Asian African Collaboration for sustainable African green revolution through Sawah and Satoyama ecotechnology to combat Global Food and Ecology Crisis in 2025, T. Wakatsuki, Shimane Univ, Japan

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

Non-Sawah upland paddy field Guinea, Aug.03

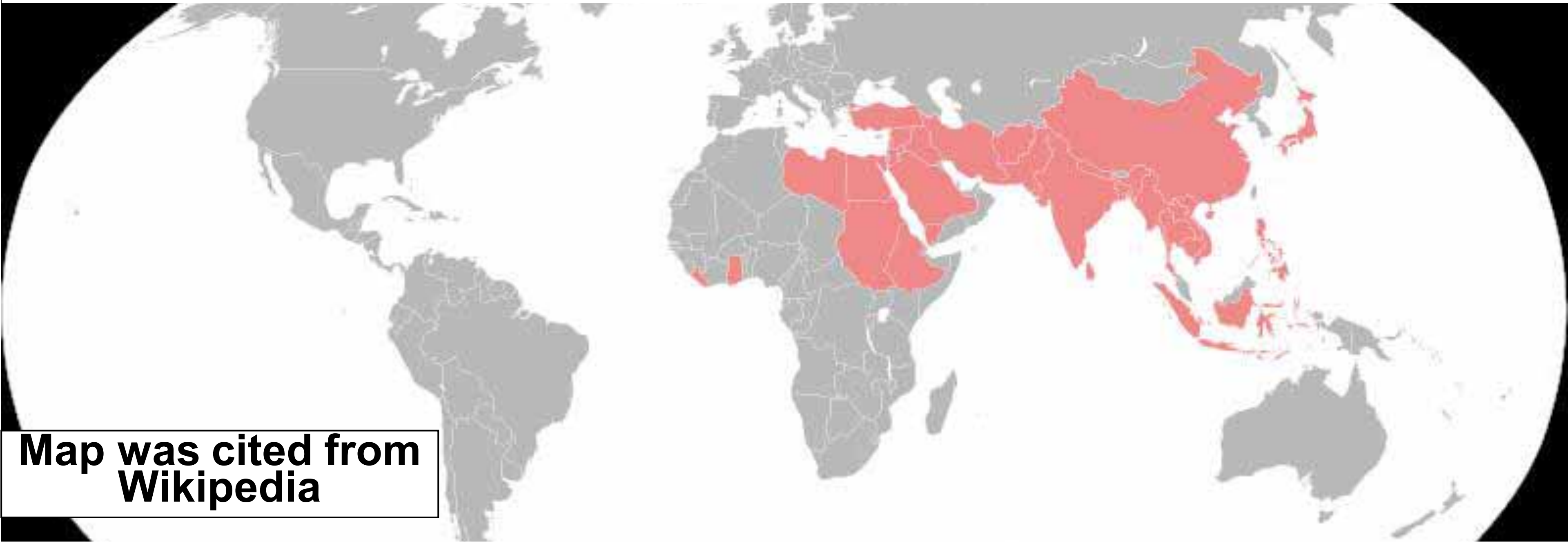
Degraded non-Sawah lowland Paddy field, Sierra Leone, Jan. 1989

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)

Indonesia: historical host for Asian African (AA) collaboration



Map was cited from Wikipedia

Bandung AA Conference 1955: By **1950**, 5 years after World War **II**, **1945**, the most Asian states were newly independent from long last colonial rule. Then the first meeting of **Asian–African** States was organized at Bandung, (after preceded conference at Bogor 1949), Indonesia, on April 18–24, **1955**. By **1960**, the most of African states were also independent thanks to Asian independent, collaboration and support.

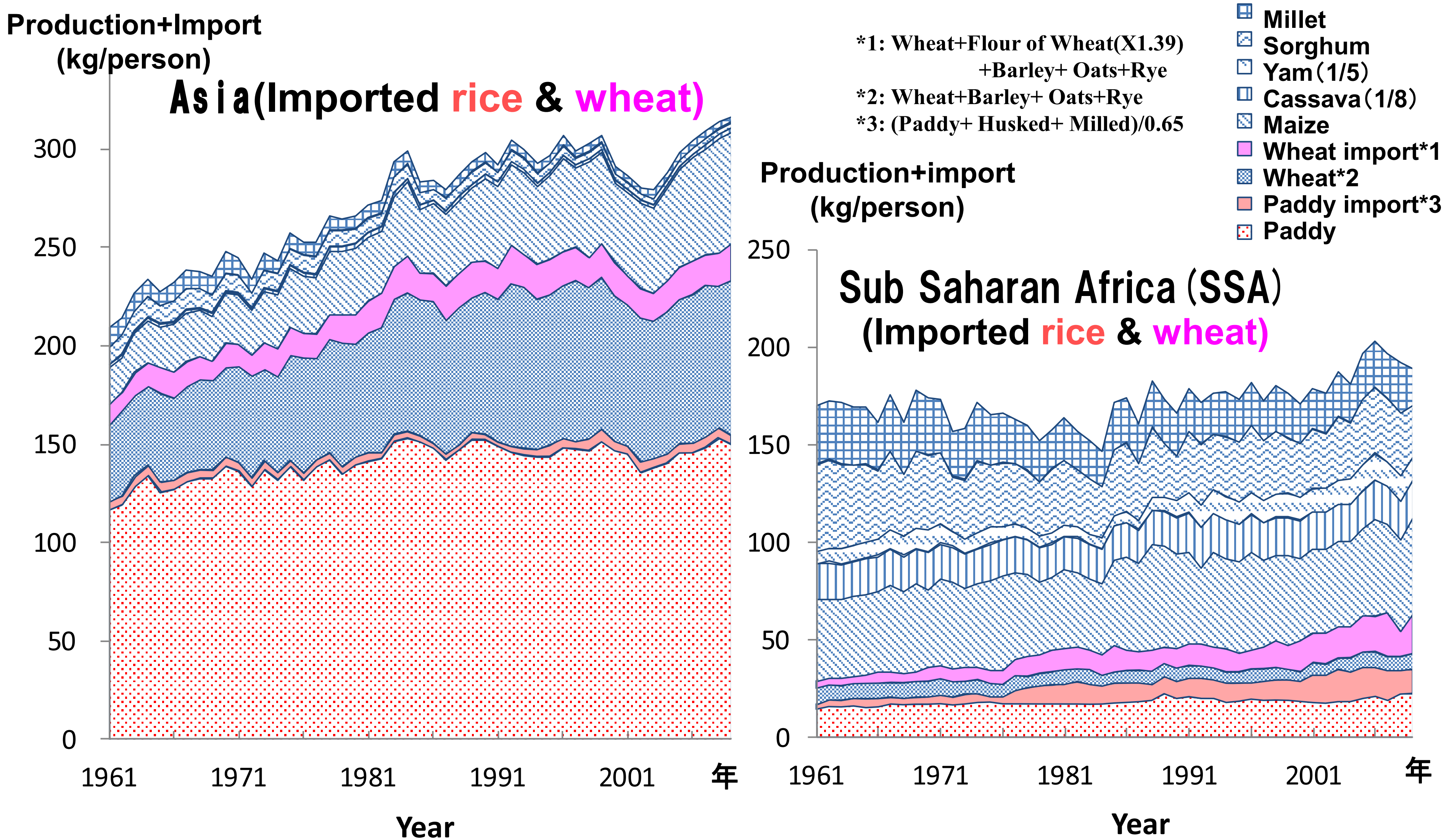
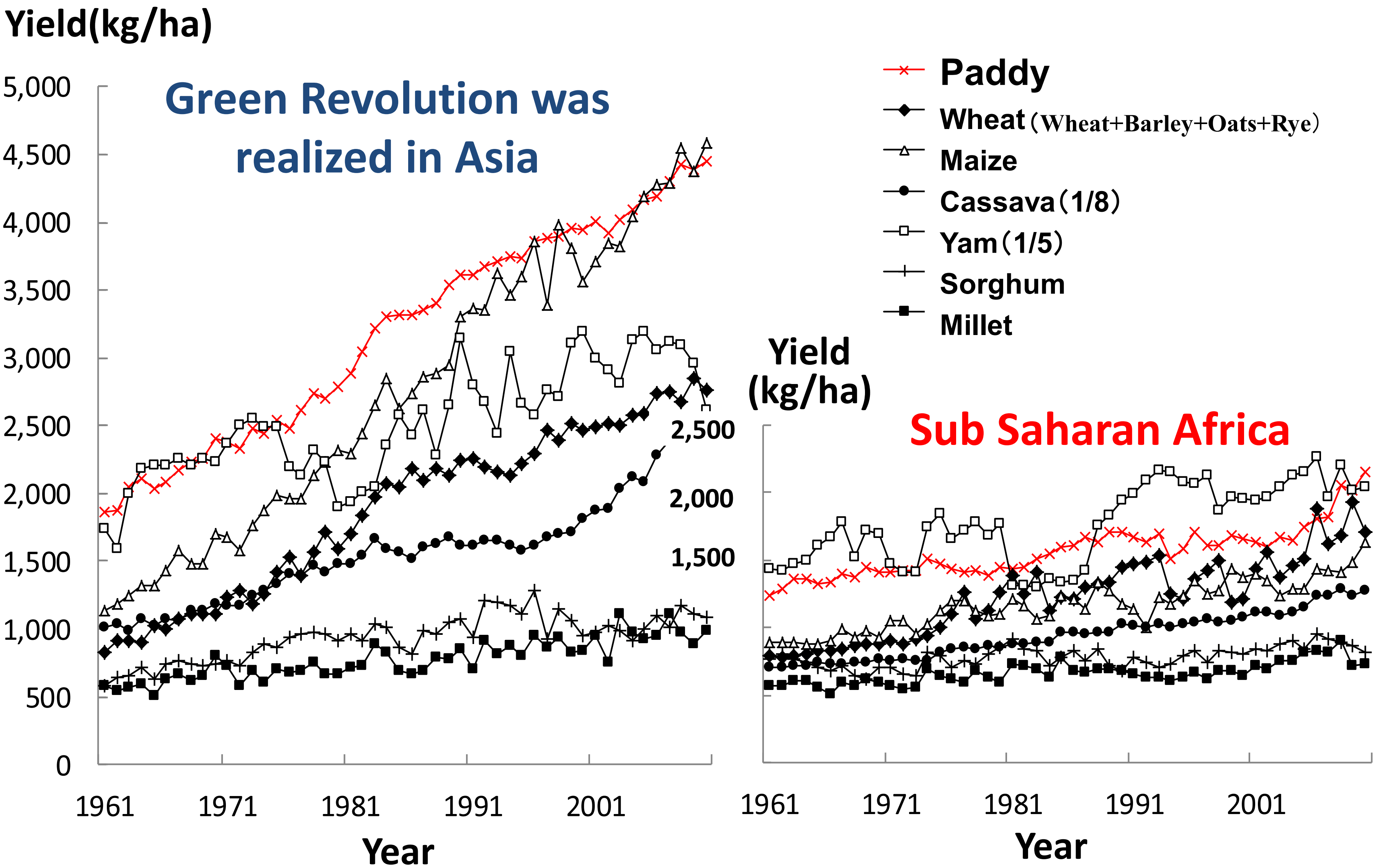


Fig. Per capita cereal equivalent food consumption (production+ import) in Sub Saharan Africa (SSA) and Asia during last 50 years.

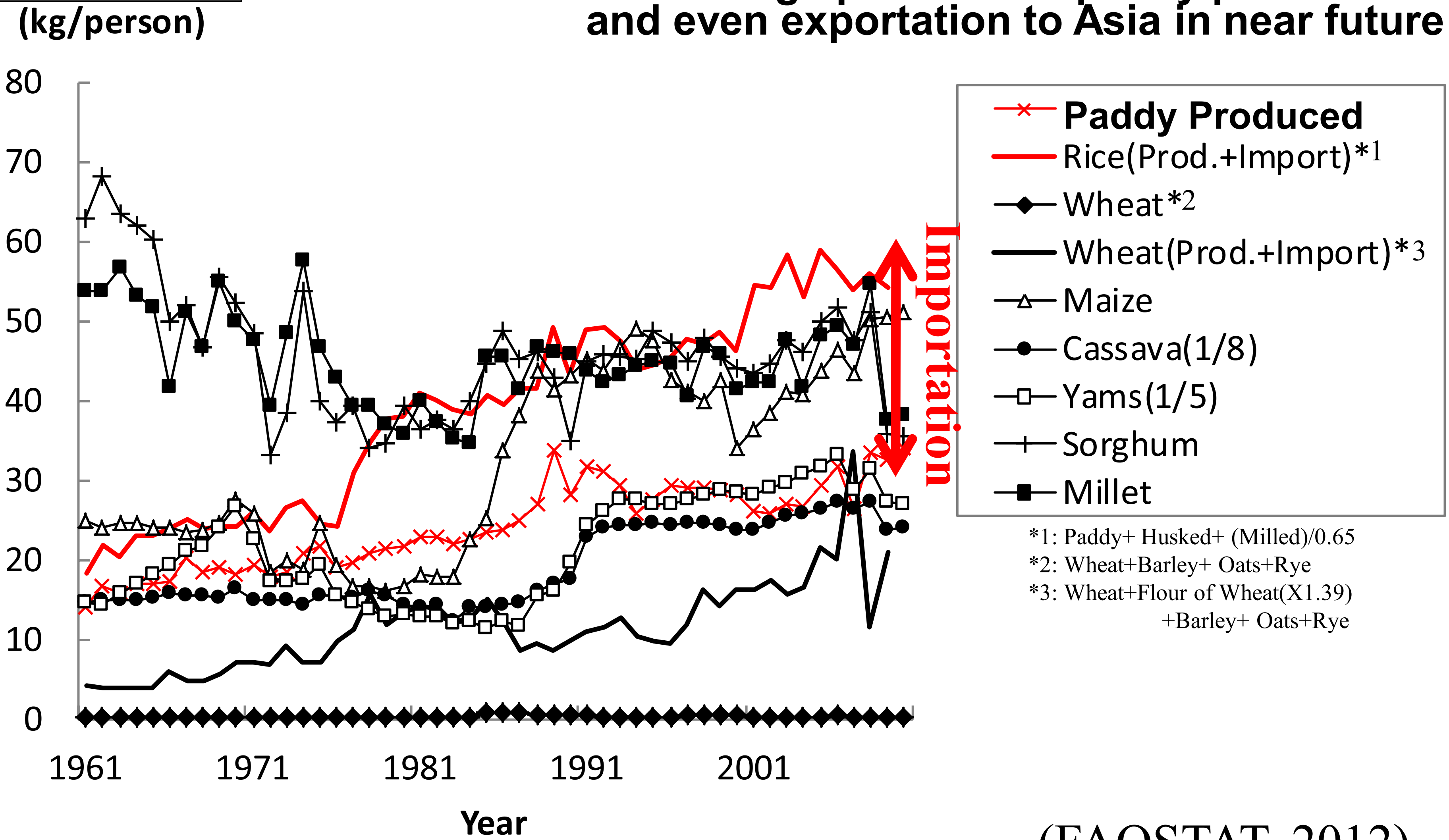
Both SSA & Asia had produced ±200kg of per capita cereal equivalent food in 1960s. 50 years after, Asia increased about 300kg, but SSA is less than 200 kg. Rice production (140%) was increased considerably. The consumption of rice dramatically increased (186%). Thus the importation of rice was increased 383%. SSA has very high potential ecology for rice production.

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.



West Africa Per Capita consumption of each cereal

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



*1: Paddy+ Husked+ (Milled)/0.65
*2: Wheat+Barley+ Oats+Rye
*3: Wheat+Flour of Wheat(X1.39) +Barley+ Oats+Rye

(FAOSTAT, 2012)

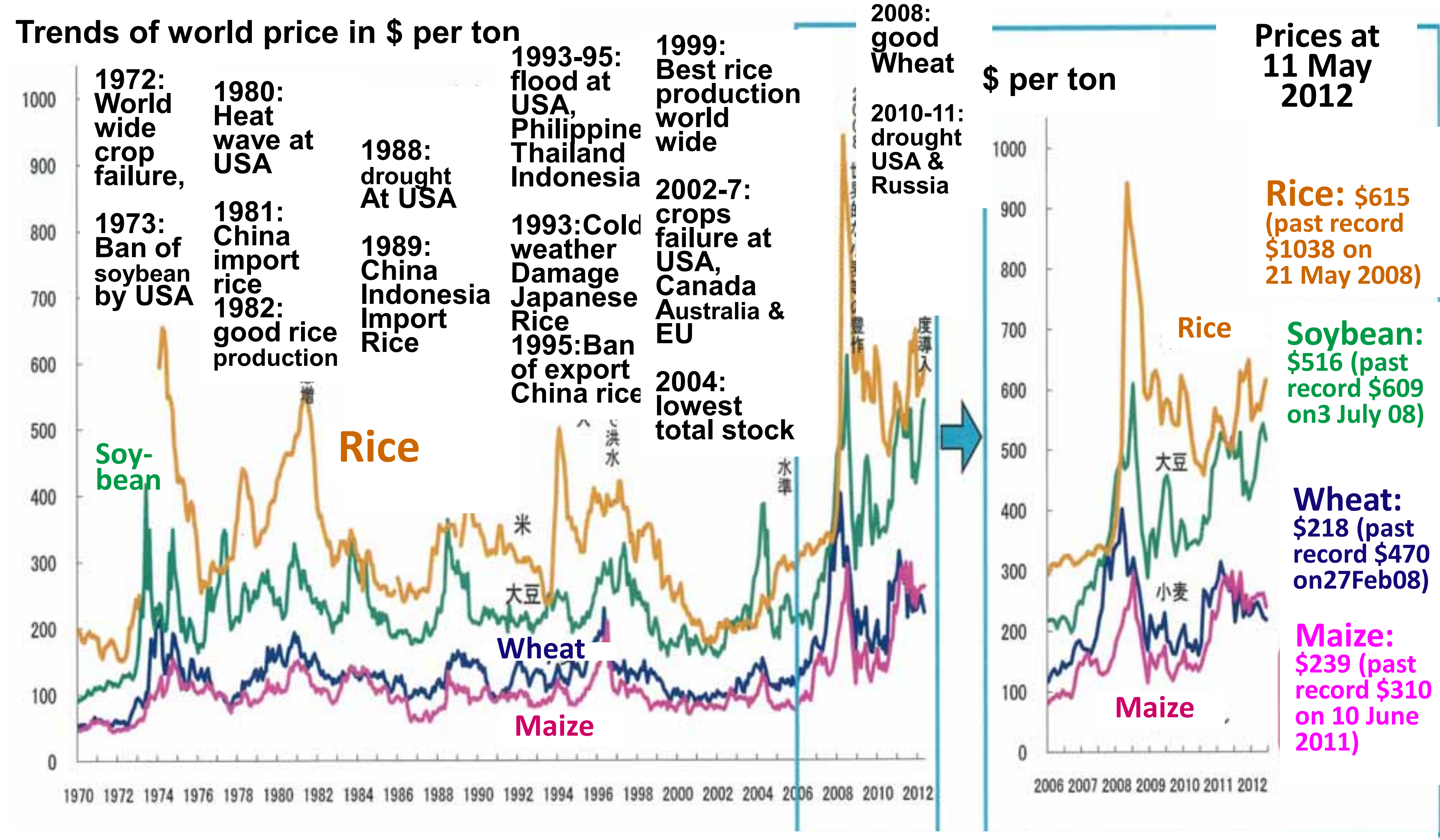


Figure 3. Trends of world trading prices of Rice at Thai (milled 2nd class FOB) , Soybean, Wheat and Maize at Chicago commodity exchange during 1961-2012 (Ministry of Agriculture, Forestry and Fishery, MAFF, Japan 2012).

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. Note FOB, Free On Board at Bangkok port.

Conceptual Summary of STI on Green Revolution in Asia

Technology: 1935: Dr. G. Inazuka's Norin 10 of Wheat. Grandfather

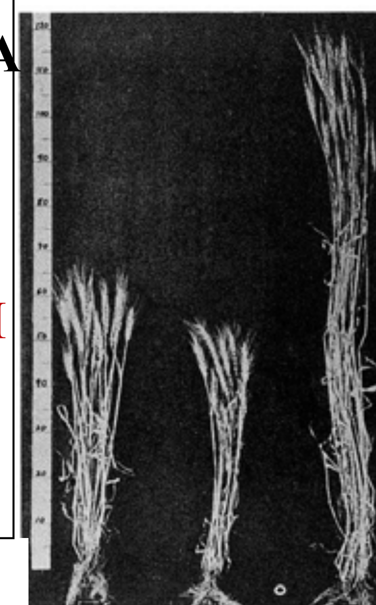
Innovation: (1) 1957: Dr. N. Borlaug, Father of High Yielding Variety (HYV) and **CG centers, like CYMMET, IRRI**

(2) 1966: IRRI's IR-8, Miracle Rice

Science: 2004: Dr. Matsuoka identified Sd 1, (Semi-dwarf gene 1) DNA

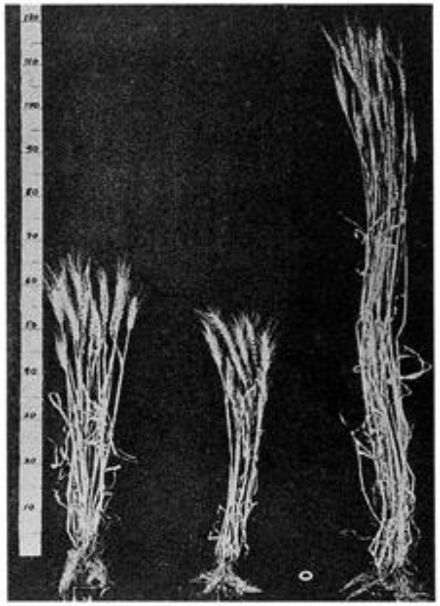
Norin 10 was bred by Dr G Inazuka at Iwate Agricultural Experimental Station, Japan on 1935 (Photographs by Senda 1996)

Right: Turkey Red
Center:Fruit DARUMA
Left: NORIN 10 was bred on 1935
Similar breeding concept was applied to breed IR-8 at IRRI
Dr. N. Borlaug was awarded Nobel Prize in Peace at 1970



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

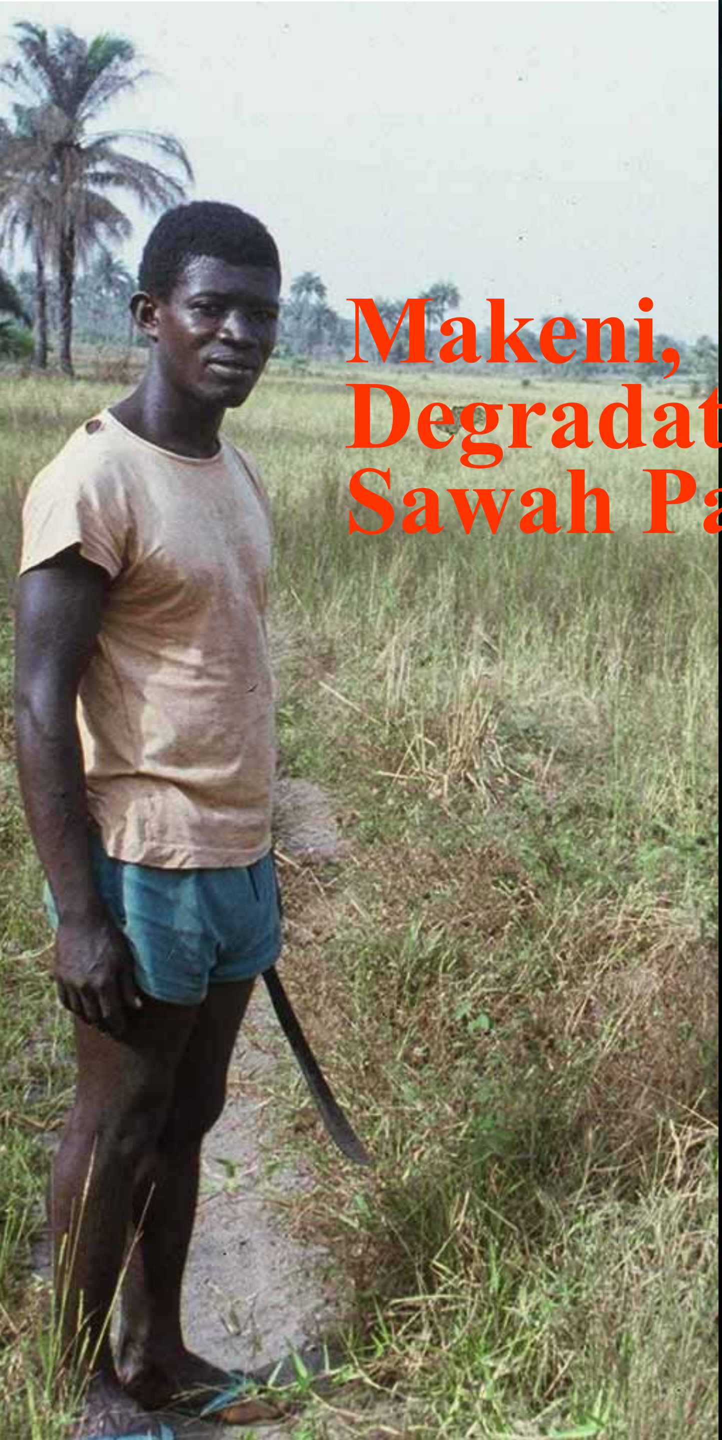
Similar breeding concept of the Norin 10 was applied to breed IR-8, Miracle Rice, at IRRI to realize Rice Green Revolution in Asia1 (Photo left by Senda 1996, down by IRRI)



Various Rice Farming systems in West Africa

Gao, Mali,
African rice(Oryza Glaberrima was domesticated in West Africa

Makeni, Sierra Leone,
Degradation of Inland Valley soil by N
Sawah Paddy cultivation)



Nigeria, Bida, Flood plain, ridge paddy planting, but weeds come

Irrigated Lowland Paddy Field (Rudimentary Sawah). No Integration of Fulbe Grazing with Nupe Rice Farming

Sokoto
Paddy field
on
flood plain
Jan. 1987

Floodplain
Paddy field
at Kebbi,
Jan. 1987

May 2011: Oasis type pump irrigated rice fields and vegetable field at Sokoto and Kebbi Flood Plain

Sawahs of Madagascar may have thousand years of history with the migration of "old" Maly-Indonesian. Sawah systems are the base of "System Rice Intensification (SRI)" (from 2009 JICA trainee of Mr. Lantonirina Gilles)

Table. No concept and term Sawah or SUIDEN (in Japanese). No proper English/French and local language in West Africa and SSA to describe eco-technological concept and term to improve farmers'rice fields, such as Sawah.

Suiden(Japanese) =SAWAH (Malay–Indonesian)

	English	Indonesian	Chinese (漢字)
Plant Biotechnology	Rice	Nasi	米, 飯, 稲
	Paddy	Padi	稲, 籾
Environment Ecotechnlogy	(Paddy) ?	Sawah	水田

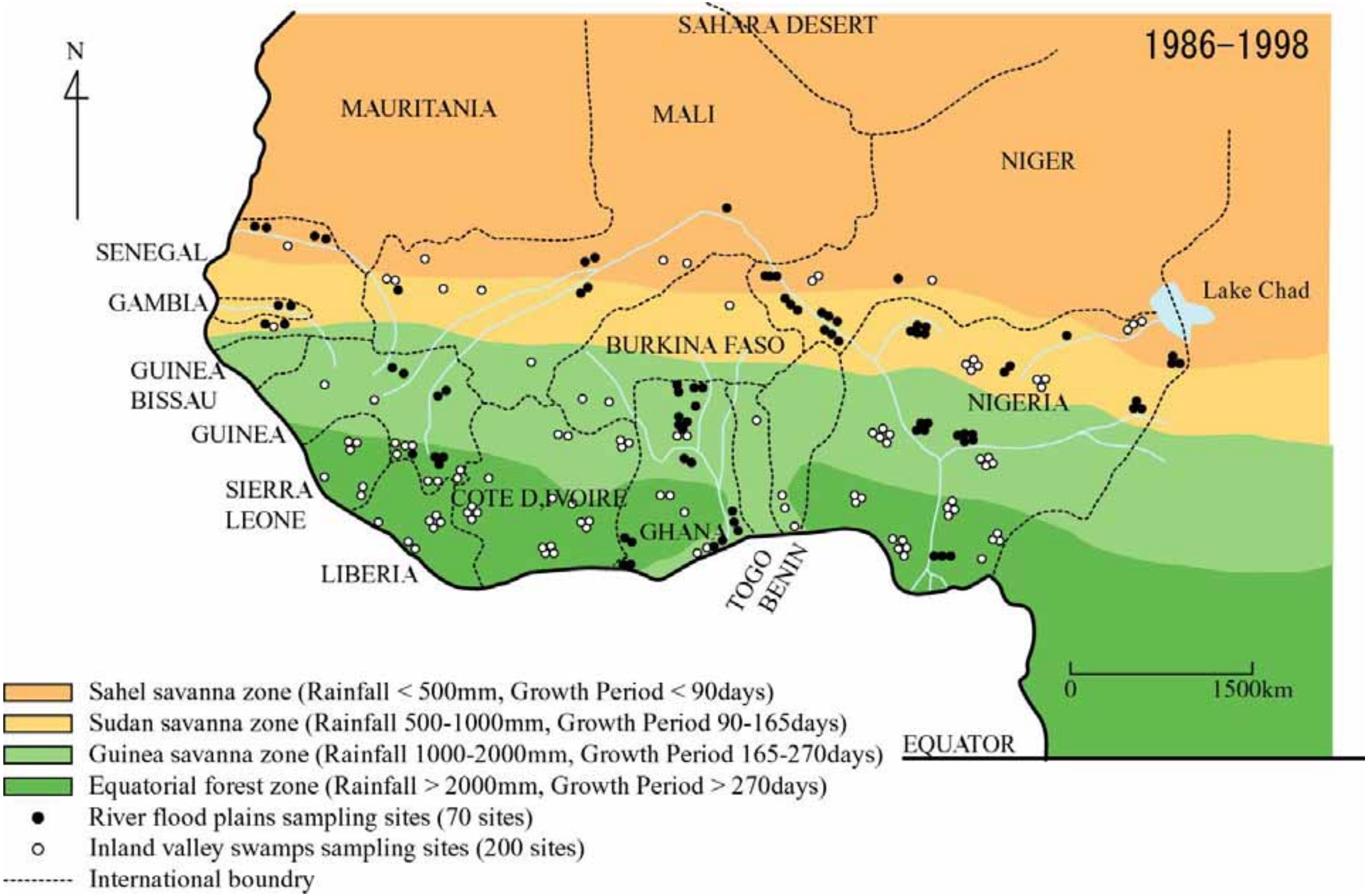


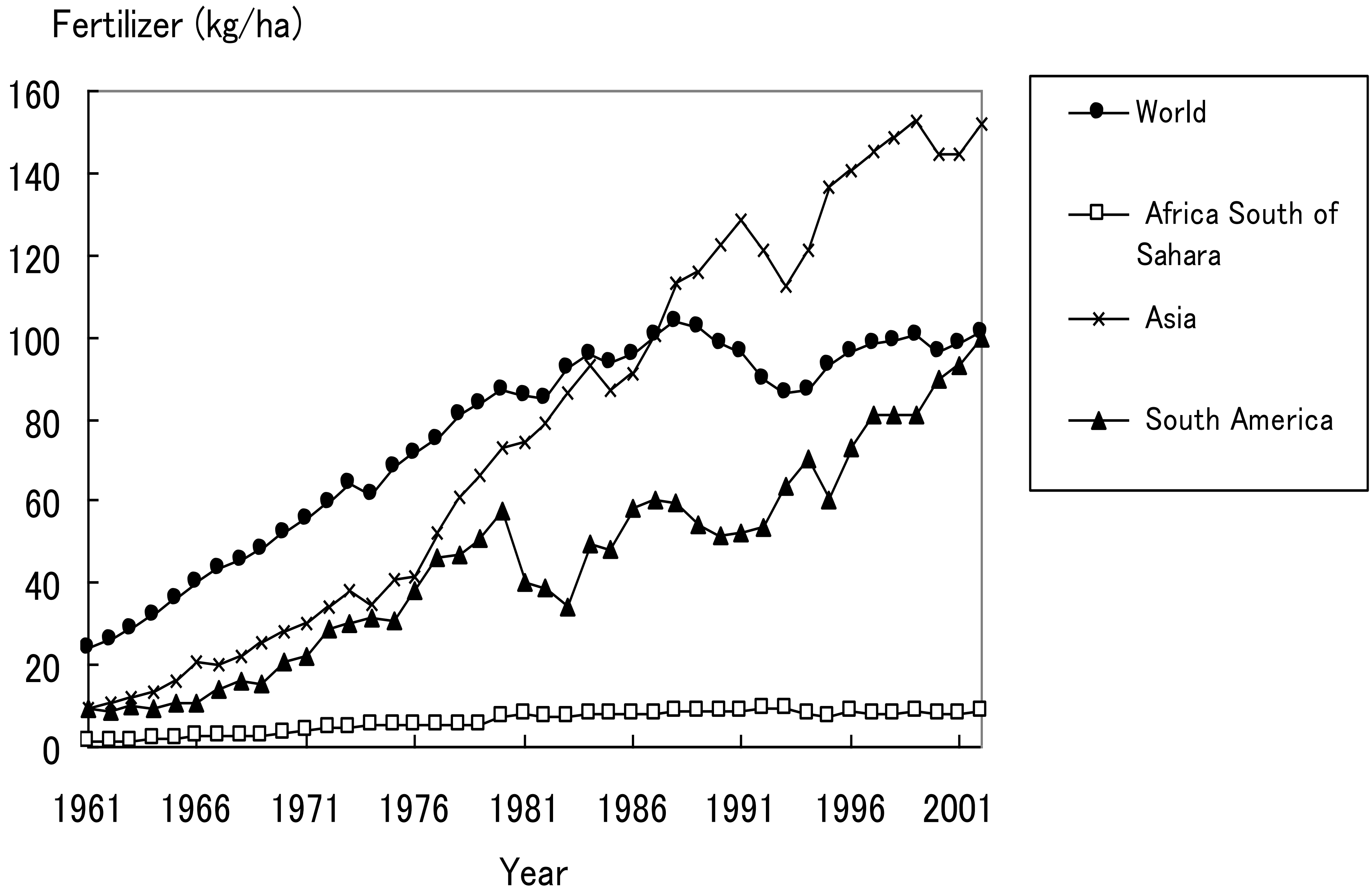
Fig. 2. West Africa map showing selected sampling sites. Soil sampling during 1986-1998.

Table 4. Mean values of fertility properties of **top-soils of inland valleys (IVS) and flood plains (FLP) in West Africa** in comparison with lowland top-soils of **tropical Asia (T. Asia)** & Japan

Location	Total C (%)	Total N (%)	Available P (ppm)**	Exchangeable Cation (cmol/kg)				Sand (%)	Clay (%)	CEC /Clay
				Ca	K	Mg	eCEC			
IVS	1.3	0.11	9	1.9	0.3	0.9	4.2	60	17	25
FLP	1.1	0.10	7	5.6	0.5	2.7	10.3	48	29	36
T. Asia*	1.4	0.13	18	10.4	0.4	5.5	17.8	34	38	47
Japan	3.3	0.29	57	9.3	0.4	2.8	12.9	49	21	61

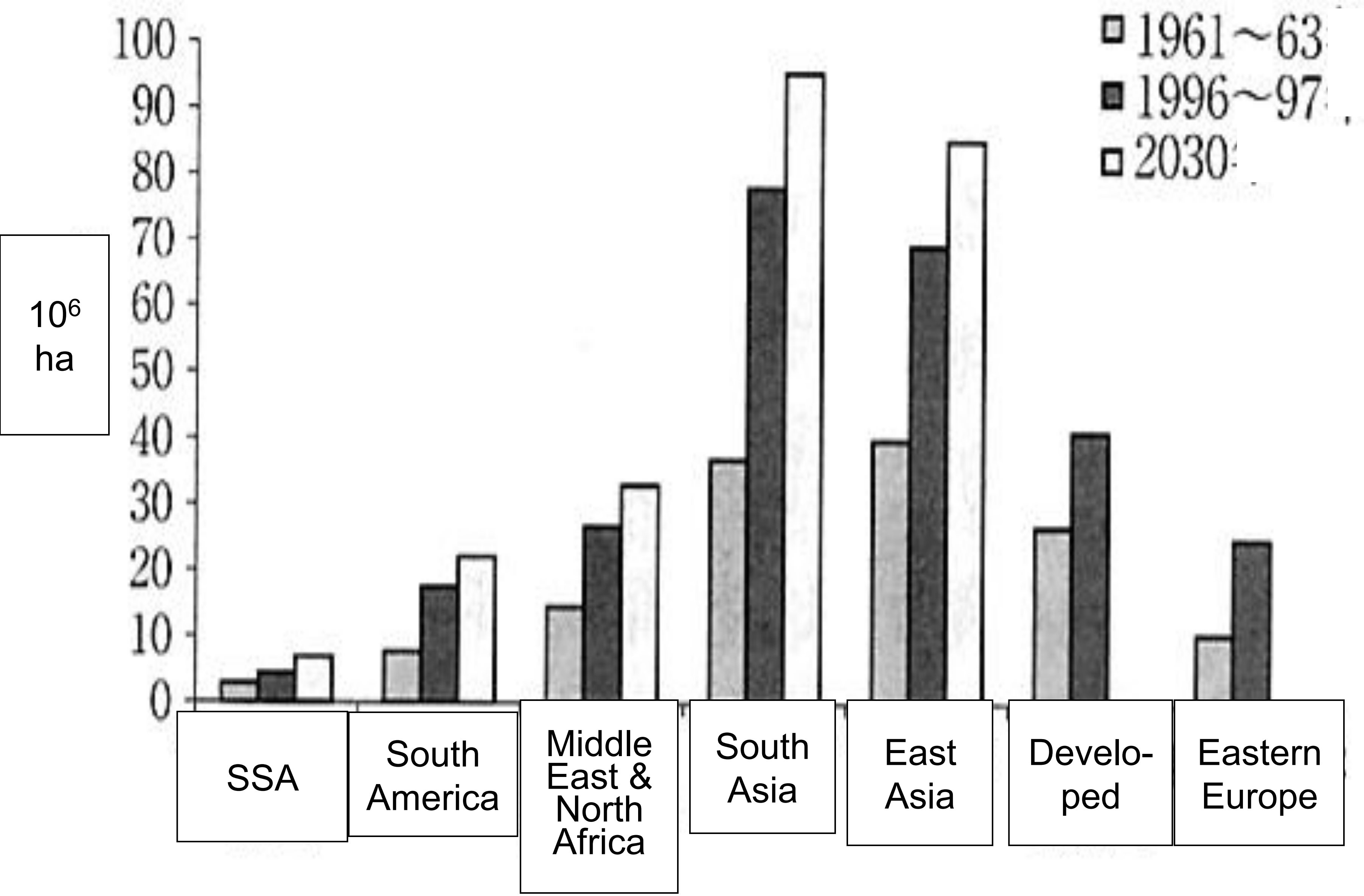
*Kawaguchi and Kyuma (529 sites), 1977, Kyuma 2004, ** Bray II.

Source: Hirose and Wakatsuki (268 sites in West African IVS and FLP by Issaka et al 1997 and Buri et al 2000), 1997 and 2002.



Fertilizer (kg/ha)
160
140
120
100
80
60
40
20
0
1961
1966
1971
1976
1981
1986
1991
1996
2001
Year
World
Africa South of Sahara
Asia
South America

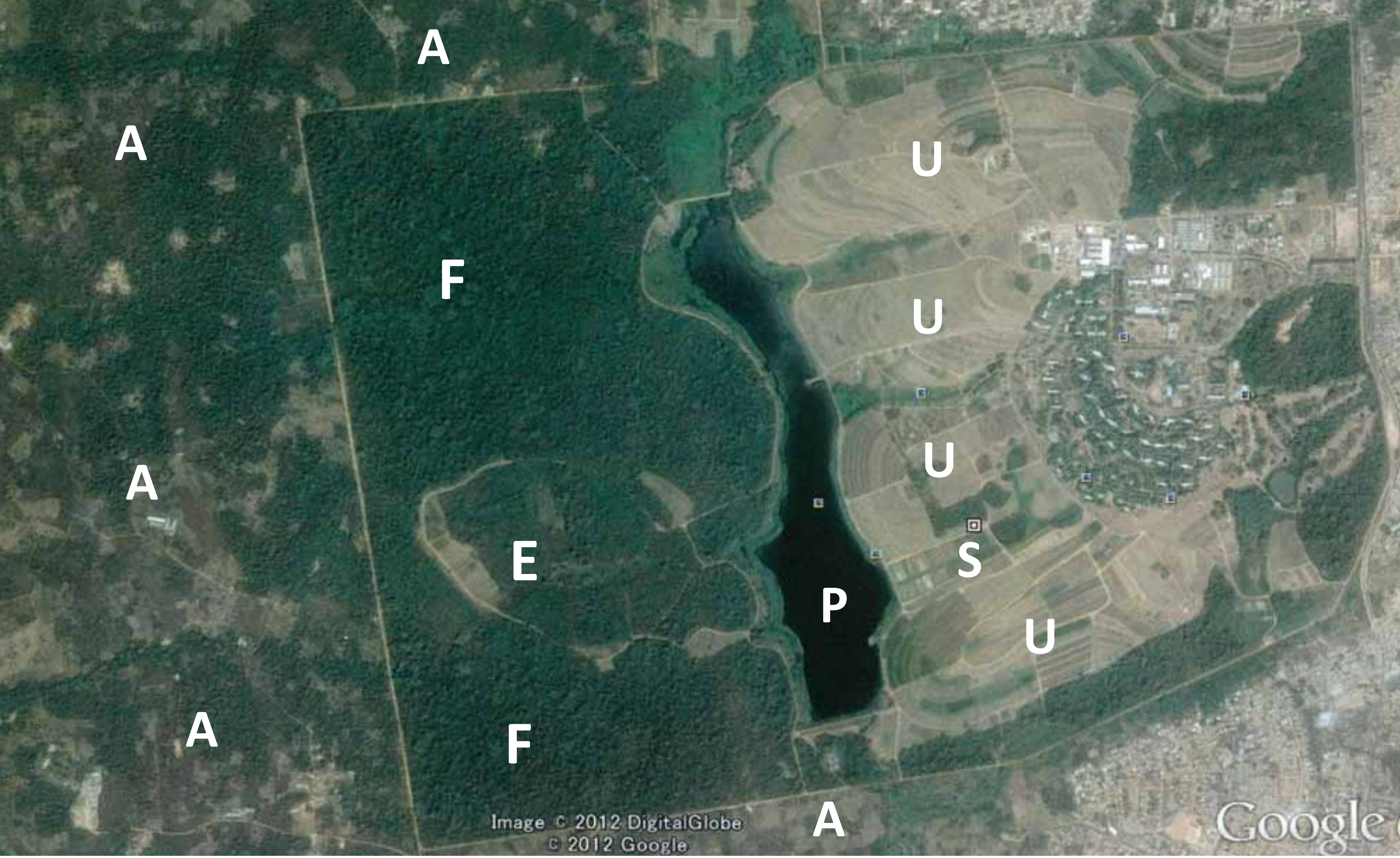
$N+P_2O_5+K_2O$



World Irrigated Area in million ha(Yoshinaga et al, FAO)

After the dramatic success by CYMMET and IRRI in 1970s in Latin America and Asia,
various HYVs were available in Sub Sahara Africa during last 40 years, 1970-2013
(although 2013 FAOSTAT data indicate, the progress is already on-going).

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



Sawah Hypthesis 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

Sawah hypothesis 1 for Green Revolution, Sawah hypothesis 2 for intensive sustainability, SATOYAMA Watershed agroforestry to combat watershed degradation and global warming

Non-Sawah upland paddy field Guinea, Aug.03

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

Sawah Hypothesis 1：Platform to apply scientific technologies. Farmers bushy rice fields have to be classified and demarcated based on topography, soil and hydrology.

Sawah developed by China farmers(Otsuka 2004)

Sawah system developed by Ghanaian Famers, 2001

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

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

Terraced sawah systems at Inland Valley, Asuka, Nara, one of the oldest in Japan, established 1500 years ago through the technology transfer by Korean emigrants to Japanese

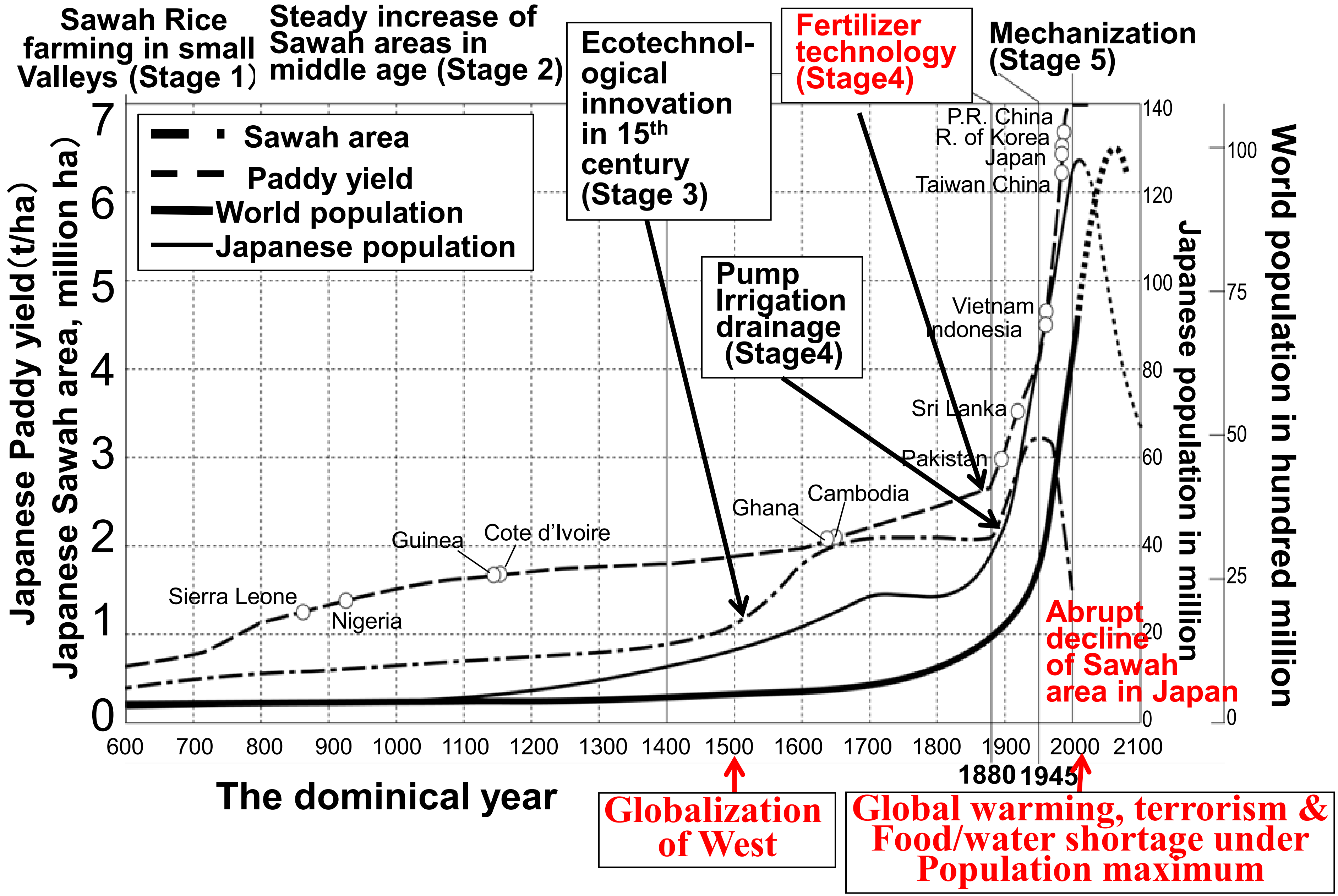


Figure 9. Historical path of Japanese and world population, Sawah area, and paddy yield in comparison with Asia and Africa at 2001/2005 of FAOSTAT data. (Takase & Kawano 1969, Honma 1998, JICA 2003, Kito 2007, Wakatsuki 2013b)

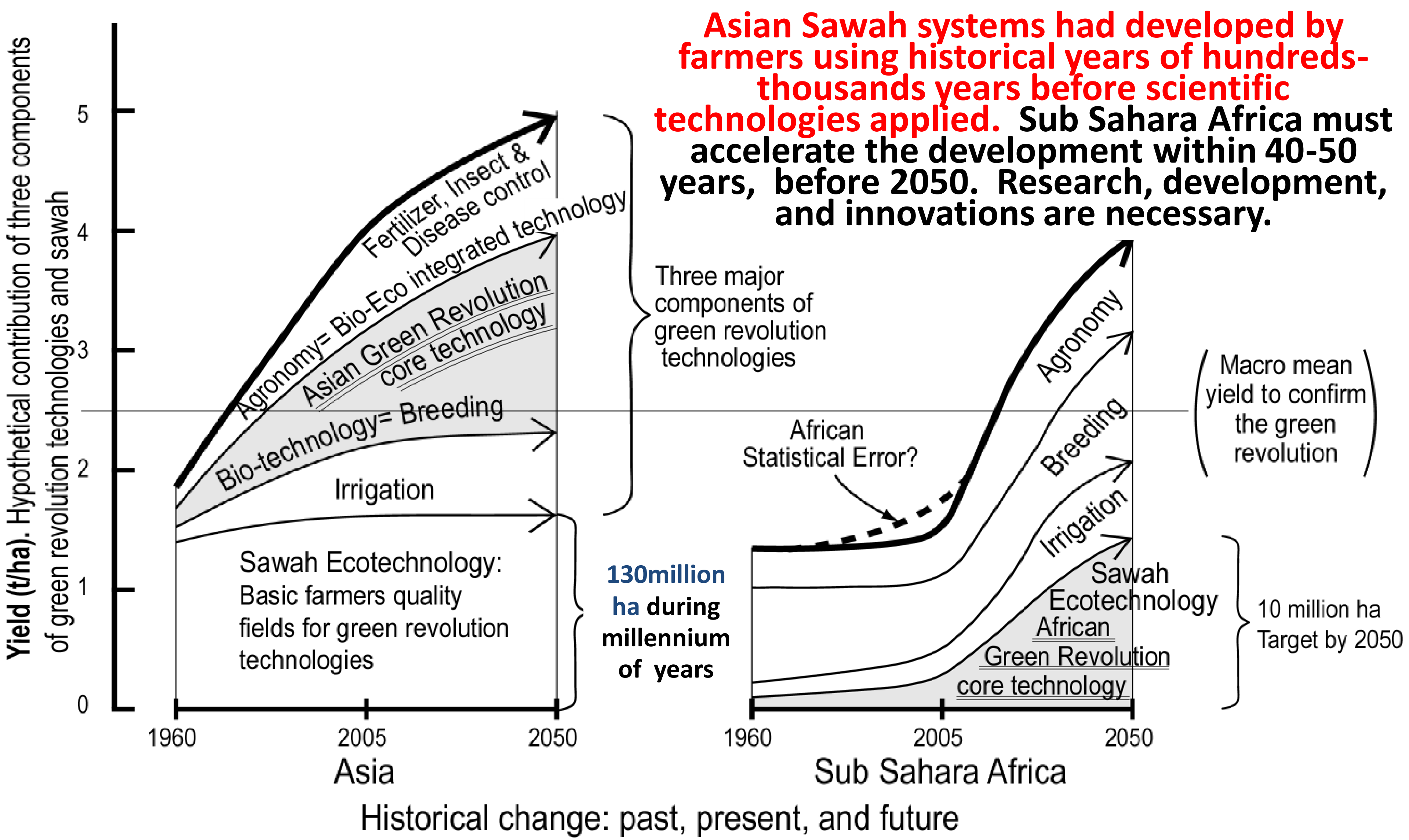


Fig. 4 : Sawah hypothesis (1) for Africa Green Revolution:

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.

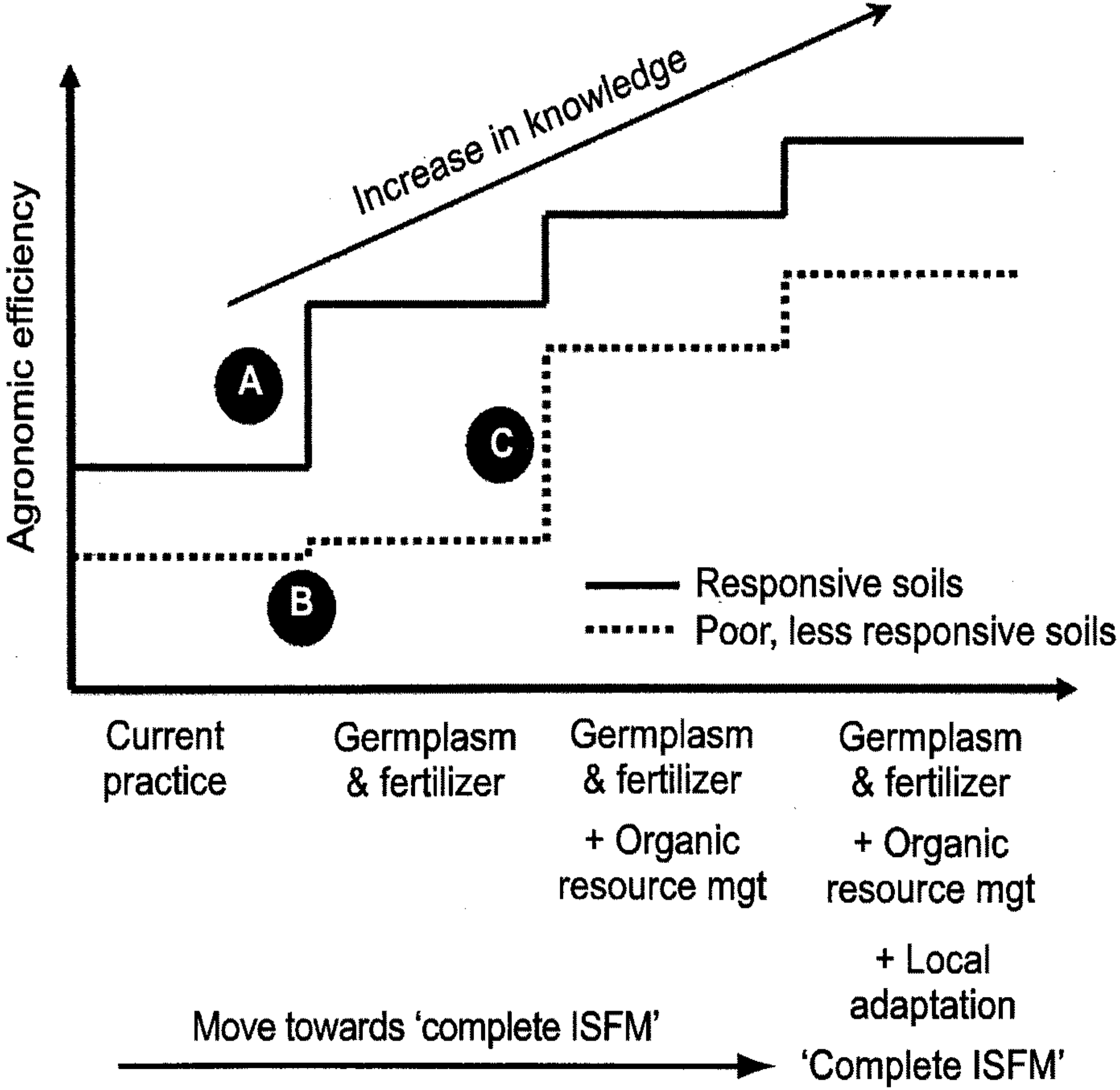
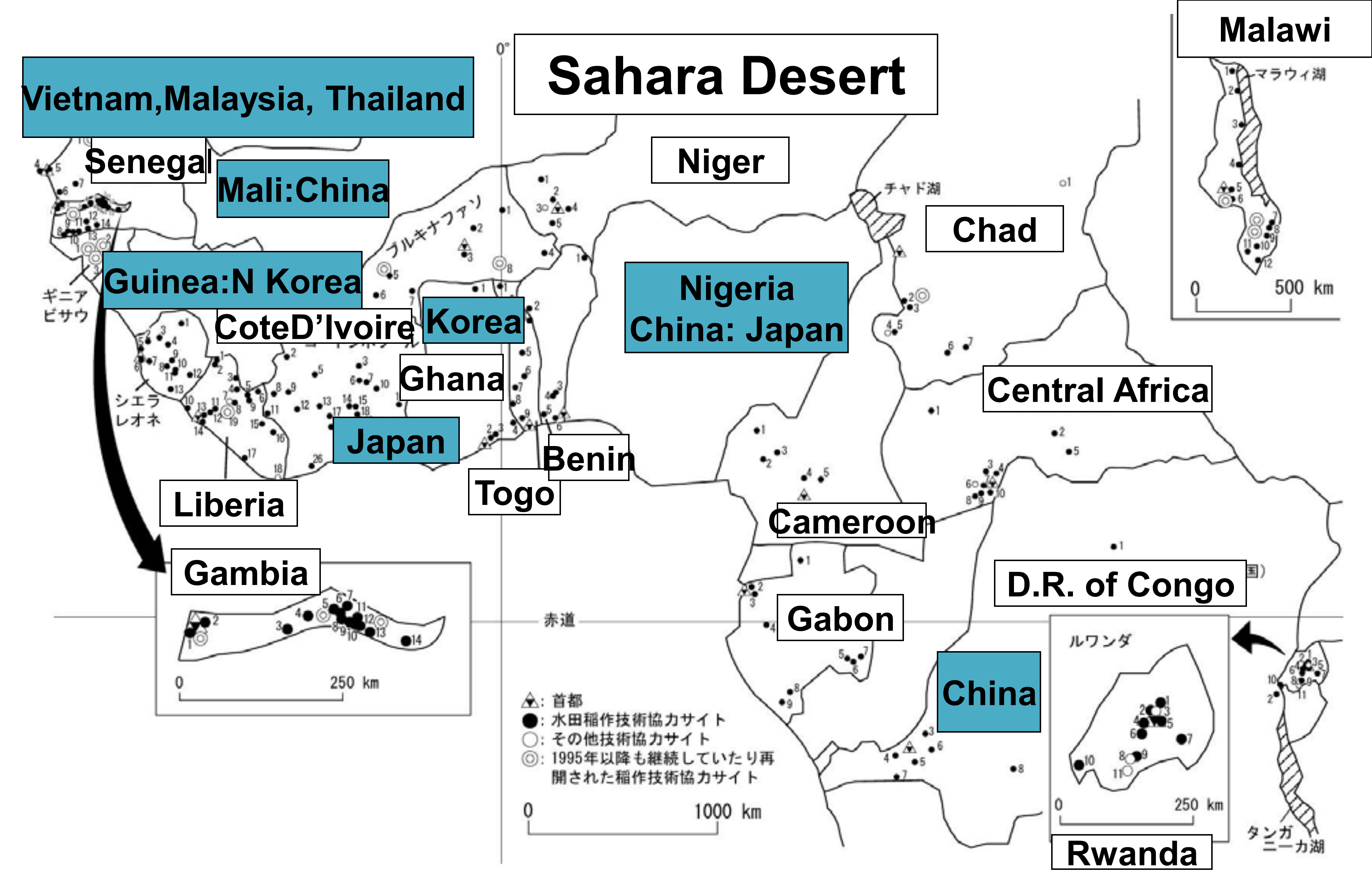


Figure 8. Concept of Integrated Soil Fertility Management(ISFM) by Vanlguwe, Bationo, Sanginga et al, (2010) can not work without proper platform like sawah



Sawah Project sites by ESAFS countries: Taiwan is Pioneer for Sawah technology transfer to Africa（Except for blue countries, all the others are the sites of Taiwan:(I) 1960-75 & (II) 1995-2007+ ?

Table 5: Comparison of farmers' site-specific personal irrigated sawah system development and sawah based rice farming(Sawah eco-technology) with large- and small-scale contractor (ODA) style developments, and traditional rice cultivation system in inland valleys of Ghana and Nigeria (2013).

	Large-scale development	Small-scale development	Sawah eco-technology	Traditional system
Development cost ($/ha)	**10000–30000**	**10000–30000**	**1000-3000 (10 yrs ago 3000-7000)**	**30–60**
Gross revenue ($/ha)†	2000–3000	2000–3000	2000–3000	500–1000
Yield (t/ha)	4–6	4–6	4–6	1–2
Running cost, including machinery ($/ha)	900–1000	900–1000	900–1000	300–400
Farmer participation	Low	Medium–High	High	High
Project ownership	Government	Government	Farmer	Farmer
Adaptation of technology	Long,	Medium to short	Medium to short, needs intensive demonstration and on-the-job training (OJT) program	Short
Technology transfer	Difficult	Difficult	Easy	Few technology transfer
Sustainable development	**Low(heavy machinery used by contractors in development)**	**Low to medium**	**High (farmer-based and small power-tiller used in development and management)**	**Medium**
Management	**Difficult**	**Difficult**	**Easy**	**Easy**
Adverse environmental effect	High	Medium	Low	Medium

† Assuming 1 ton paddy is worth US$ 500; one power-tiller costs US $ 3000-5000 in West Africa depending on the brand quality and accessories (2012 values). Selling prices are $1500-$3000 for farmers in Asian countries.

Site Specific & farmers' personal irrigated Sawah development to realize green revolution in Africa
(Farmers self-support efforts is a Key)

June 99, **JICA Sawah project**

Aug 09
JIRCAS site

Farmers sawah technology will prepare the platform for the green revolution technologies

Soil and Wooden Weir, because of farmers' self-support

Farmers' to farmers technology transfer

On the job sawah ecotechnlogy training including PhD program, NCAM

On-The-Job training: Sawah, Fadama and ADP staffs, & farmers

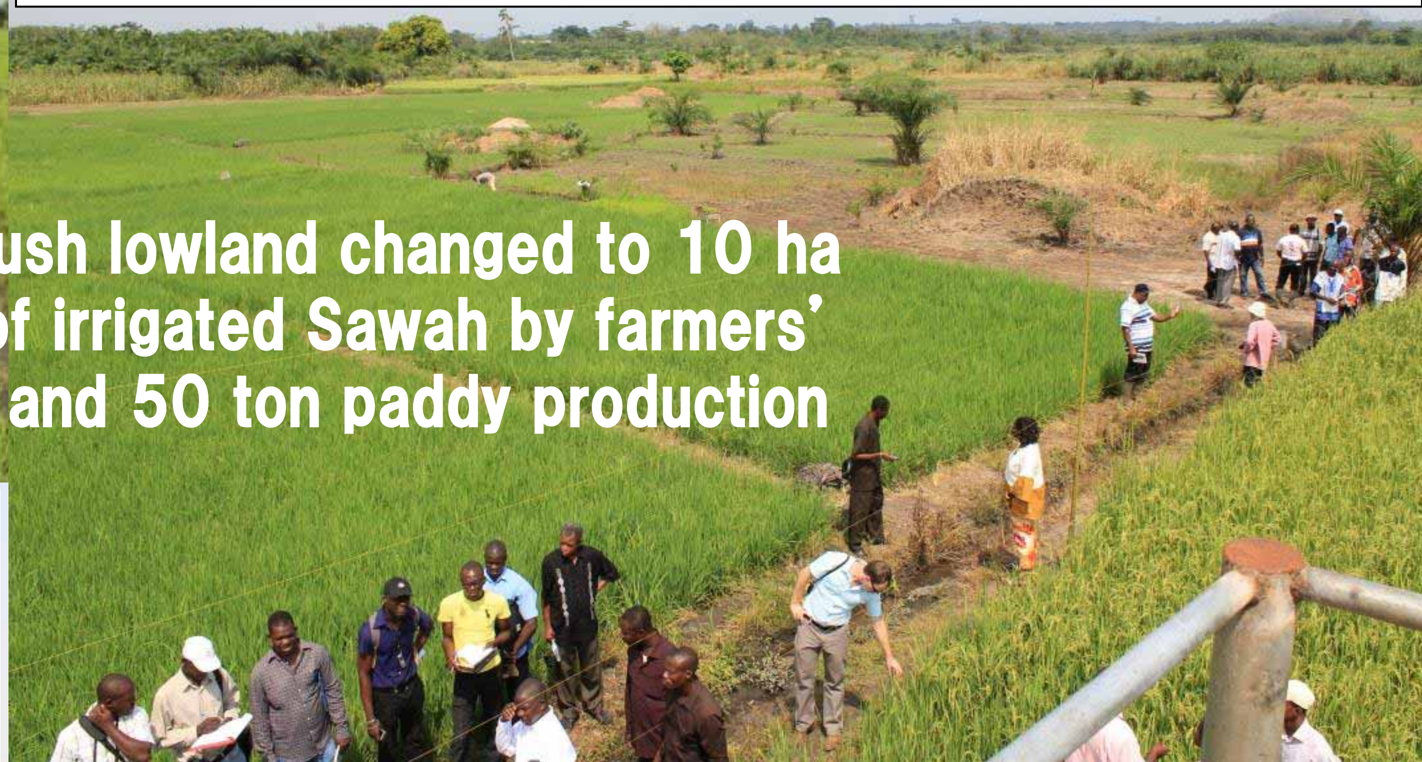
New Sawah development in Biemso No village.1 by
Farmers' self-support efforts and Farmers to farmers' technology transfer
Through the backstopping Ghana Soil Research Institute

sawah system bunding based on topography

On the job training

Powertiller assisted leveling

International workshop on sustainable sawah development by farmers' self-support efforts was organized at Kumasi, Ghana in collaboration Ghana & Nigeria, JIRCAS-Japan, AfricaRice and our Sawah project. (Nov. 2011)



Bush lowland changed to 10 ha of irrigated Sawah by farmers' and 50 ton paddy production

Sawah technology was transferred to the staffs of AfricaRice, Togo and Benin (Afari, Ghana, Nov.2011)

Pump based Sawah at floodplain. Paddy yield 7t/ha at Kebbi, Nigeria(May 2011)

Table 6. Four Skills of Sawah Ecotechnology Innovation to Develop Farmers Personnel Irrigated Sawah Systems to Realize Green Revolution

(1) Site & Time Selection & *Sawah* system design

(a)Rice cultivation >15ha
Farmers strong will to improve technology
(b)Hydrology & quality
(>30 L/s, >5 months/year)
Maximum flow <10ton/s
(c)Topography and soil
Slope ±1%
Not extremely sandy
(d)Privately own the land
or at least Secured rent longer than 5-10 years
(e) *Sawah* system design
Sawah layout
Leveling quality
Bundding quality & Mgt.
Drought and Flood control measeures
(f) Powertiller and trailer trafic road
(g) Water intake, storage, distribution, & drainage
Simple sand bag & wooden dam/Weir dam, barrage
Canal system
Interceptor canal
Pond and fish pond
Pump irrigation
small, middle, large
Central drainage

On-the-job training on site-specific *sawah* development & management

Collaboration between farmers & scientists, engineers, and extension office is very important

Farmers know site specific hydrological conditions which are the most important for site election

The successful example of *Sawah* ecotechnology innovations:
(1) Oasis type pump irrigation in floodplain (Sudan savanna zone, Kebbi state)
(2) Spring based irrigation system (all climatic zones)
(3) Overflow dykes on small rivers (Guinea savanna zone, forest transition zone, forest zone)

(2) Efficient & Low cost Sawah Development: Skill & Technology

(a)Skills for bush clearing & de-stumping
(b)Skills for bunding, canal construction and treatment surface roughness
(c)Cost for hired labors, tools, powertiller purchasing and management
>10ha of development/3-5 years using one powertiller
Purchasing $3000-5000/10ha
Running $2000-3000/10ha
Tools & materials $1000/10ha
(d)On-the-job training cost
Scientist & engineers $1000/ha
Extension officer $500/ha
Leading Farmer $250/ha

Sawah development: at least 10ha by one Power-tiller

Target cost: $1000-3000 /ha

Target speed of develop-ment: >3ha/year /powertiller

(3) Socio-Economic Skills for Rice farmers enpowerment

(a) Group organization & leading farmers training
(b)Training of powertillers assisted sawah development & sawah based rice farming
(c)Post harvest technology using small harvesters of $10,000 per set if sawah area >25ha & paddy production >100ton per year
(d)Loan system to buy agric. Machines and sawah lands
(e)Land tenure arrangement for secured rent >5-10 years

(4) Sawah based rice farming

(a)Management of water intake, storage, distribution, & drainage sytems
(b)Management of bunding & leveling
(c)Water Managt. of sawah
depth of water
irrigation timing
(d)Puddling skills
(e)Skills of Nursery & trans-planting
(f)Weed, pests, and birds Managt.
(g)Managnt. of Fertilizers, nutrient & organic matters
(h) Variety selection & Managnt
(i)Achievement of targeted yield

(1)Immediate target: Paddy yield >4t/ha, >20ton paddy /powertiller

(2)>50t paddy /year /power tiller will accelerate *sawah* Development

(3) Basic research on sustainable paddy yield >10t/ha is important

(1) To train qualified sawah farmers and or groups who could develop sawah >5ha and get annual paddy production >20ton using one powertiller within three years after the initiation of sawah development.
(2) To train the leading *Sawah* farmers is the key for sustainable and endogenous sawah development. The leading farmers can train farmers and farmers groups to achieve the target as qualified *Sawah farmers*.
(3) If site selection is suitable, sawah can be developed far easier in Africa than in Asia.

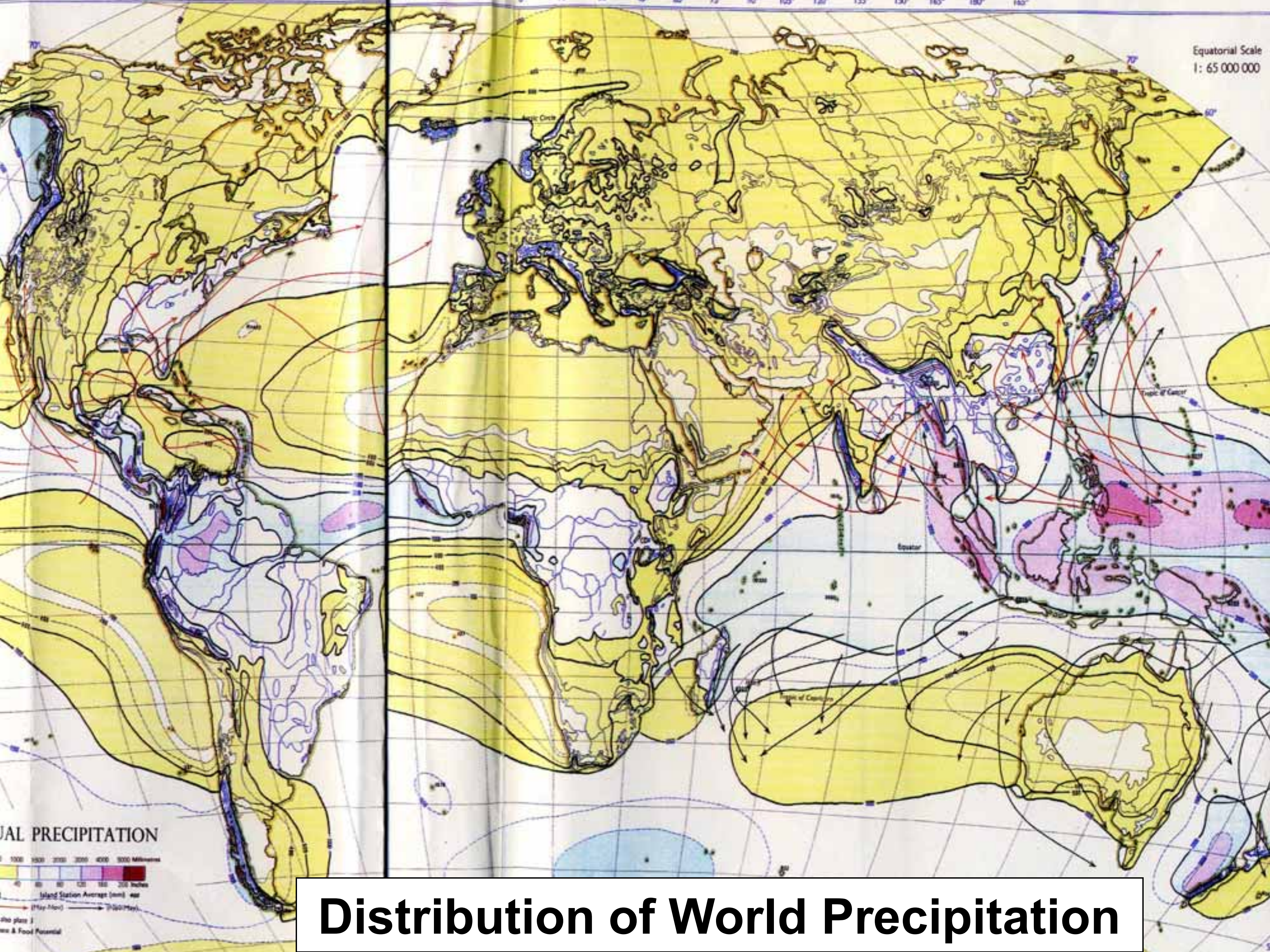
Sawah technology can reform traditional ODA & contractor based development : farmers to farmers technology transfer sites > > sites of extension officers > researchers' demonstration sites>> Traditional ODA

Table 1 Distribution of lowlands and potential irrigated sawah in SSA (Hekstra, Andriesse, Windmeijer 1983 & 1993, Potential Sawah area estimate by Wakatsuki 2002,2012)

Classification	Area (million ha)	Area for potential irrigated 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%)

Note 1. Although priority target is the inland valley because of easier water control, some flood plains can be high priority, such as Sokoto, Kebbi, Yobe and Borno where personal pump irrigated sawah is efficient

Note 2. Estimated potential sawah area is 3million ha (annual paddy production 12 million ton) in Nigeria and 20 million ha in Sub Saharan Africa (SSA). Estimated area came from the relative amount of water cycle in monsoon Asia, which has 130 million ha sawah. However, if innovative technology will be developed, 1, 5 and 50 million ha of irrigated sawah can be developed in Ghana, Nigerian and SSA, respectively, in future.



Distribution of World Precipitation

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

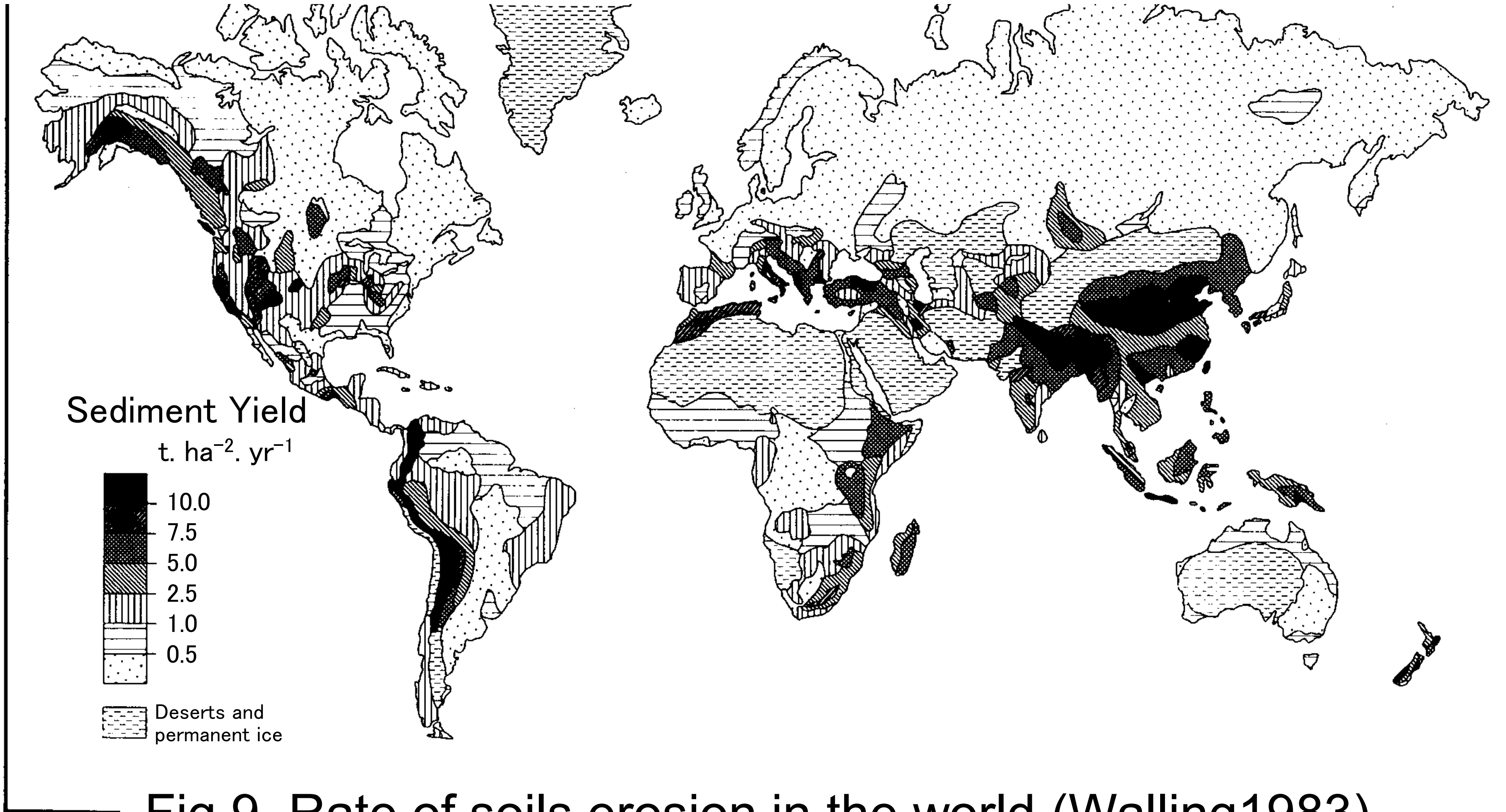
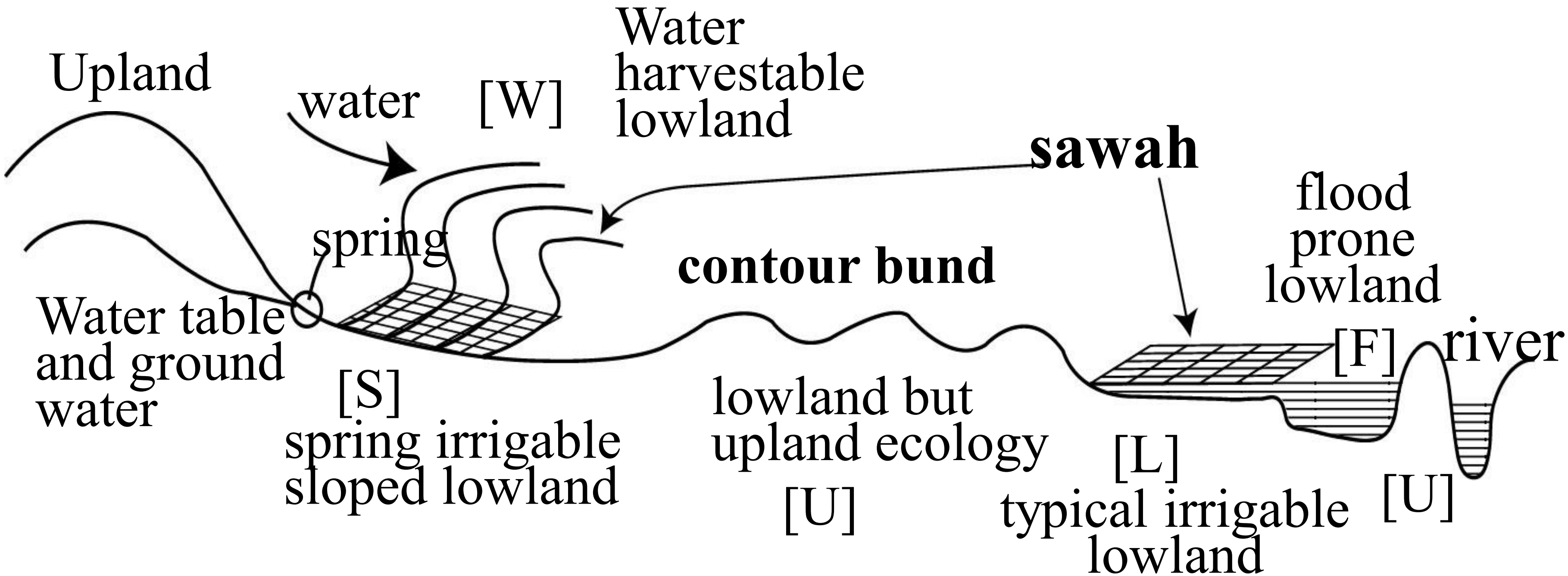


Fig.9. Rate of soils erosion in the world (Walling1983)



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

Lowland sawah development priority

[S] [L] [F]* > [W] > [U]

***Even huge flood plain, farmers can practices sawah based rice farming using pump, except for 2-3 months flood period**

Fig. 11: Very Diverse Nature of African Lowlands Need on Large Scale Action Research and On The Job training on Site Specific Sawah Development and Sawah Based Rice Farming

Possible Target of Soil Science, Technology and Innovation

Bio-technology/Science/Innovation：

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

Operational platform is Cell of organisms

Eco-technology/Science/Innovation：

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.

Table 1. Biotechnology and Sawah Eco-technology Options and Complementation for Rice Production

(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

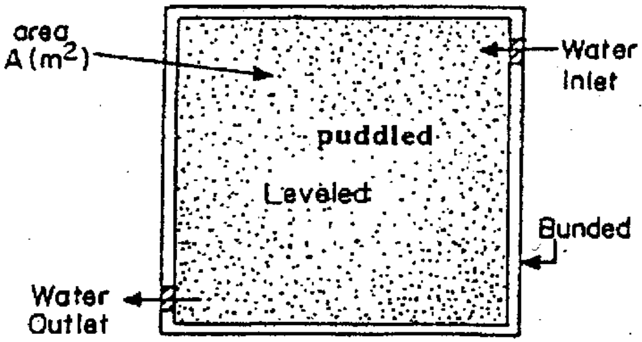
Ecotech: Carbon sequestration by Sawah systems through the control of oxygen supply, use of Biochar, and organic farming. System rice intensification and other ultra high yield agrsnomic practices

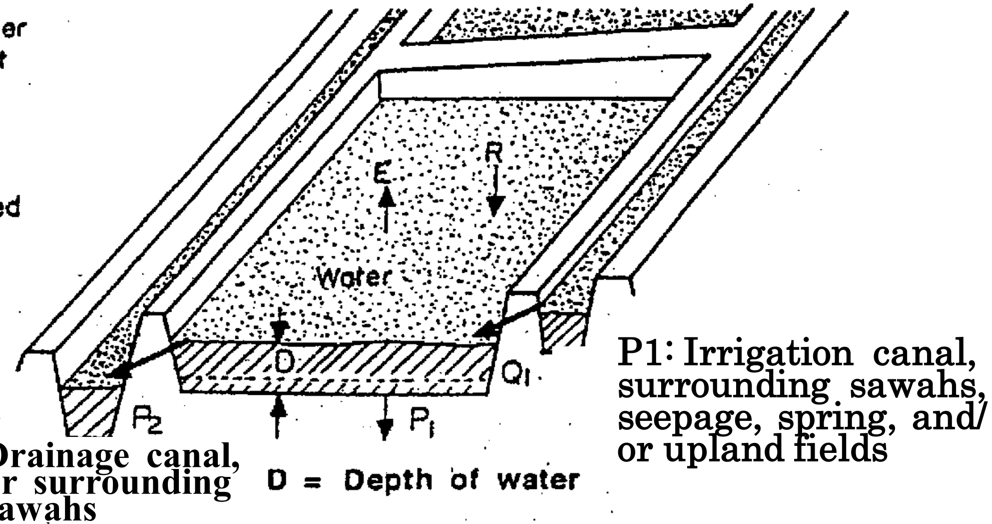
(5) Food quality and Biodiversity

Biotech: Golden rice, other vitamine rice gene

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

Quality of Sawah determines the quality of water control, then quality of soil management and performance of various agronomic practices for rice production

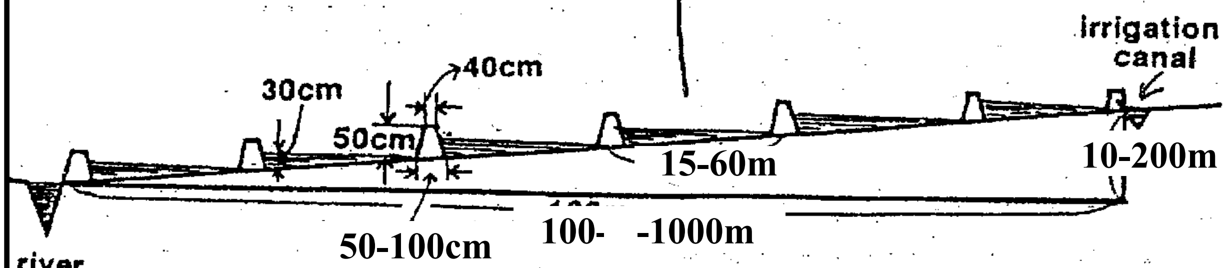




INPUT = R (rainfall)
+ Q1(seepage and irrigation)

OUTPUT = Et(evapotranspiration)
+ P1(infiltration)
+ P2(seepage and drainage)

Quality of a Sawah was determined by the quality of leveling, bunding, puddling, and inlet/ outlet of water including ground water control functions, even if the same farmer, soil, and climate



Possible layout of SAWAH on typical inland valley bottom slope in West Africa

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

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

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.

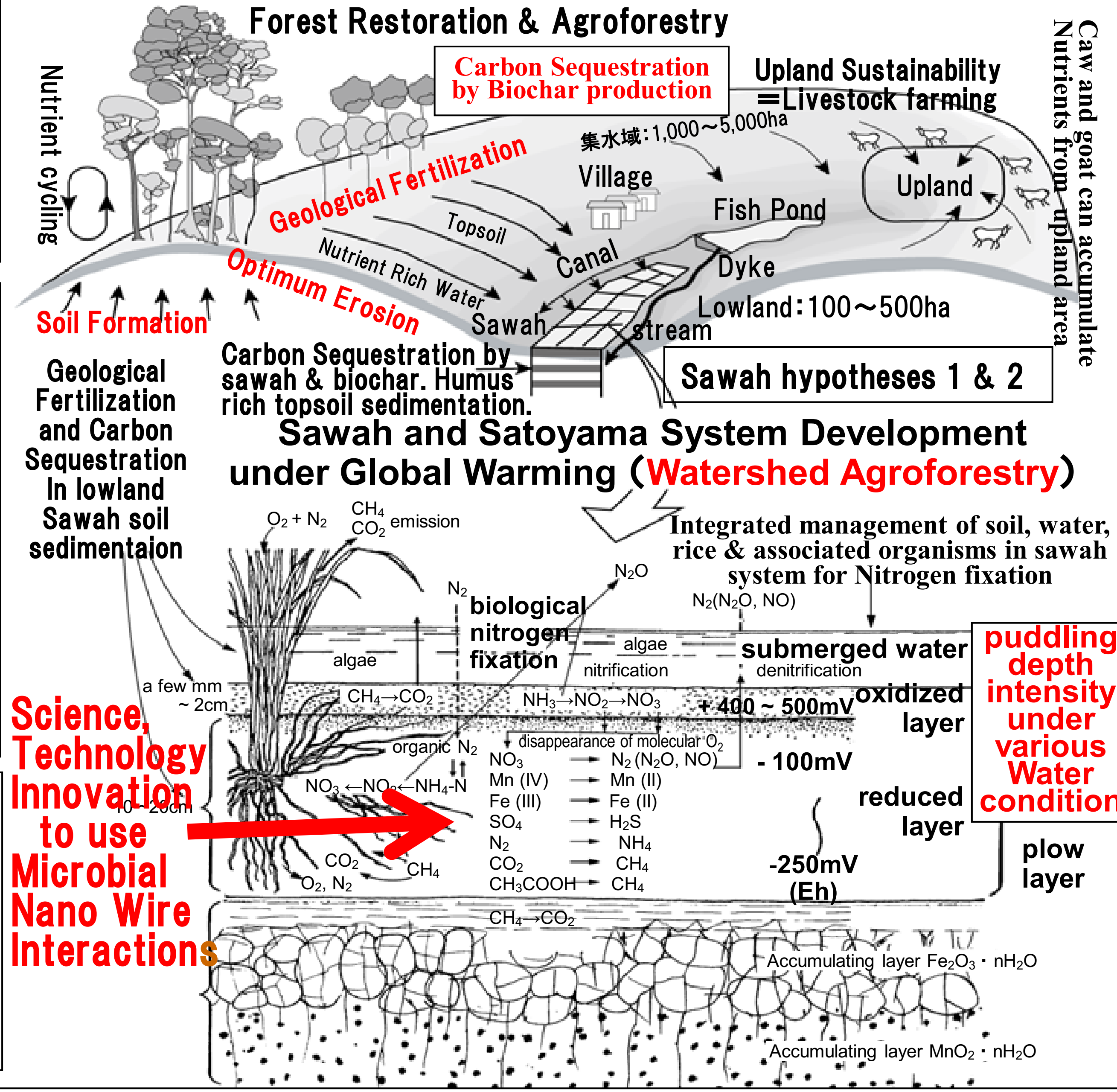


Fig. 6. Sawah hypothesis 2 of multi-functionality & creation of African SATOYAMA (or Watershed Agroforestry) systems to combat food crisis and global warming.

Conceptual Summary of STI on Green Revolution in Africa to Solve Global Food and Ecological Crises by 2025-50

Science: Integrated Ecological Science, Soil and Water Management will be Key

Technology: Eco-Technology ?
Bio-technology, or
Bio-Eco-Integrated Technology

Innovation: Innovators can implement and socialize the ST. Participants of ESAFS 11


TERIMAKASIH
Be innovator
Nupe's Traditional,
Paddy fields
Nigeria
New Sawah
Field
Thanks