Sustainable intensification and diversification strategies for African rice-based cropping systems

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No Sawah, No Green Revolution

Guinea, Aug.03

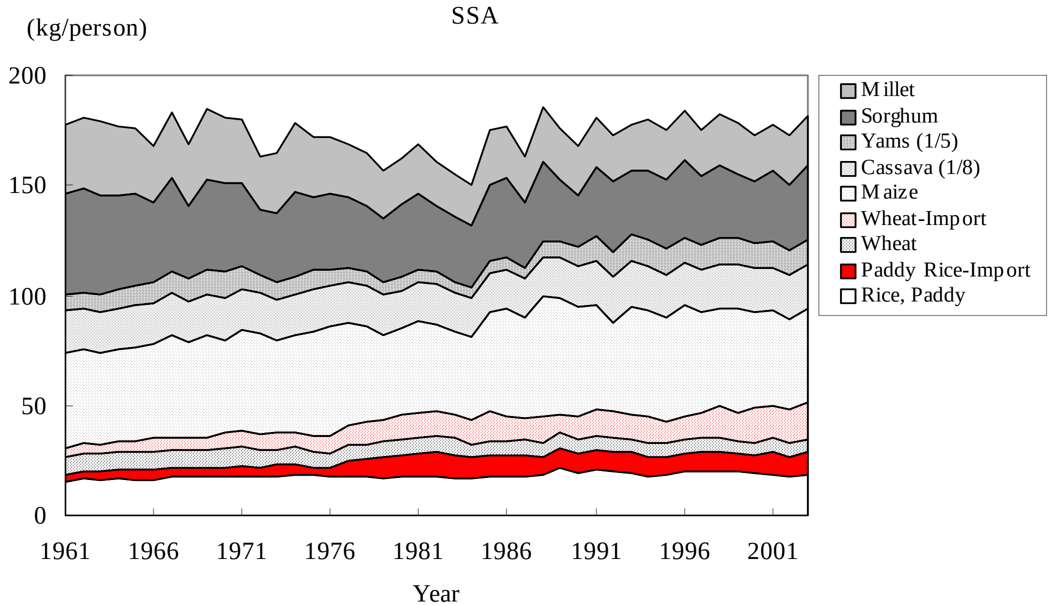
Inland valley, Sierra Leone, Jan.89

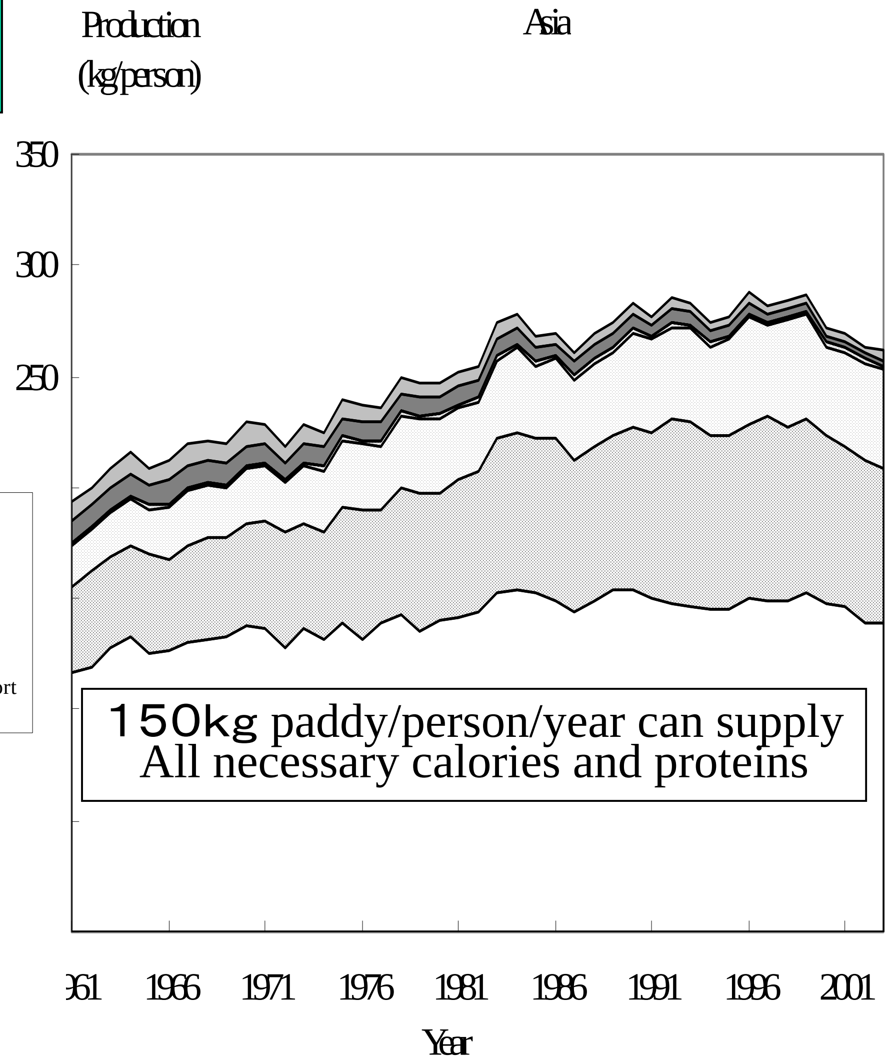
Water control through Sawah system is prerequisite for Green Revolution in SSA

Nupe's indigenous rudimentary Sawah system, Nigeria,Sep.05

CRI/JICA Sawah project, Ghana, Aug.01

Production trend (kg/person) of diversified African crops in comparison with Asia





African crops are diverse, even production potential of rice is higher than demand, rice is importing. Wheat has not enough production potential in majority of SSA countries. Rice is also the highest quality cereals in terms of egg protein equivalent among the other 6 crops

Fulbe (maybe also Masai?) cows are not integrated well in the rice farming: Diversity but not good integration in majority of African Agriculture

Nupe farmers' traditional water control systems: Irrigated but rudimentary sawah system because of no availability of animal traction (and small machinery)

After rice Nupe farmers grow various crops

Ashati, Ghana

Sustainable intensive mixed cropping

World record
Igbo, Nigeria

Sustainable Diversification is not a major problem in SSA. Current major problem is how to realized sustainable intensification: Green Revolution

African nature of Diversity Agriculture may contribute tropical Asian and American agriculture in future.

NERICA rice also may contribute to help Asian rice in future, because of its potential genetic diversity

What is Sawah?

From plateau to Bangkok plain, July 06

Lagos Airport, Aug. 05

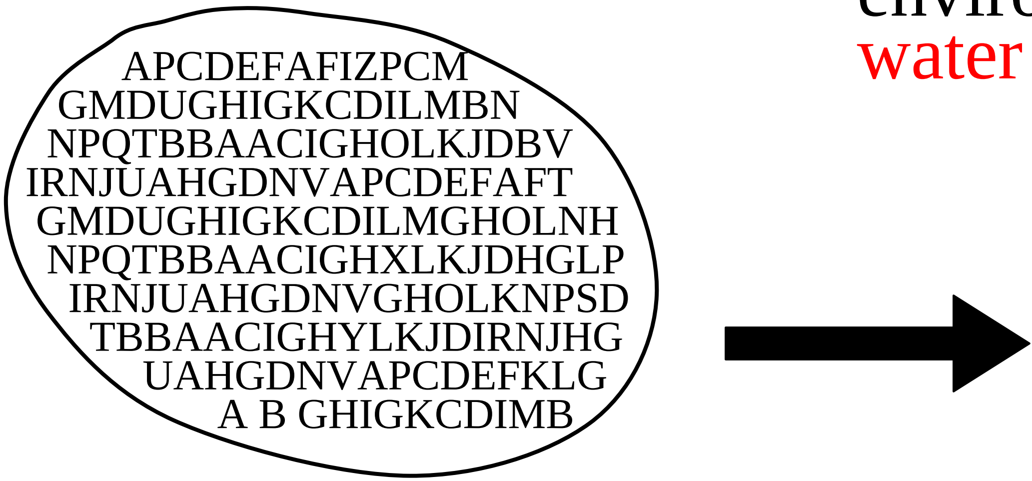
Farmers fields are demarcated

No clear demarcation:Land is not injured

Northeastern plateau area in Thailand, July 06

Dar es Salaam airport, July 06

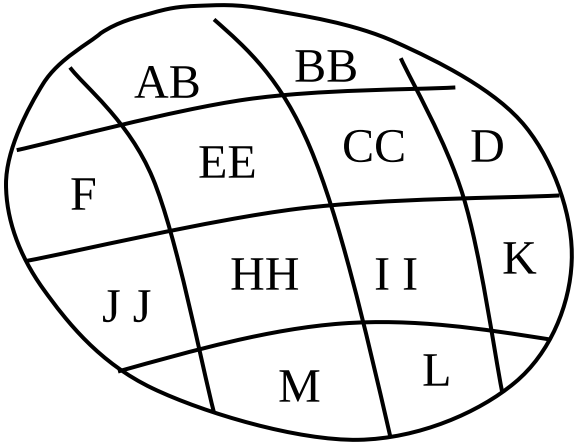
Farmers' Fields: Diverse and mixed up environments



mixed up varieties
A B C D E ………

Fertilizer, Irrigation, and HYV are not effective: No Green Revolution

Sawah based eco-technology: Diverse but well characterized, classified,and improved rice environment, especially for water control

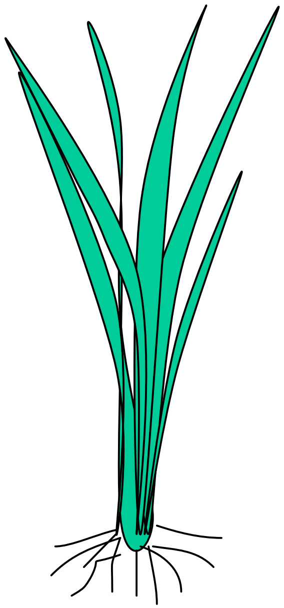


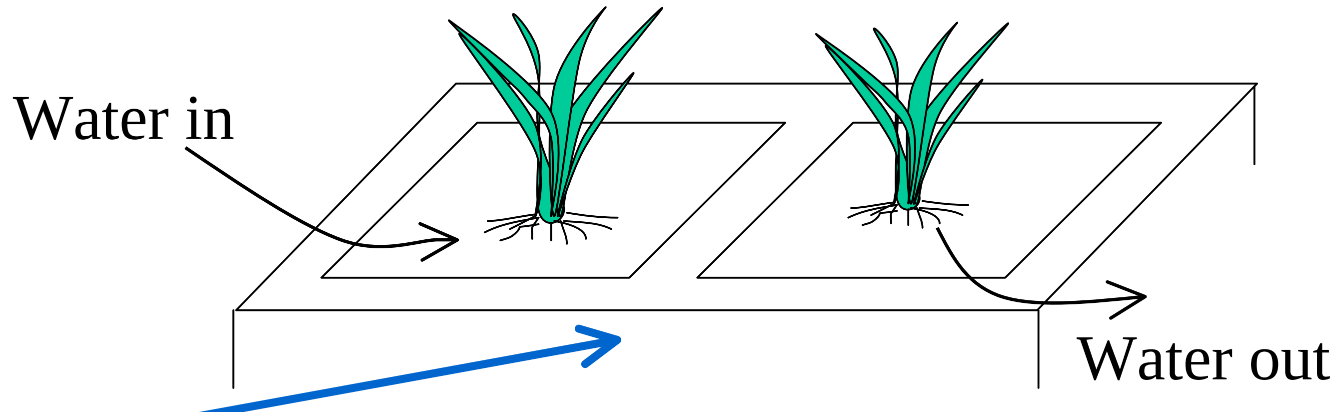
pure variety A
pure variety B
pure variety C
pure variety D
pure variety E

Successful Integrated Genetic and Natural Resource Management, i.e., Agronomy, needs classified demarcated land, eco-technologically

Biotechnology and Ecotechnology

Rice variety **and** **Rice with Sawah Systems**





Sawah is a man-made, improved rice-growing environment with demarcated, bunded, leveled, and puddled fields, for water control. Sawah is soil based eco-technology

Varieties could solve the main problems in Asia
Is this also true in SSA?

Because of diverse soil, geology, topography, hydrology, climate, vegetation and socio-cultural conditions, the technologies for sawah development and management are very diverse. Therefore we have to research and develop the technology to accommodate in diverse SSA ecology.

Rice (variety) and environment (Sawah) improvement

Both Bio & Eco-technologies must be developed in balance

Sawah: Lacking the concept, term and eco-technology. This makes disturbing the balanced approach for rice development in West Africa and SSA last 30 years

Confusion in paddy, irrigation, water control, and sawah systems

Farmers' job

Government Job

- Sawah Hypothesis (1): Antecedent for Green Revolution :
  Are Farmers' field conditions ready to accept irrigation water, fertilizer, and HYV or not?
- Sawah Hypothesis (2): We have to overcome scarce nutrient and water: Sustainable rice productivities under Sawah is 10-15 times higher than upland rice fields
- Must remember that lacking the concept & term, "Tsunami" made the Sumatra disaster enormous

No proper English/French ecotechnological concept and term to improve farmers'rice fields, Sawah or SUIDEN (in Japanese)

Suiden (Japanese)=SAWAH(Malay-Indonesian)

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

Weeds are stronger: upland rice, Bida

Nupe's traditional partial water control system

Nupe's indigenous partial water control system

No ecotechnology measures

Inland Valley, Sierra Leone

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

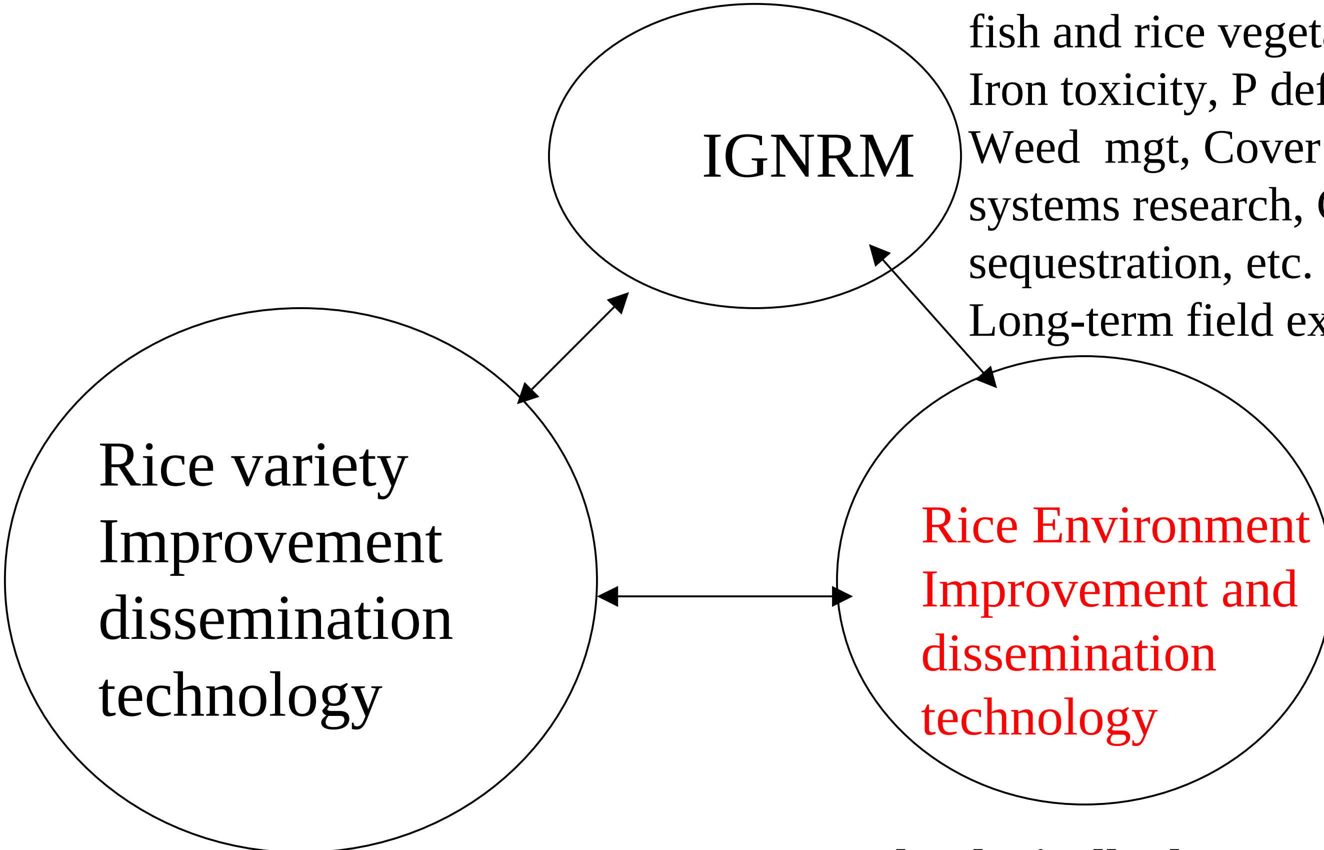
Table Mean gain yield of 23 rice cultivars in low land ecologies at low (LIL) and high input levels (HIL), Ashanti, Ghana (Ofori & Wakatsuki, 2005)

		← ECOTECHNOLOGICAL YIELD IMPROVEMENT					
	Entry No. Cultivar	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

Entry 1- 7 : Early - maturing cultivars、Entry 8-23: intermediate - maturing cultivars

IGNRM for Green Revolution technologies :

Water, Fertilizer and Soil mgt, Legume, Manure, animal traction ,power tiller, fish and rice vegetable after rice, BNF, Iron toxicity, P deficiency, IPM, Striga, Weed mgt, Cover crops, Cropping systems research, CH4 emission, carbon sequestration, etc. Crop Physiology, Long-term field experiments



Missing link is “sawah” in SSAfrica

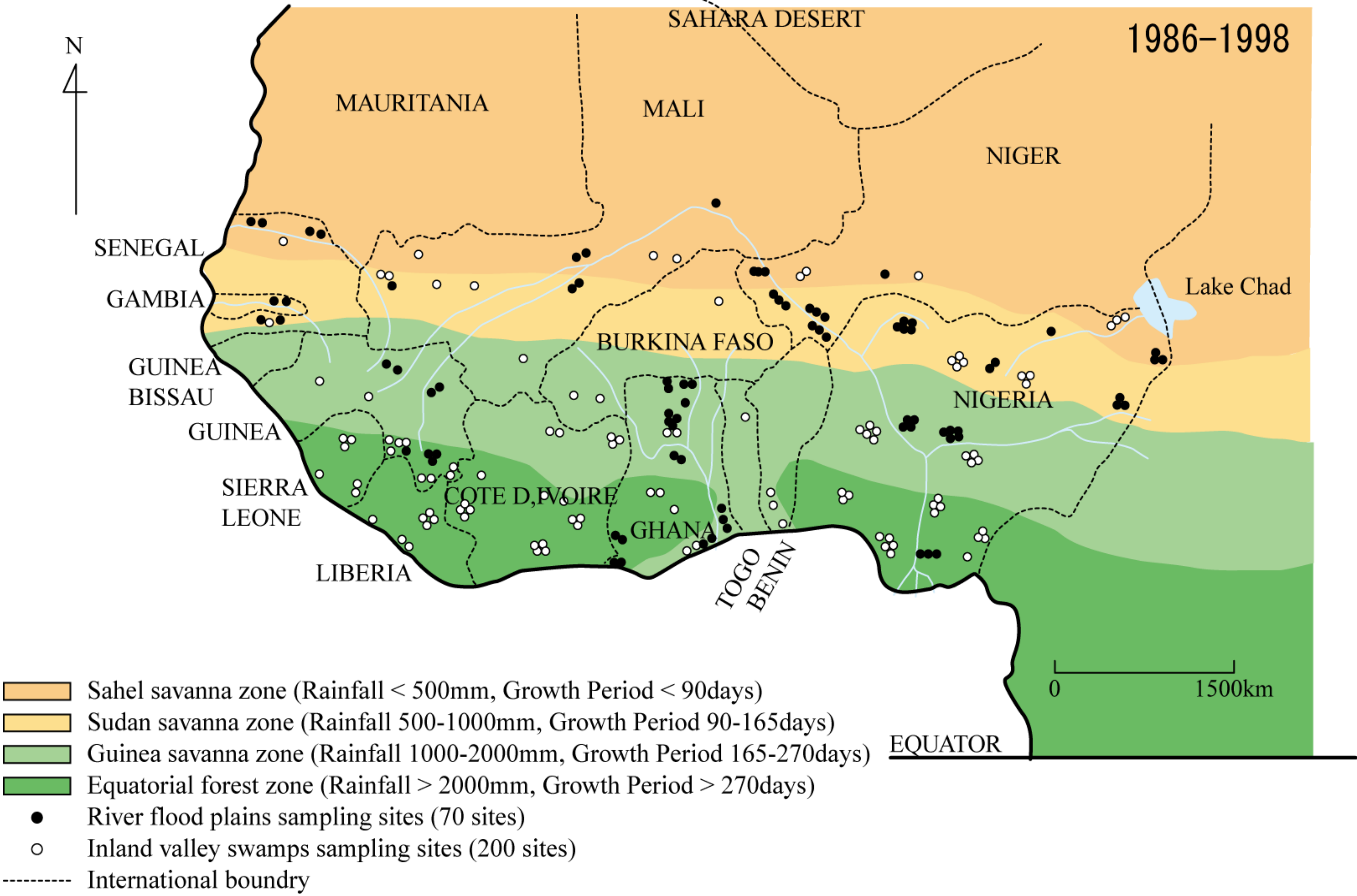
High yield
High quality
High tolerance

Ecotechnologically demarcated field for water Management has to be existed:

High quality leveled rice field (±5cm)
High quality bunded rice field (no leaking)
High quality puddled rice field (nursery)

Concept of Integrated Genetic and Natural Resources Management (IGNRM) for green revolution technology :

Missing link is Sawah which is lacking in majority of famers’ fields



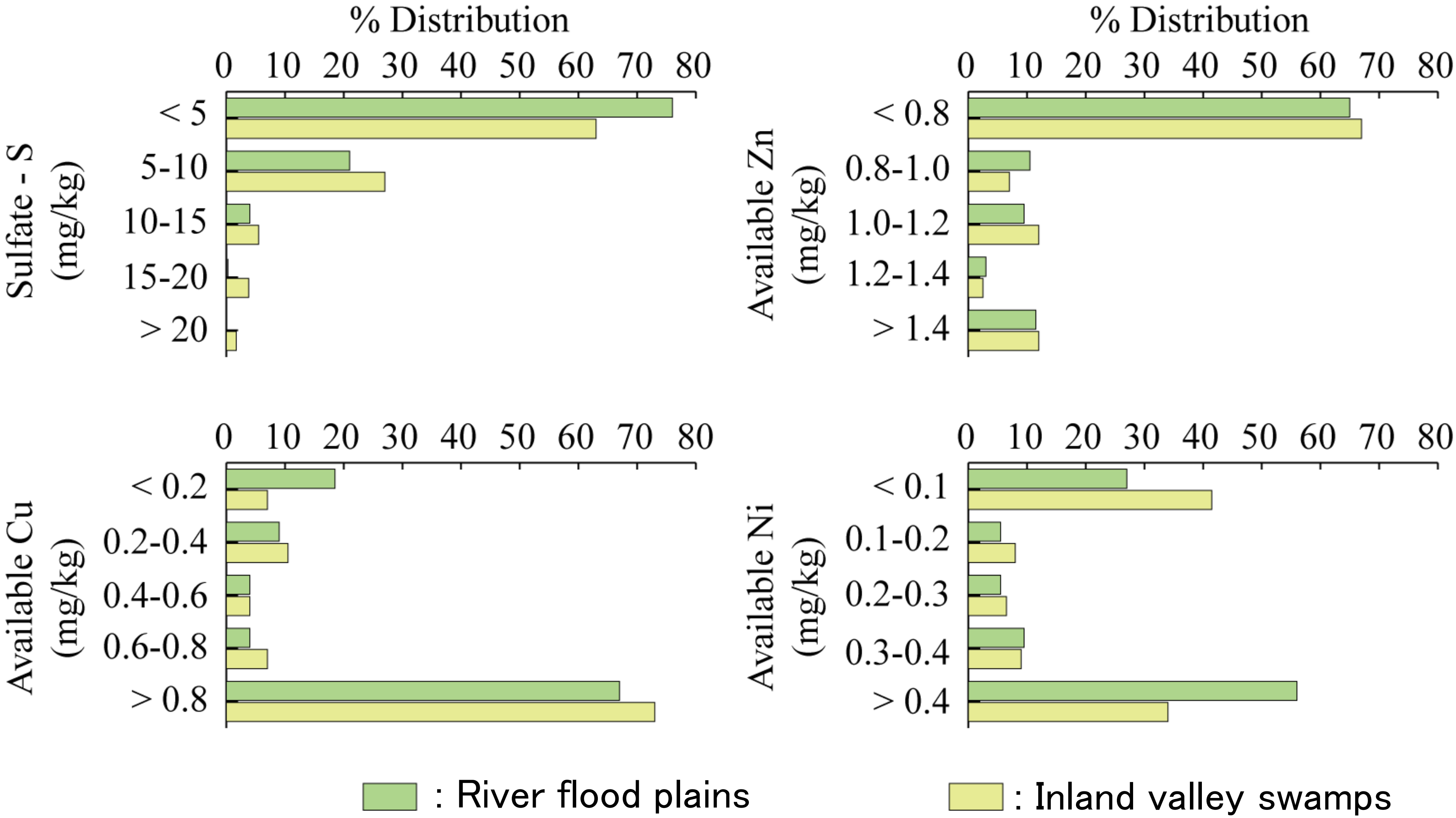
West Africa map showing selected sampling sites of lowland soils. (Buri and Wakatsuki, 2000)

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 (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,** Bray II.

Source: Hirose and Wakatsuki (268 sites), 1997.



S & Zn Deficiency: Frequency distribution of topsoil (0–15cm) available nutrients in West Africa lowlands. (Buri & Wakatsuki. 2001)

How can we overcome such low level nutrients & scarce water in Sub Sahara West Africa

- To develop lowland sawah is the answer.
- The integrated management of lowland & upland, for example, watershed agro-forestry, is also key eco-technology
- The core region of West Africa has similar climate, soil, hydrology, and crops to northeastern Thailand:The important site in Asian African collaboration in future

Sawah hypothesis (II): Sustainable Productivity of lowland Sawah fields are more than 10 times higher than Upland Fields: This is not experimented results scientifically, but experienced results in Asia

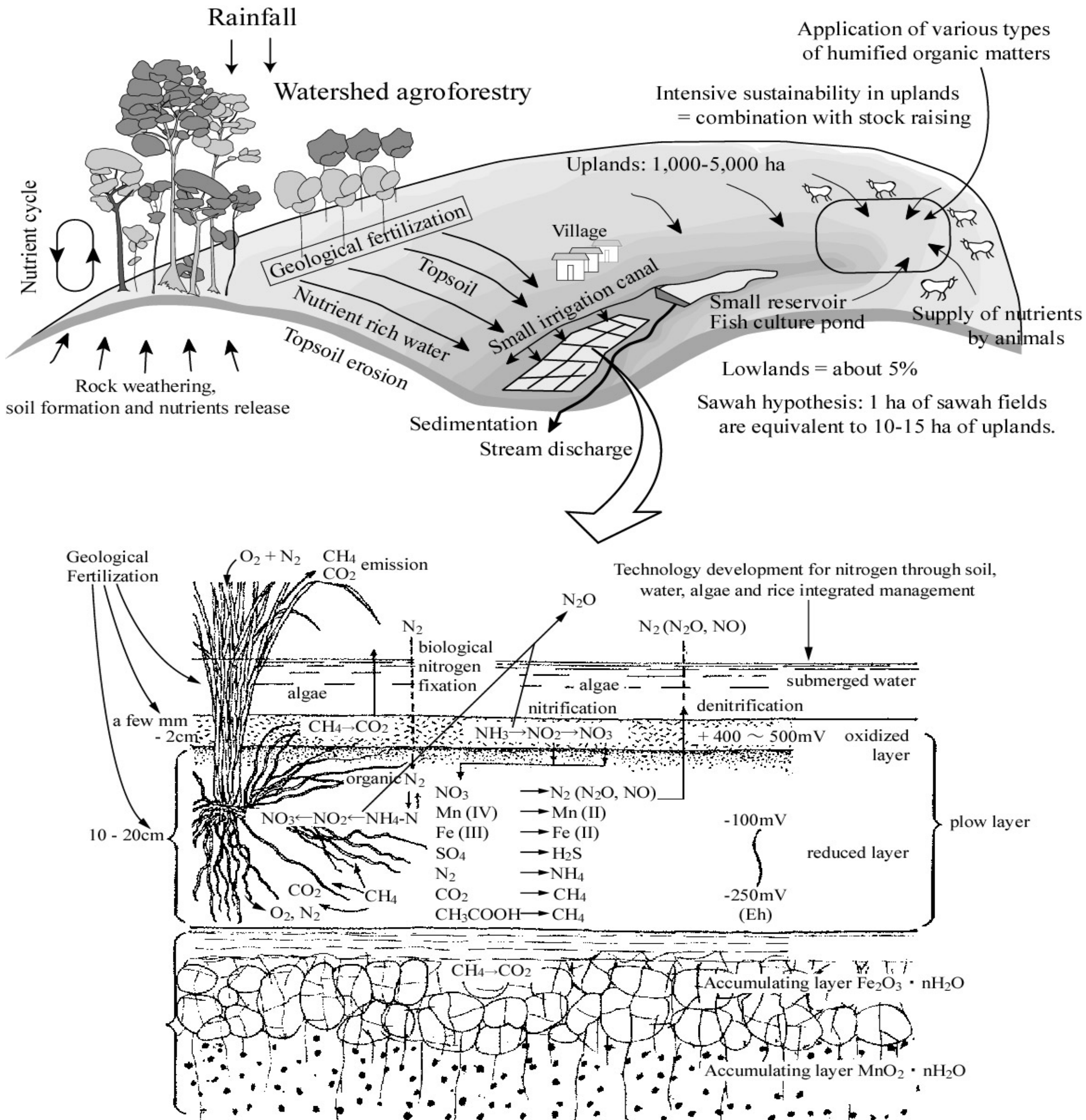
1ha sawah = 10-15ha of upland

	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

(1) The optimum landuse pattern and landscape management practices optimize the geological fertilization through the control of optimum hydrology in watershed



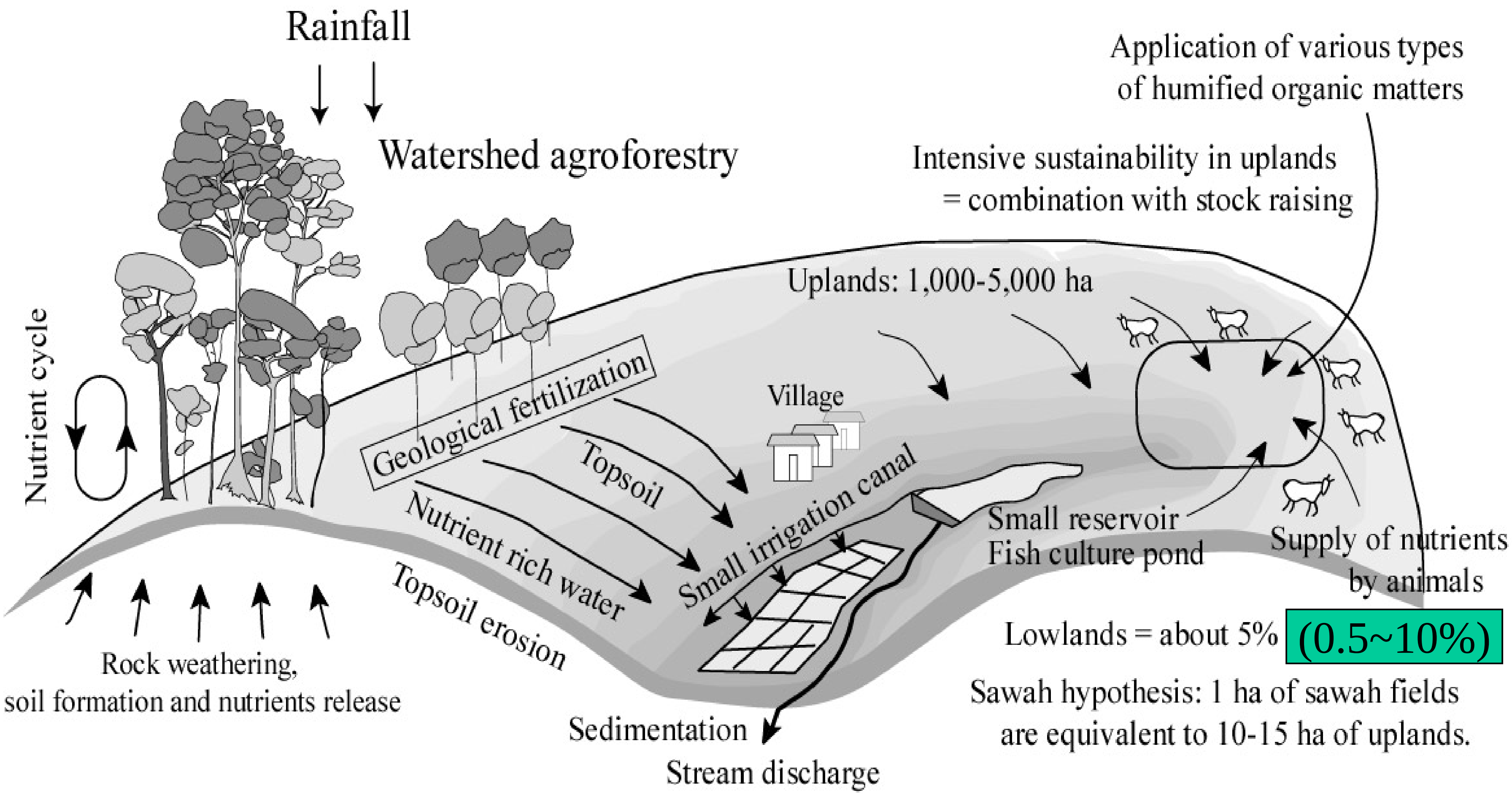
(2) Sawah systems as multi-functional constructed wetlands

Macro- and Micro-scale Ecological Mechanisms of Intensive Sustainability of Lowland Sawah Systems

(1)Geological Fertilization: lowland can receive water, nutrients, and fertile toposils from uplands.

(2) Multi-functional Constructed Wetlands for control weed and enhanced Supply of N, P, Si, and other Nutrients

(1) The optimum landuse pattern and landscape management practices optimize the geological fertilization through the control of optimum hydrology in watershed

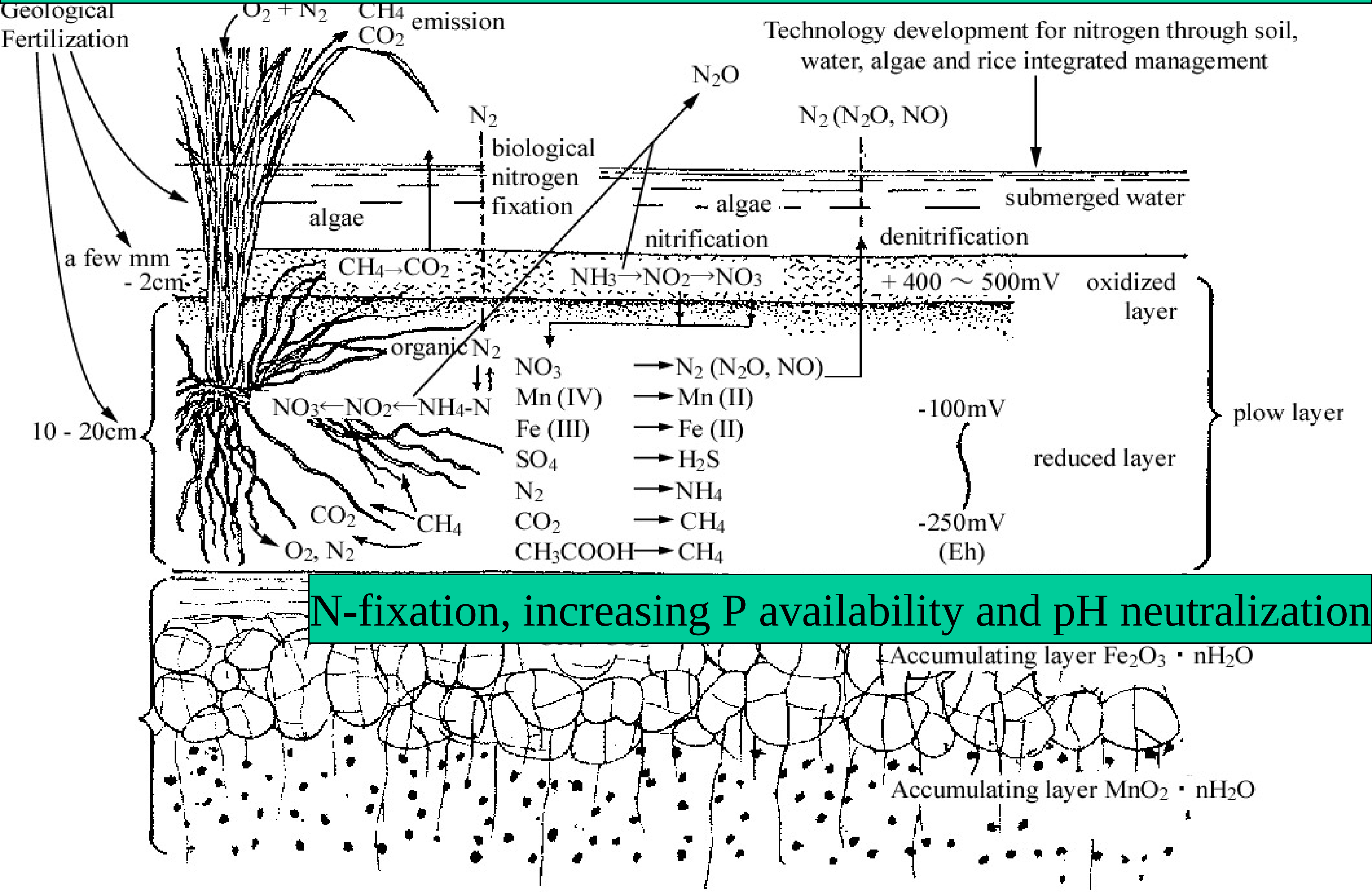


Concept of Watershed Eco-technology, i.e.Watershed Agro-forestry:Multi-functional Sawah type wetland is a key component

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

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

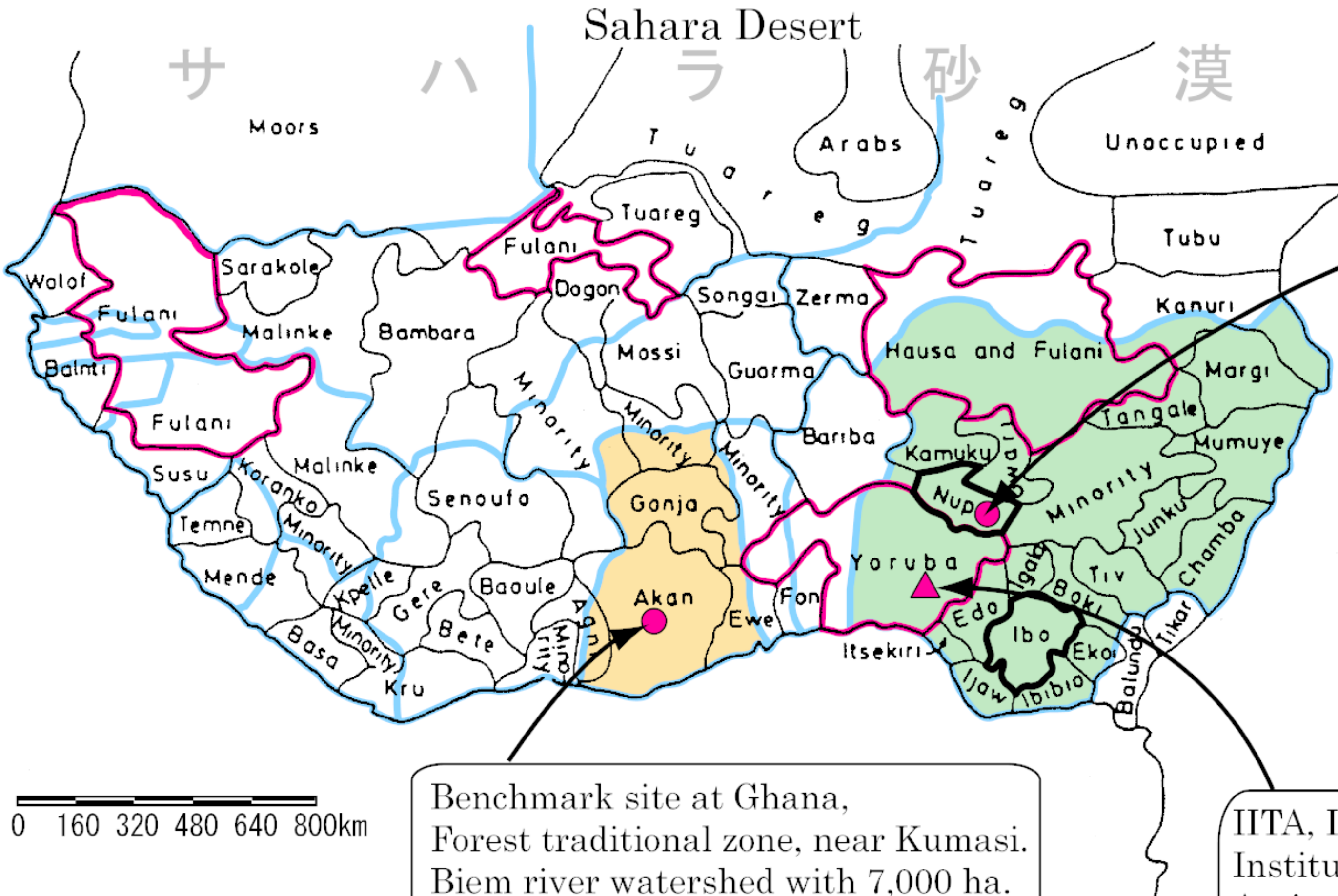
Topsoil, water, and nutrients accumulation through watershed agroforestry



N-fixation, increasing P availability and pH neutralization

(2) Sawah systems as multi-functional constructed wetlands

Examples of ecotecnological research & Developemnt



Benchmark site at Nigeria, Guinea Savanna zone, near Bida city.
Emikpata river watershed with 5,000 ha.
Geology: Nupe sand stone, Cretaceous
Annual rainfall: 1,000 mm

1986－present

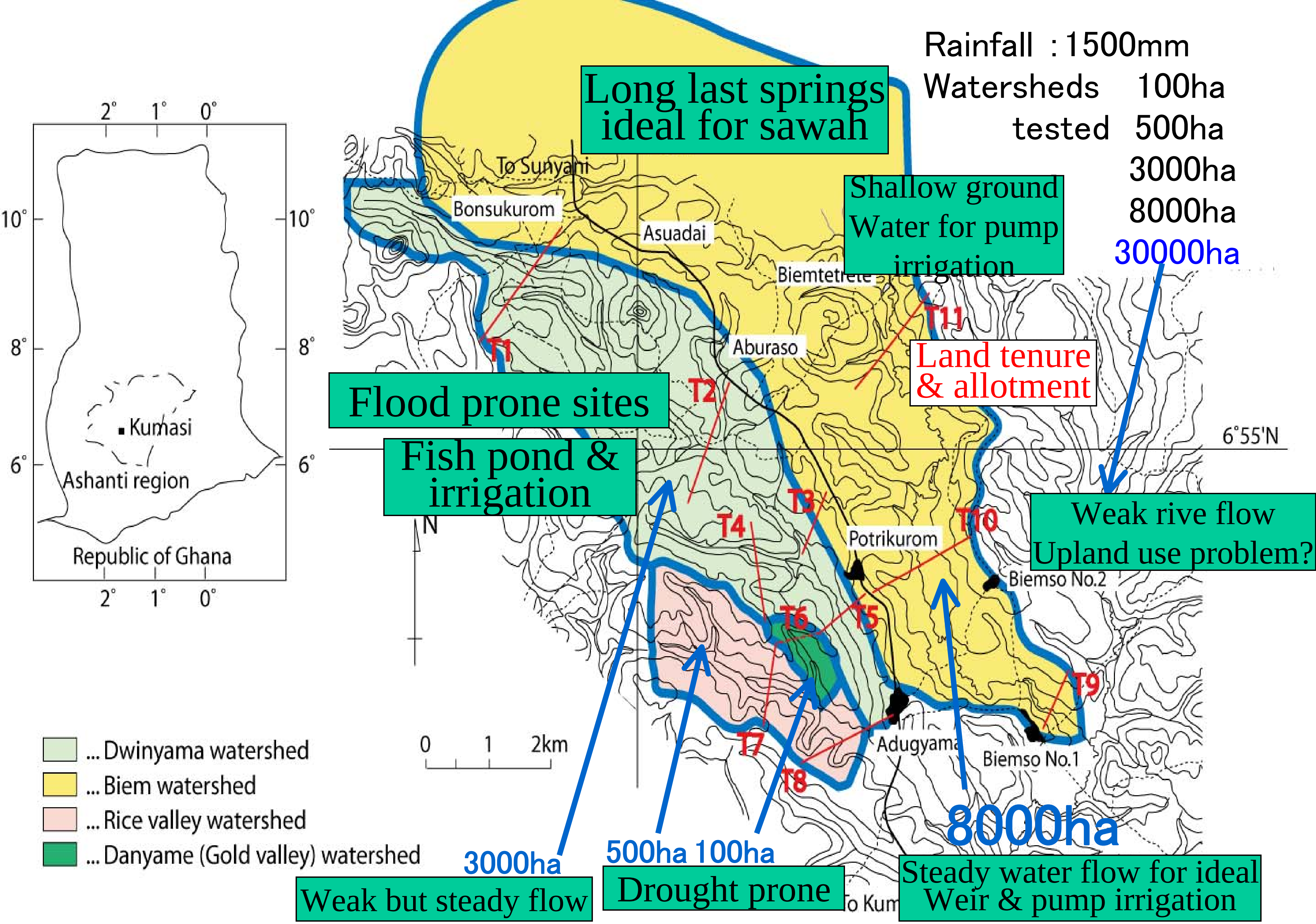
Benchmark site at Ghana, Forest traditional zone, near Kumasi.
Biem river watershed with 7,000 ha.
Geology are Gramite and Gneiss.
Annual rainfall is 1,500 mm.

1994－present

IITA, International Institute of Tropical Agriculture, Ibadan, WIN office

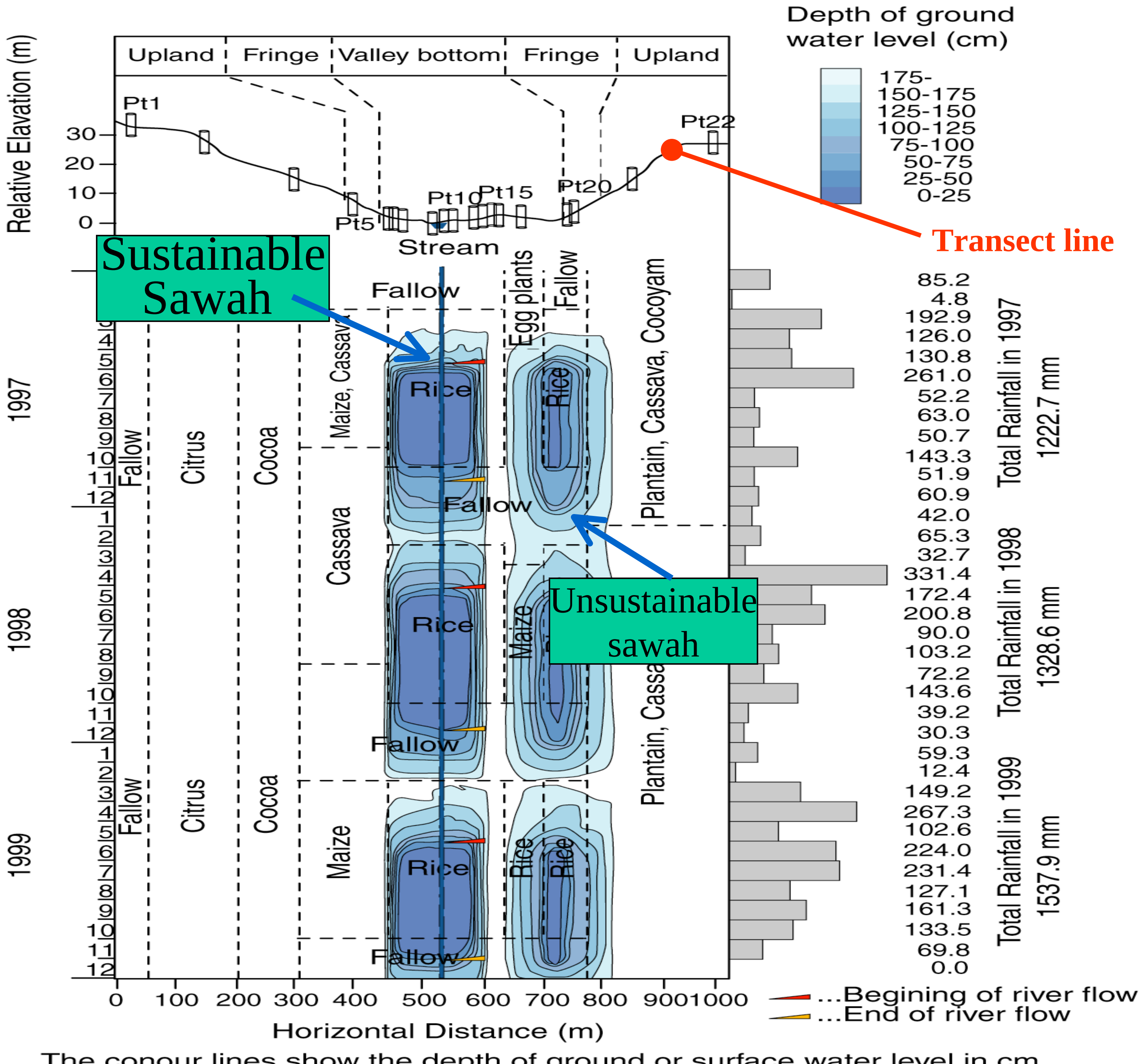
Two benchmark watersheds in Ghana & Nigeria. Map shows countries with major ethnic groups in West Africa

CRI-CSIR/JICA Sawah project for Integrated watershed management, 1997-2001



Research site showing the location of transects in the watersheds.

Although hydrology is the base for success of Sawah, the performance of various ecotechnologis in watershed can be evaluated by water flow.



Cross–section of topography, rainfall pattern, ground/surface water and land use dynamics in stream flow inland valley (Transect 5), Dwinyan watershed, Ashanti Region, Ghana.

Top-survey, Inland valley, Ashanti, Ghana

Canal construction by farmers

Simple barrage by farmers’ efforts

Spring Irrigated Rudimentary Sawah, Nupe

Sawah construction can be done by farmers' self-support efforts

Manual Leveling needs hard-works for Sawah system construction

Power-tiller operated leveling, Ashanti, Ghana
Sawah can/must be produced by farmers

The leveling needs skilled & concerted works

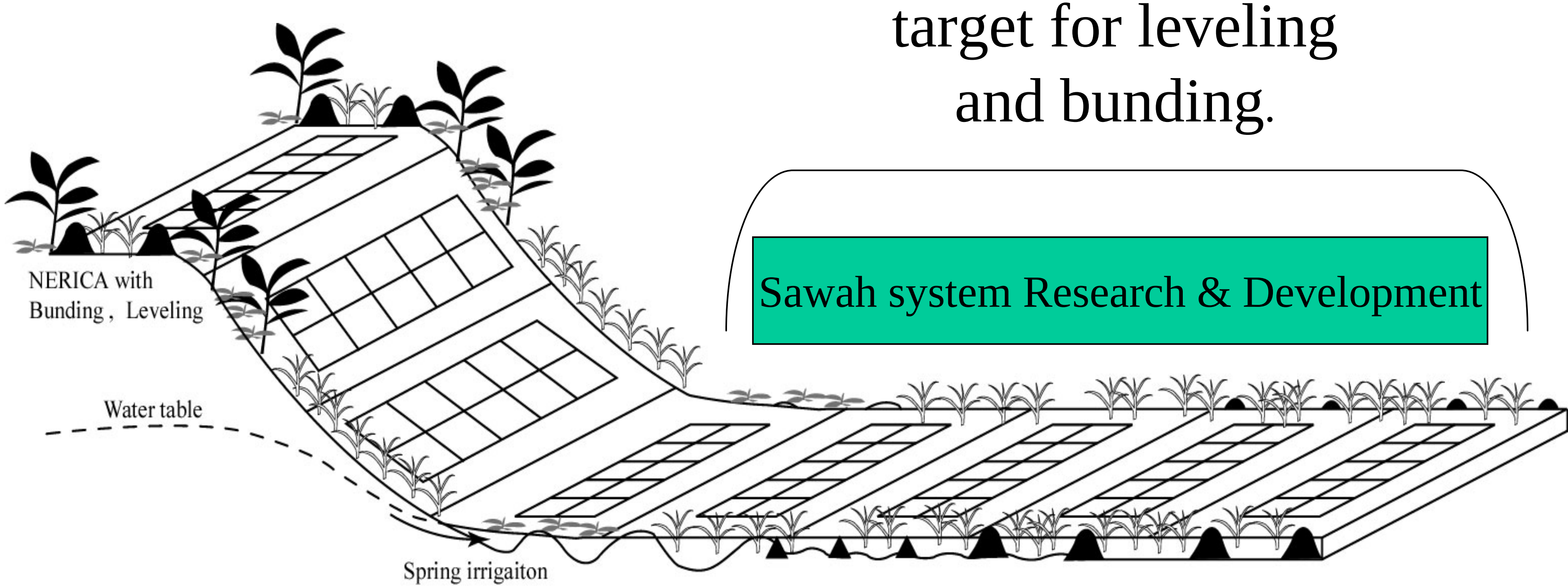
Sawah is ecotechnology based Multi-Functional constructed Wetland: Production, Environment, and Cultural landscape

Rice farmer’s field demarcation based on soil, water, and topography are the starting point for scientific observation, technology generation, and application.

Upland leveling & bunding are limited only for good soil

Lowland is the target for leveling and bunding.

Sawah system Research & Development



Water table and water management continuum(WARDA2004, 2006)

Can watersheds of in SSA sustain Sawah system? High rate of soil erosion and lowland sawah soil formation can be compensated by high rate of soil formation:Again Ecological Balance is a Key

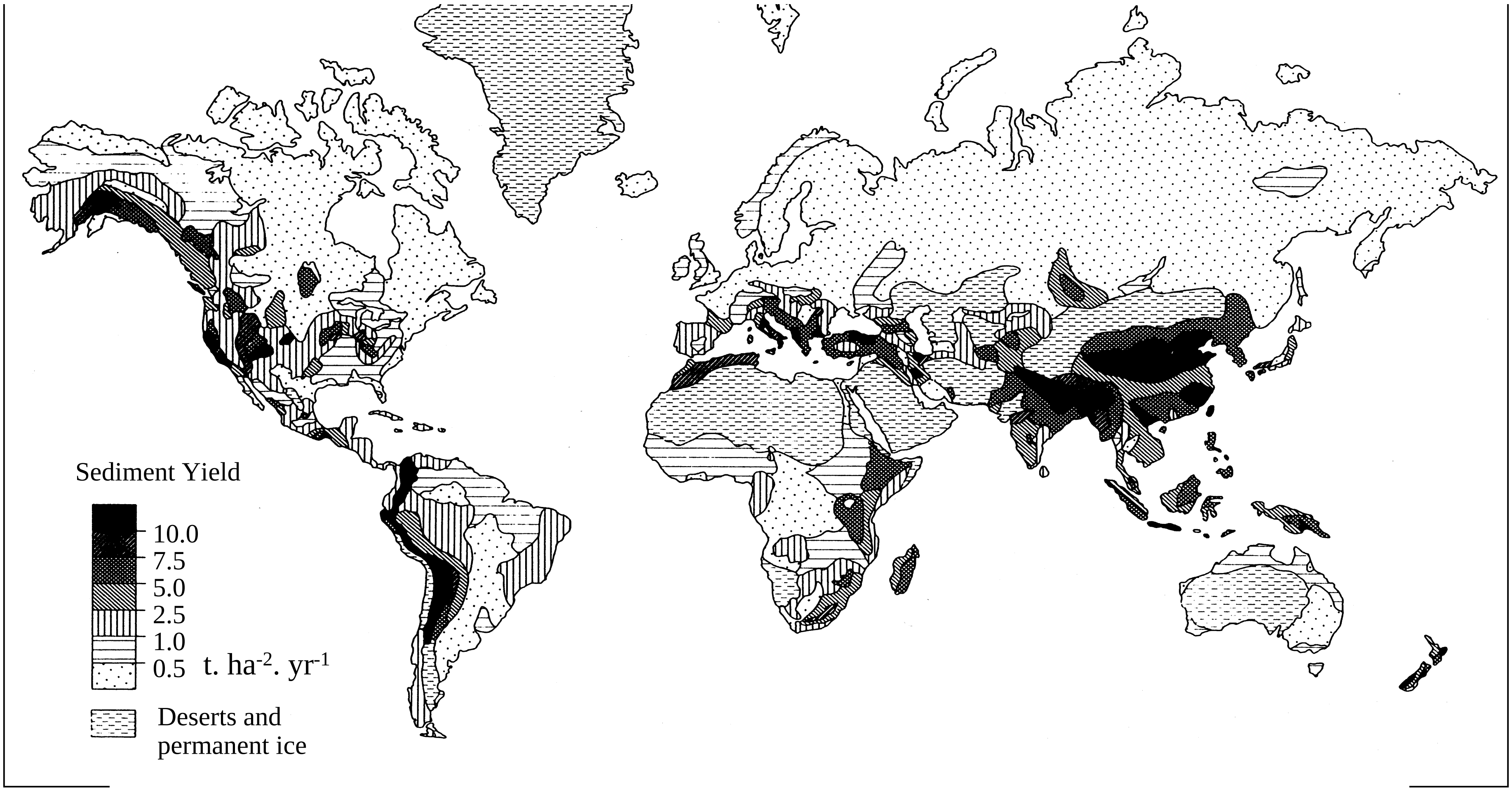
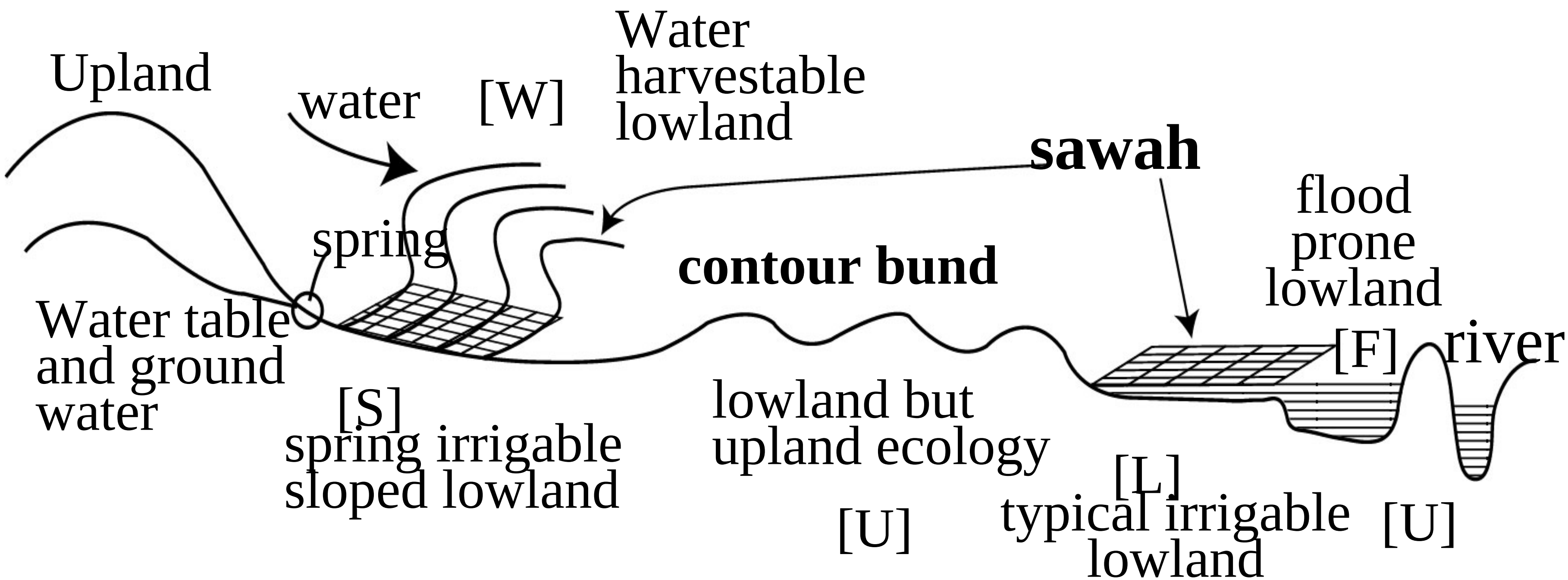


Fig. 1. Rate of soils erosion in the world (Walling1983)



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

Lowland sawah development priority

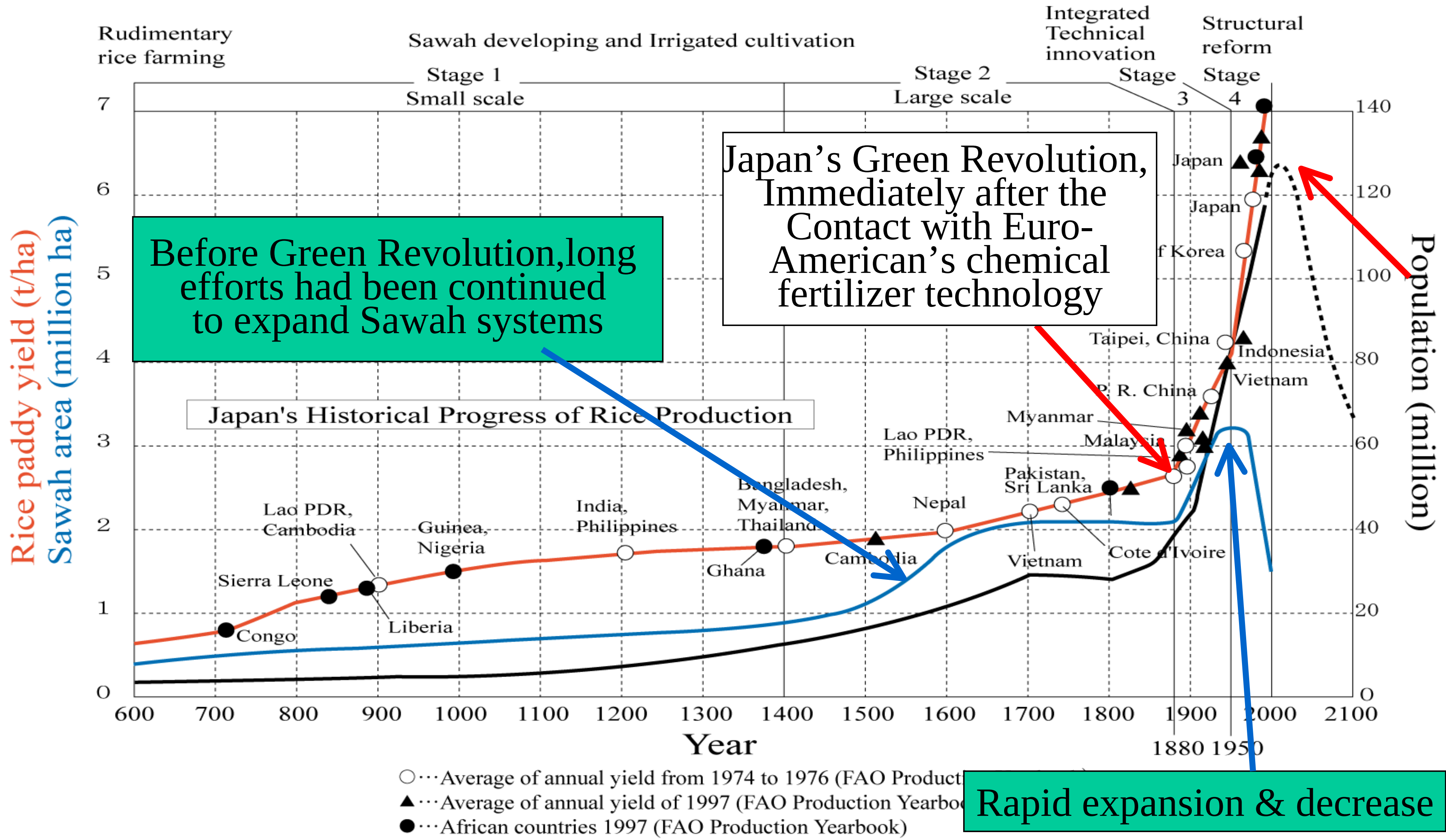
[S] > [L] > [F] > [W] > [U]

Concept of Characterization and quantitative mapping of Lowland diversity for sawah development (bunded, leveled, puddled rice land) . depending on the watershed land use, lowland topography, soil, hydrology and Agroecological zones

Estimation of rice production trend by each rice ecology in West Africa during 1984-1999/2003 and 2015 estimation by T.W. (WARDA strategic plan in 1988, African rice initiative 2002, Sakurai 2003, WARDA strategic plan 2004, FAOSTAT 2005)

	Area (million ha)			Production (million ton/y)			Yield (t/ha)		
	1984	1999/03	2015	1984	1999/03	2015	1984	1999/03	2015
Upland	1.5	1.8	2.0	1.5	1.8	2.0	1	1	1
contribution (%)	57%	40%	30%	42%	23%	13%	No yield increase		
Rainfed lowland	0.53	1.8	3.0	0.75	3.4	7.0	1.4	2.0	2.4
Irrigated lowland	0.23	0.56	0.80	0.64	1.9	3.0	2.8	3.4	3.8
Total	2.6	4.7	6.0	3.4	7.7	14	1.3	1.6	2.4

Farmers' sawah fields are the most important infrastructure:farmers' fields come the first
Japanese Experiences



Source: The chart was supplemented by the Study Team by adding FAO data published in its Yearbooks to: Takase, K. and Kano, T., "Development Strategy on Irrigation and Drainage" in the Asian Development Bank, Asian Agriculture Survey, 1969, p.520.

Takase & Kano,1969, modified

Rice yields & sawah area of historical path in Japan in comparison with rice yields in Asia & Africa

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

Classification	Area (million ha)		Percentage(%)
Coastal swamps	16.5	(5?)	7
Inland basins	107.5	(4?)	45
Flood plains	30.0	(10?)	12
Inland valleys	85.0	(15?)	36

Possible area of sawah development (million ha)

Max 20million ha (Estimated sawah area came from the relative amount of water cycle in Monsoon Asia, which has 100 million ha of sawah)

Biotechnology (seed) & Ecotechnology (sawah)

Need Balanced Research and Development

We are going to have many good varieties but farmers fields are/were not ready to accept them in SSA

NEGLECTED PRIORITY MATTERS

- **Massive On The Job farmers' Training program for Sawah based rice technology: Asian African collaboration**
- **Water, soil, and topographic characterization and mapping of Inland Valley Watersheds and flood plain for sustainable lowland sawah development**
- **In Asia, lowland availability is major limiting factor, but it seems water availability in relation to topography and climate will be major limiting factor in SSA's Sawah Development**

Integrated Genetic & National ResourceManagement Technology: Need clear concept and target, which can be examined and monitored

Bio-technology

Variety

Lowland NERICA
600,000 ha
Other HYVs
1,000,000ha
by 2015

↔

Eco-technology

Sawah

Inland Valley & Flood Plain
Sawah
Improvement 800,000 ha
New development 800,000 ha
by 2015

Monitorable Target of Increase

$(4\text{-}2)$ t/ha x $4 \times 10^5 + 8 \times 2 \times 10^5$

$\rightarrow 4.8 \times 10^6$ t/y

Conclusion: Integrated ecotechnology and biotechnology based ***African Green Revolution***

These are still rudimentary Sawah (Bida, Nigeria), but the number of sawah based rice farmers who are consciously developing water & soil management systems are steadily increasing in past 15 years. Prerequisite will be soon satisfied therefore within 10-20 years, the green revolution will be realized in SSA, especially in West Africa,if proper balanced strategy & policy were adopted for African green revolution