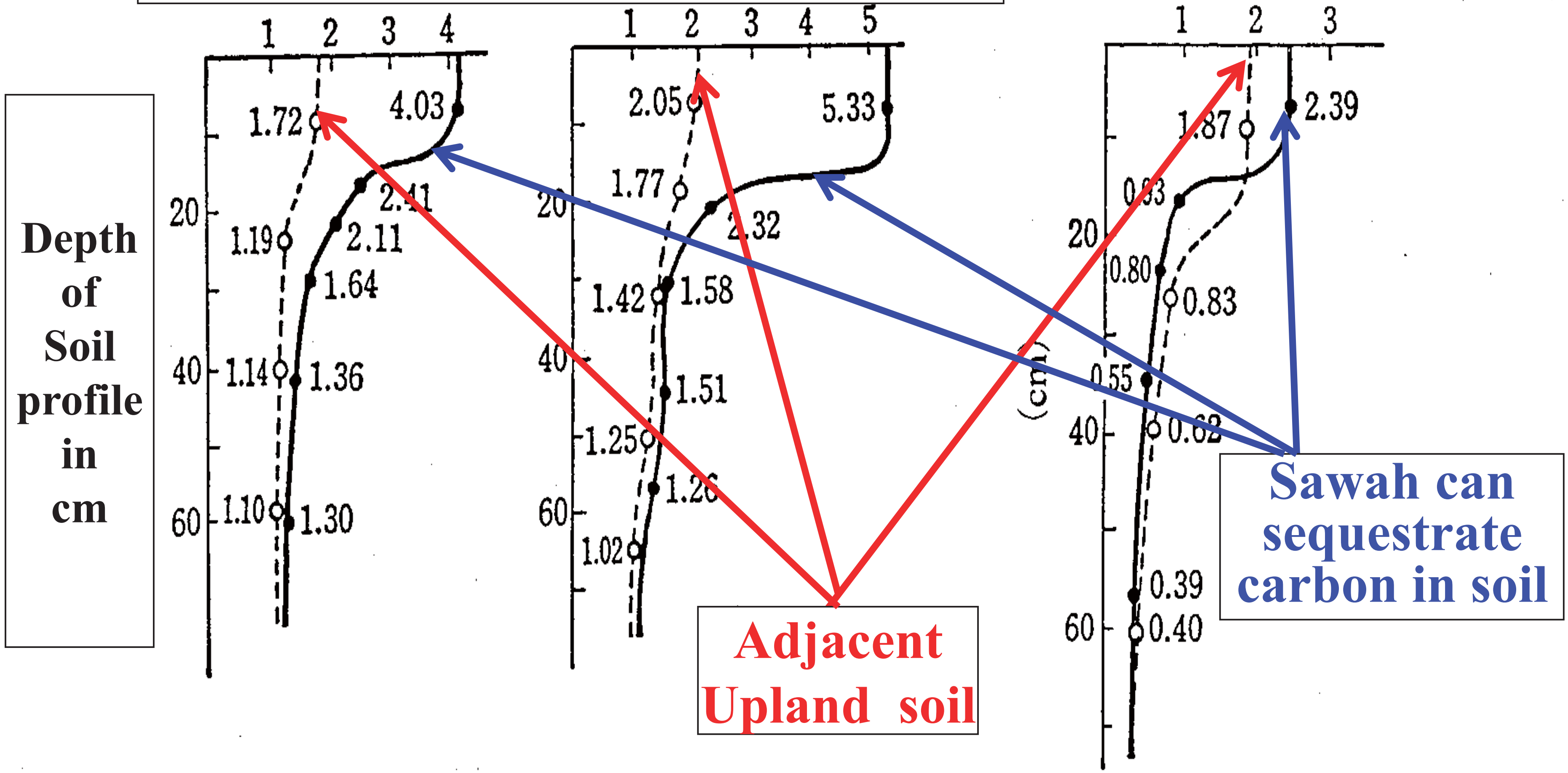


	Soil No.	Soil Texture	pH	Content (%) OM	Fe	Mn
▼	28	Clay	4.9	2.9	4.70	0.08
●	35	Clay	3.4	6.6	2.60	0.01
▽	40	Clay	3.8	7.2	1.50	0.00
■	57	Clay loam	8.7	2.2	0.63	0.07
□	94	Clay	6.7	2.6	0.96	0.09
○	99	Clay loam	7.7	4.8	1.55	0.08

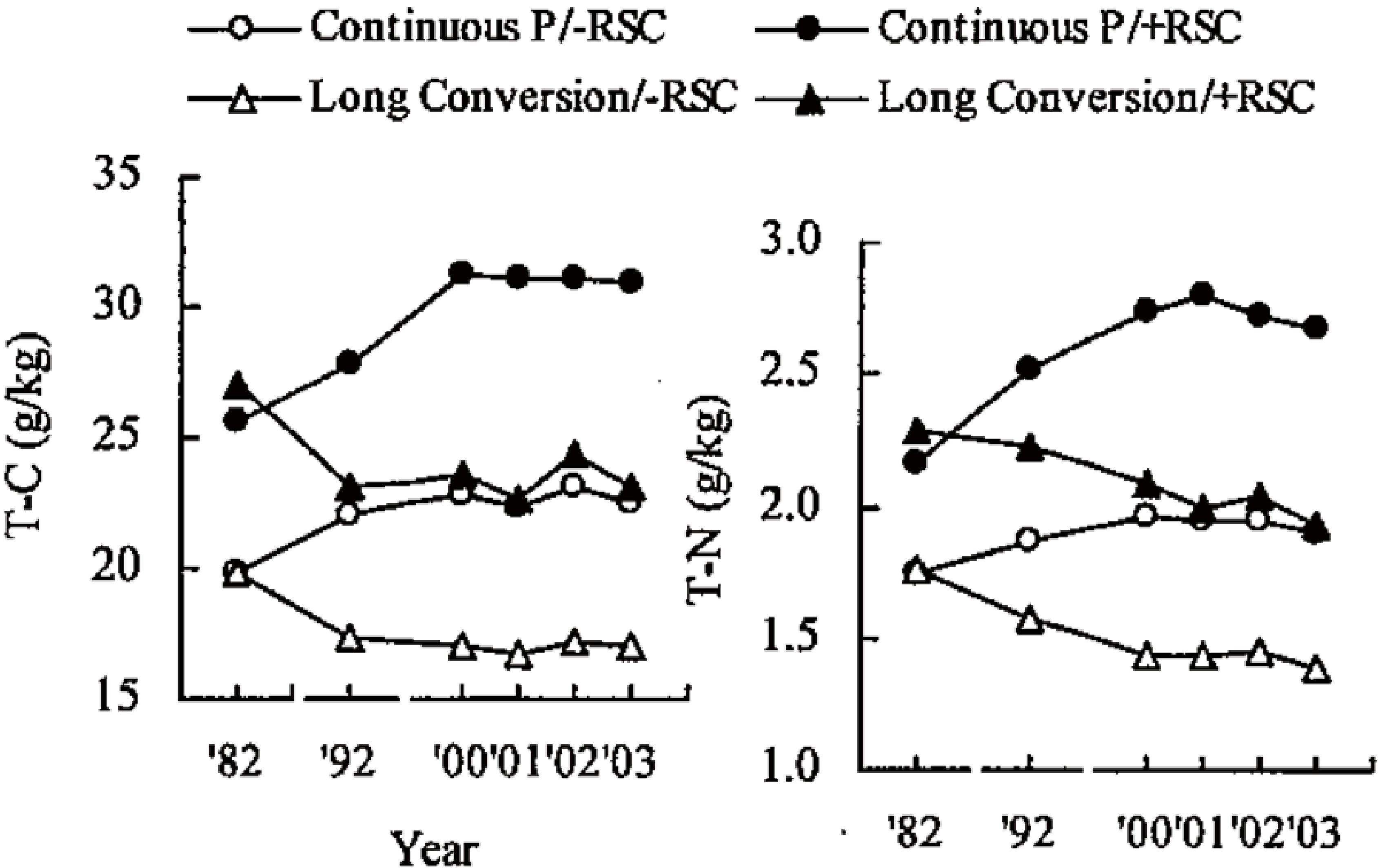
Fig. Sawah soil neutralization through submergence (Ponnamperuma 1976)

Organic matter % in Lowland Sawah soils in comparison with soils in upland management condition

Upland terraced sawah and upland Non-sawah



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

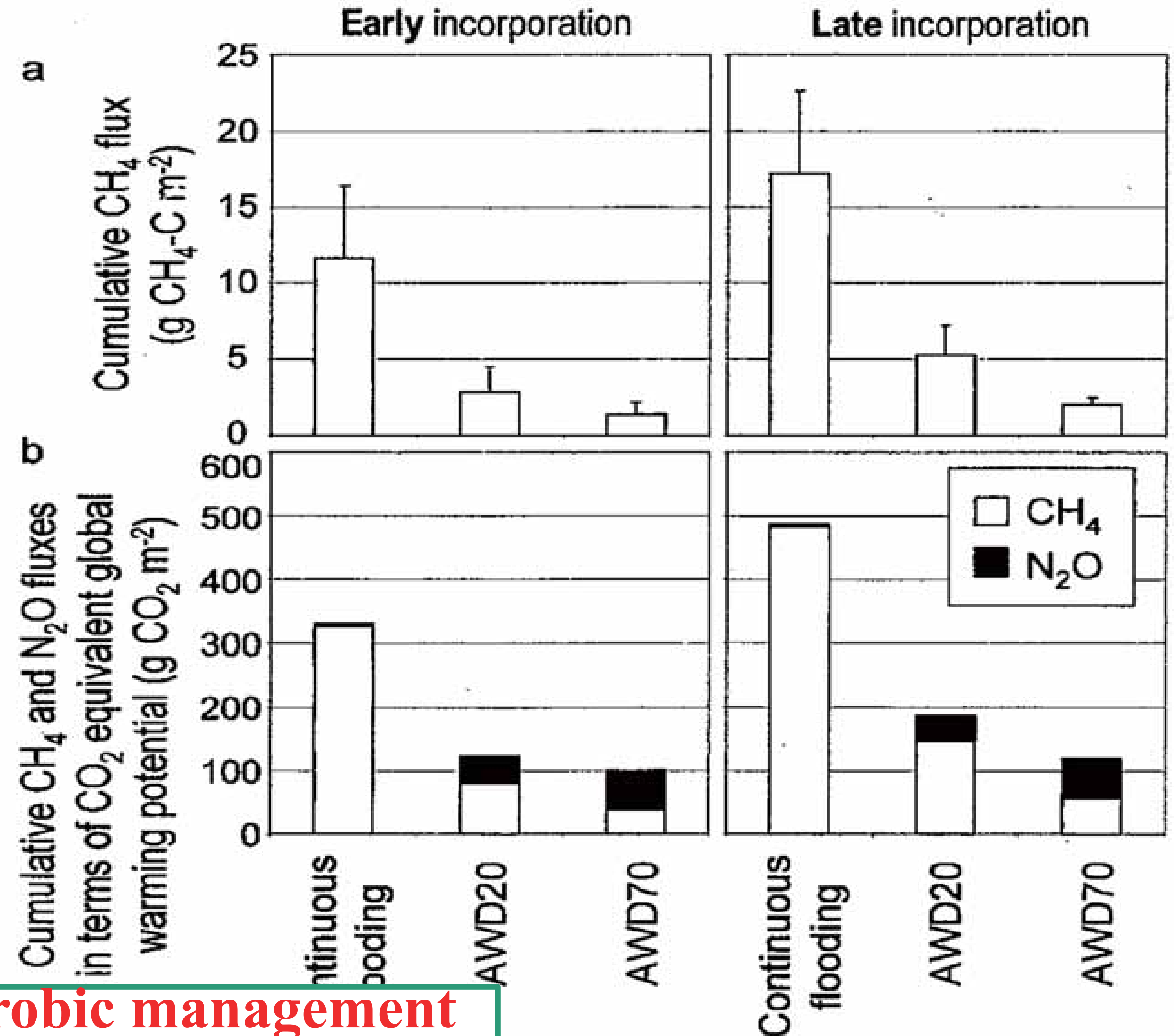


Upland/aerobic management reduce 50-100gC or 200-400gCO_2 /y/m^2

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

(Nishida 2007)

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



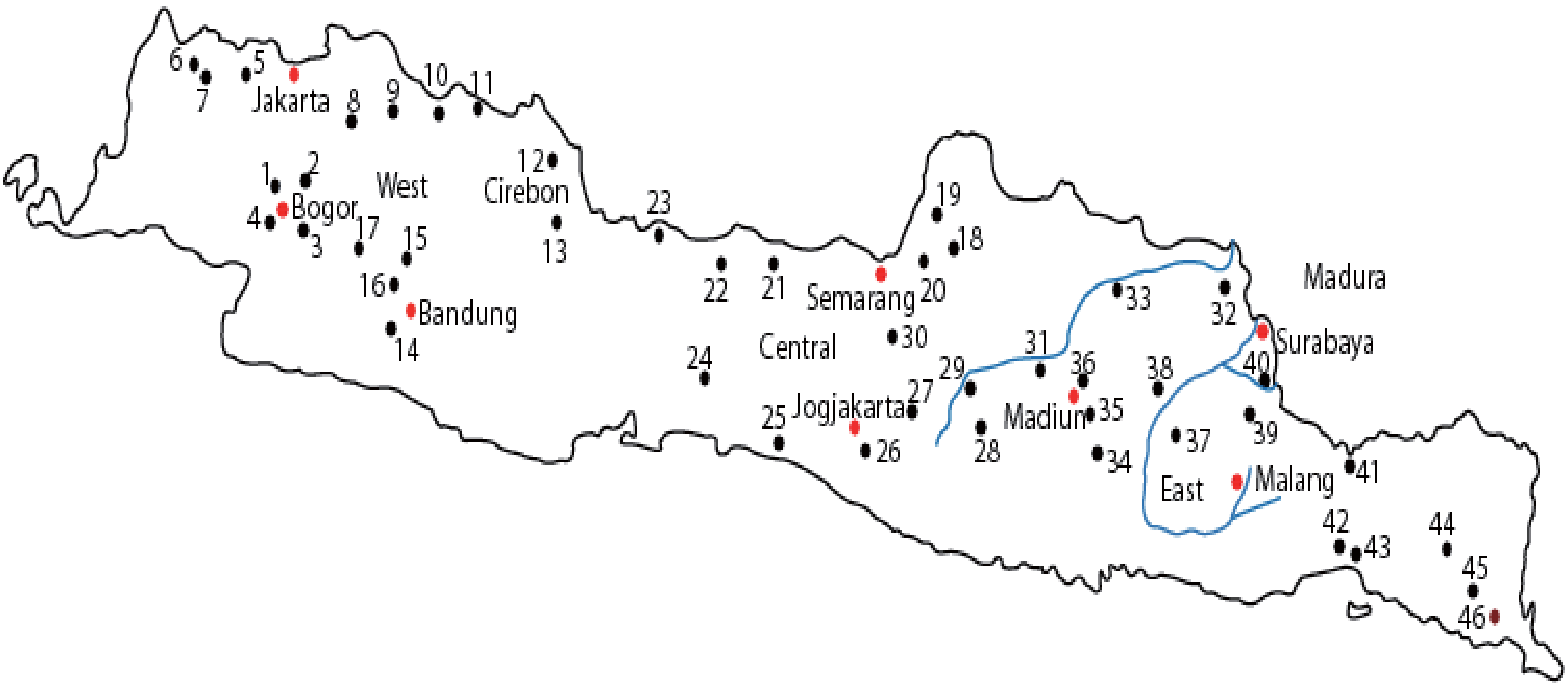
Upland/aerobic management reduce 200-400gCO_2 /y/m^2

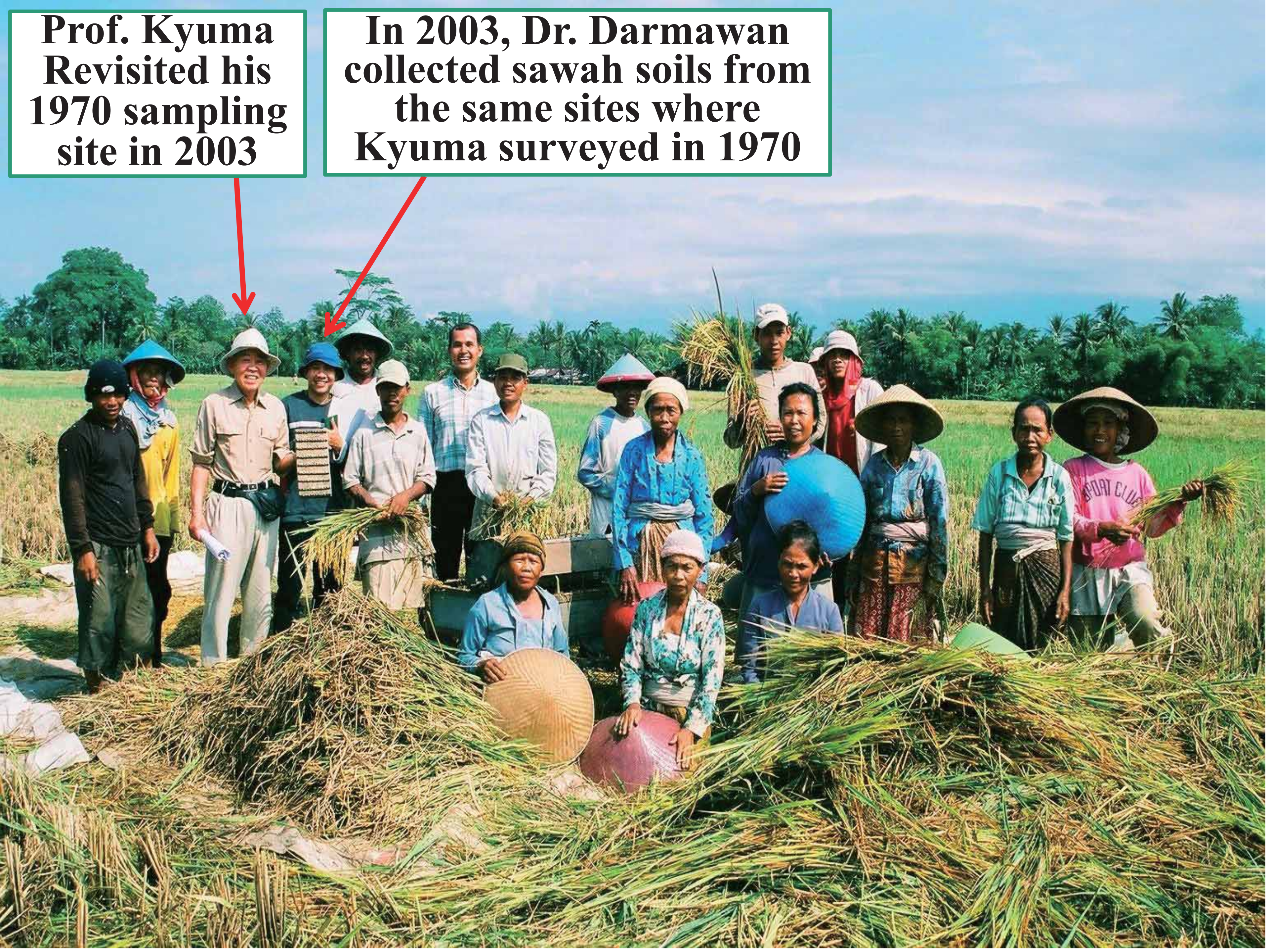
Figure 1. Cumulative CH_4 flux (a) and cumulative CH_4 and N_2O fluxes in terms of CO_2 equivalent global warming potential (b) during rice cropping period (January 29, 2007 (transplanting) – May 8, 2007 (harvest around this date); the conventional cropping period in dry season in the region). Bars indicate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

(Hosen 2007)

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

Sawah soil carbon change of Java, Indonesia, during 1970-2003, the Green revolution period (Darmawan et al. 2006)




Prof. Kyuma Revisited his 1970 sampling site in 2003
In 2003, Dr. Darmawan collected sawah soils from the same sites where Kyuma surveyed in 1970


In 2003, Dr. Darmawan collected sawah soils from the same sites where Prof Kyuma surveyed in 1970

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 (Darmawan et al. 2006)

	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. *$P < 0.05$; **$P < 0.01$; ***$P < 0.001$

Both C & N increased 30% per30 years during Green Revolution

Table 1. Research, technology development, innovation and dissemination in the area of eco-technology are just emerging, although it philosophy is to study the past to learn new things, i.e., learning from history「温故知新」 Agriculture needs Good Environments and Good Varieties. Both Biotechnology and Ecotechnology have to be researched, developed and innovated in good balance

Bio-technology：

To improve varieties through breeding, i.e., Genetic improvement. Target is DNA improvement.

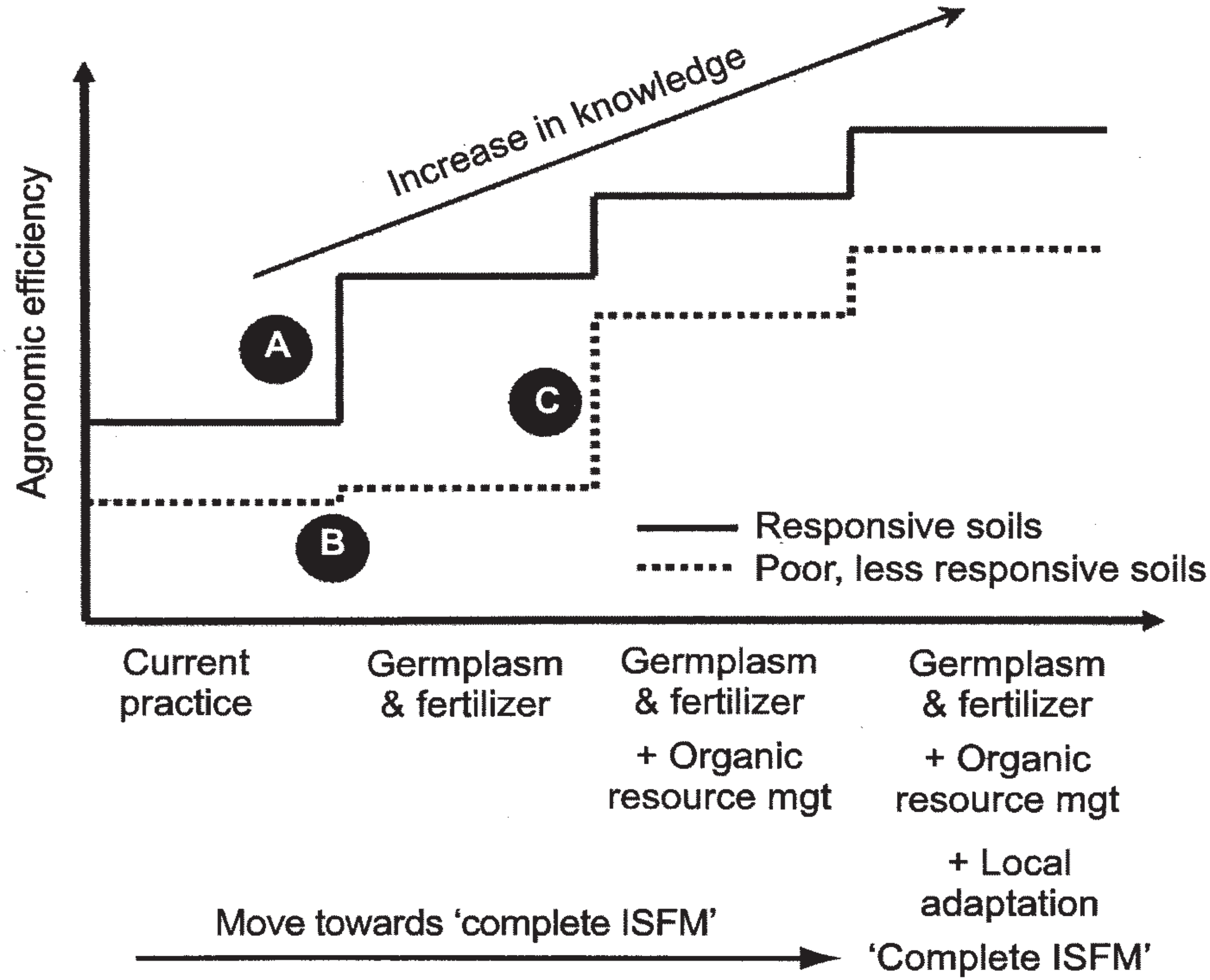
Operational platform is Cell of organisms

Eco-technology：

To improve growing ecology through sawah research, i.e., Improvement of water cycling and soil condition.

Target is soil and water. Operational platform is sawah in watersheds.

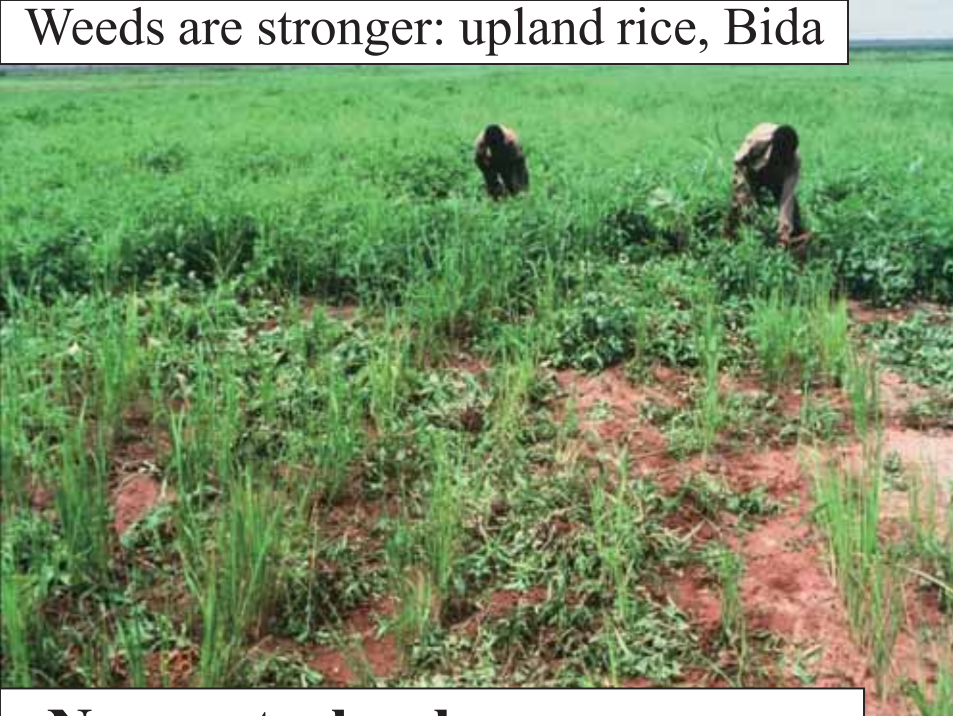
Integrated soil fertility management (ISFM)



(Vanlguwe,Bationo, Sanginga et al., 2010)

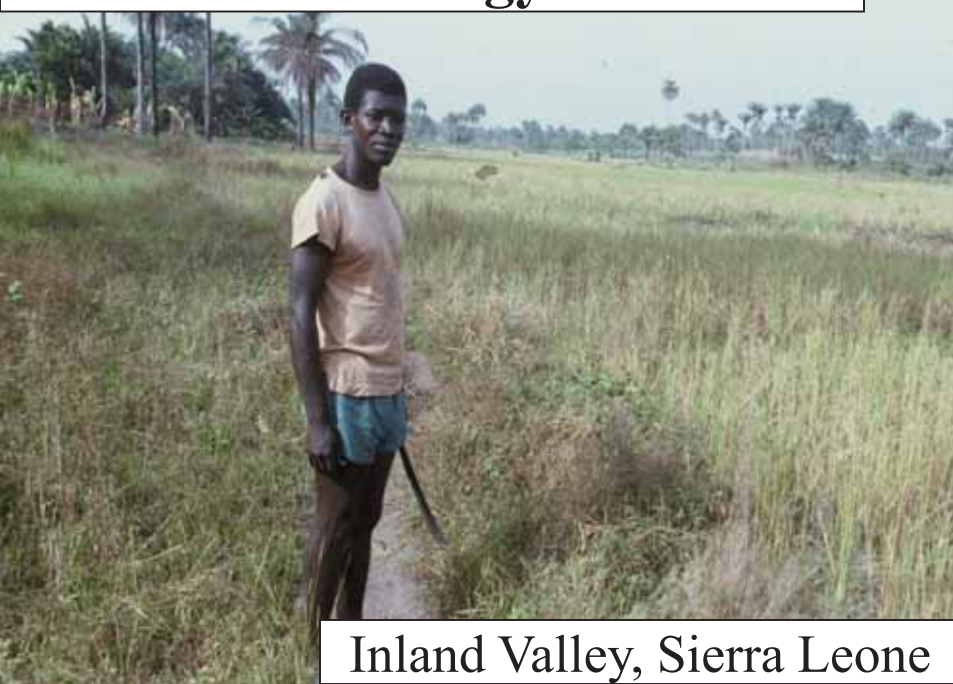
Figure 11. Concept of Integrated Soil Fertility Management can not work without proper platform like sawah

Weeds are stronger: upland rice, Bida



Nupe's indigenous partial water control system

No eco-technology 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 2. 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 (t/ha)		Rainfed sawah (t/ha)		Upland like fields (t/ha)	
			HIL	LIL	HIL	LIL	HIL	LIL
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

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

Poor tillering and aggressive weed in non sawah field

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

Submerged sawah: Multi functional ecosystems of various interaction between rice, algae, fish, goose, microbes, & others

Left :nitrogen fixing Azola

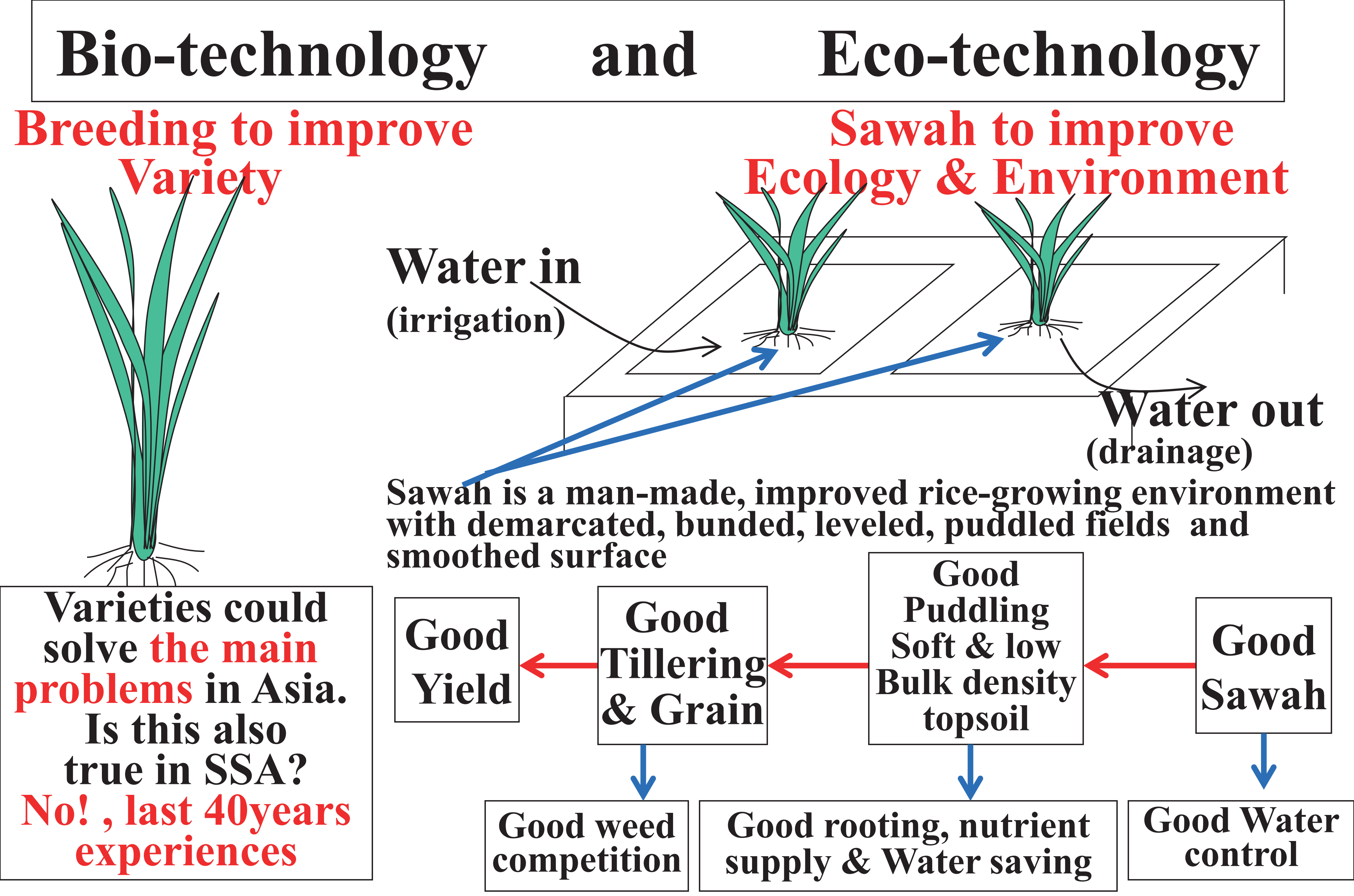


Fig 12. Rice (variety) and environment (Sawah) improvement. Both Bio & Eco-technologies must be developed in appropriate balance

Table 4. Biotechnology and Sawah Eco-technology Options and Complementation for Rice Production

(1) Water shortage and Flood damage

Biotech: 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 agronomic practices

(5) Food quality and Biodiversity

Biotech: Golden rice, other vitamin rice gene

Ecotech: Fish, duck and rice in sawah systems. Satoyama agroforestry systems

Table 5. 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 neutralizing 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 and to conserve bio-diversity

(3) Sawah systems as to control flooding by enhance dam function through bund management

(4) Sawah system as ground water recharge system and to soil erosion control

(5) 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

Sawah rice farming: Ecotechnology for Food, Environment, Landscape, and Culture(Multi-functionality) (World Heritage, Ifugao people, Philippine,Koudansha Co. Ltd, 1998)

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

Japanese Inland Valley system (SATO-YAMA): Integration of Forest, Pond & lowland Sawah in watersheds

Sawah is Multi-Functional Wetland: Rice, Algae, and Microbes' Complex Ecosystems

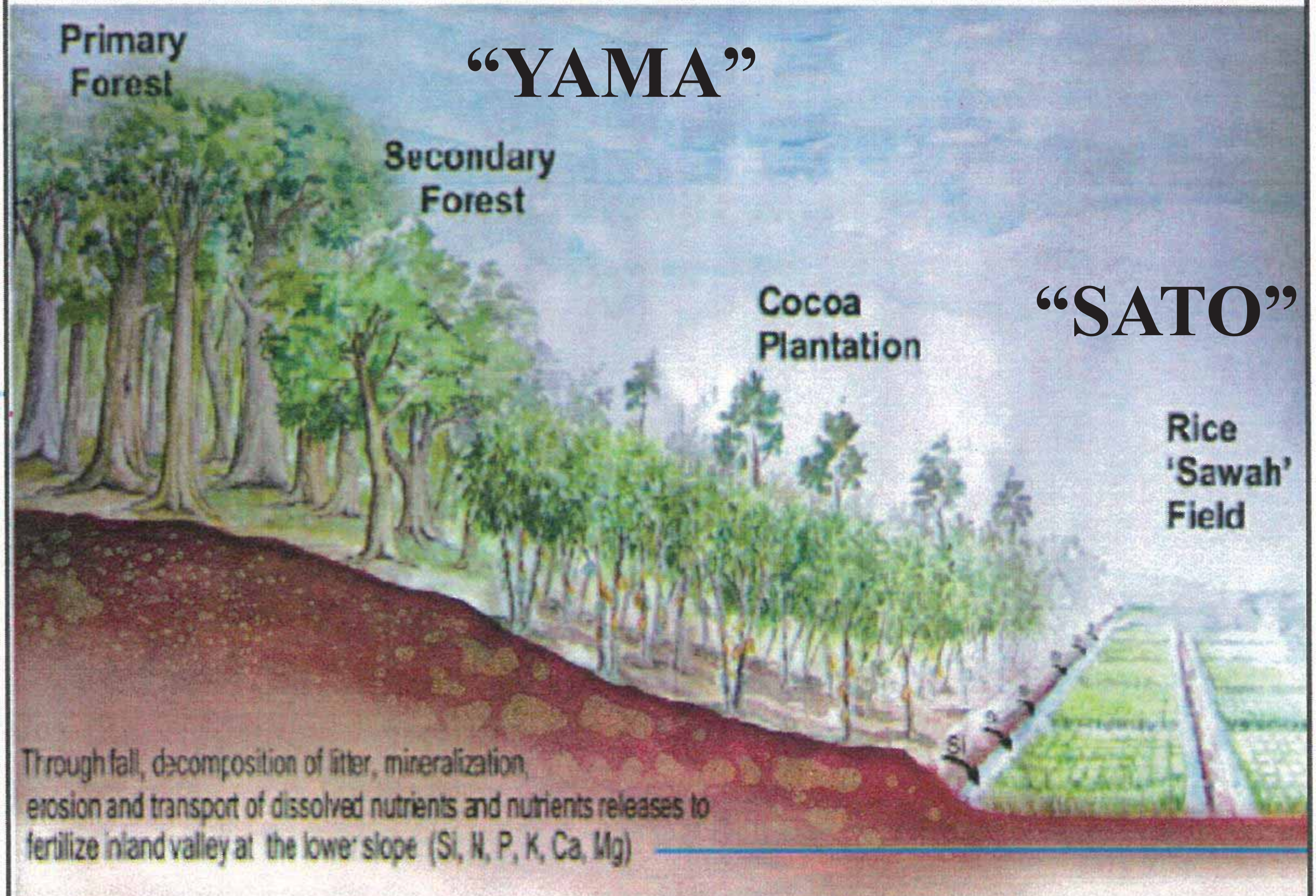


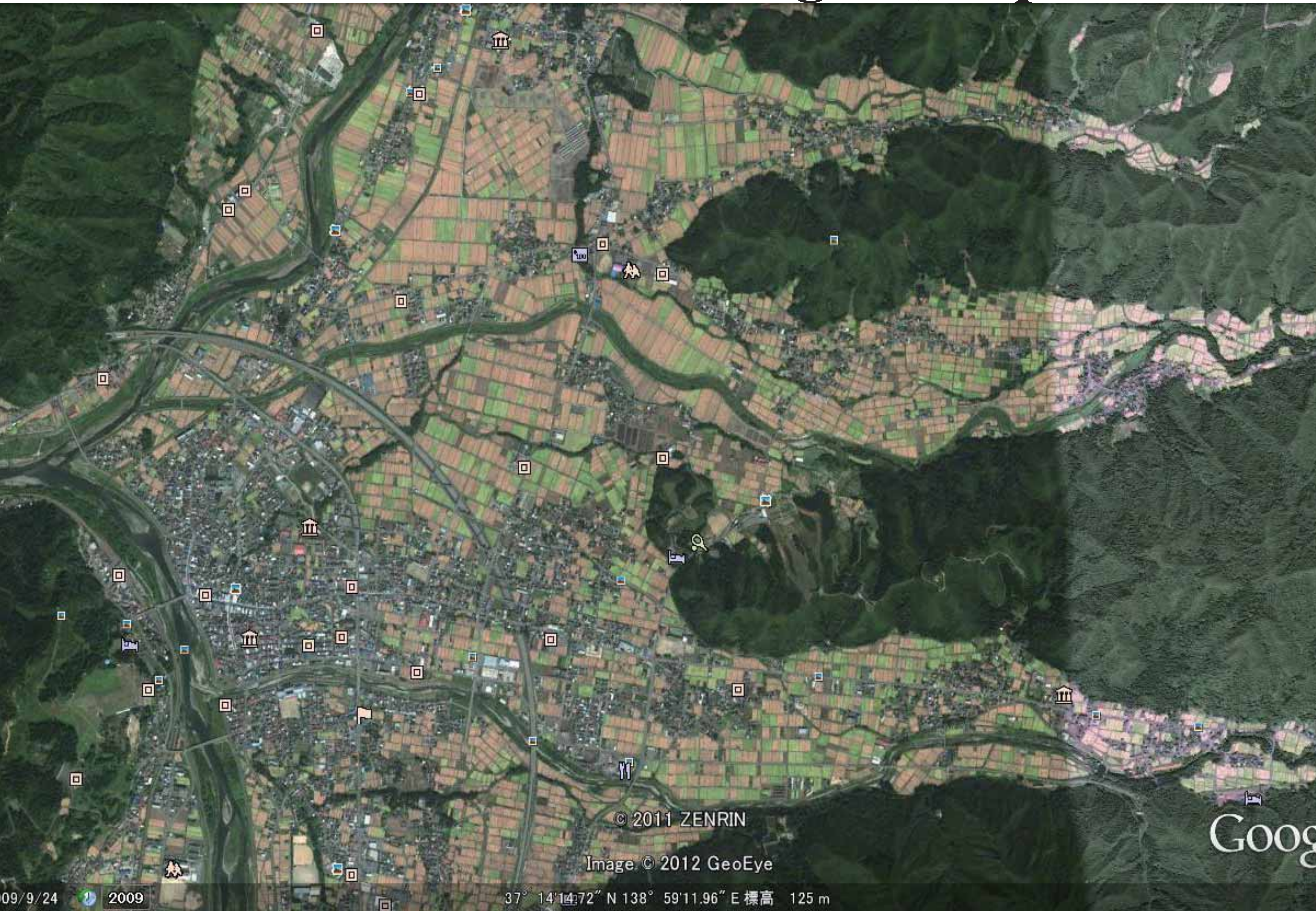
Figure 10. One Example of Africa SATO-YAMA Concept Map by Dr. Owusu, FoRIG, Ghana which is a watershed agro-forestry applicable to Cocoa belt region in West Africa.

Kumasi, Gold valley Site, Non Sawah and Cacao farm

Kumasi, Tawiah Site, Terraced sawah and Cacao and citrus farm

Kumasi, SRI assisted Baniekrom Site, lowland sawah, oilpalm, Cacao in opposite side and access road & citrus farm in front side (August 2013)

Minami Uonuma, Niigata, Japan



Mt, Oscar's Sawah rice and Cacao farm, at Afari, Kumasi, Ghana


Thanks
Traditional Nupe's
Paddy fields
Nigeria
New Sawah
Field