# West African Rice Green Revolution based on Sawah Ecotechnology in African Satoyama Watersheds.

Wakatsuki, Fashola & Buri

## 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

# Key words & Key concepts

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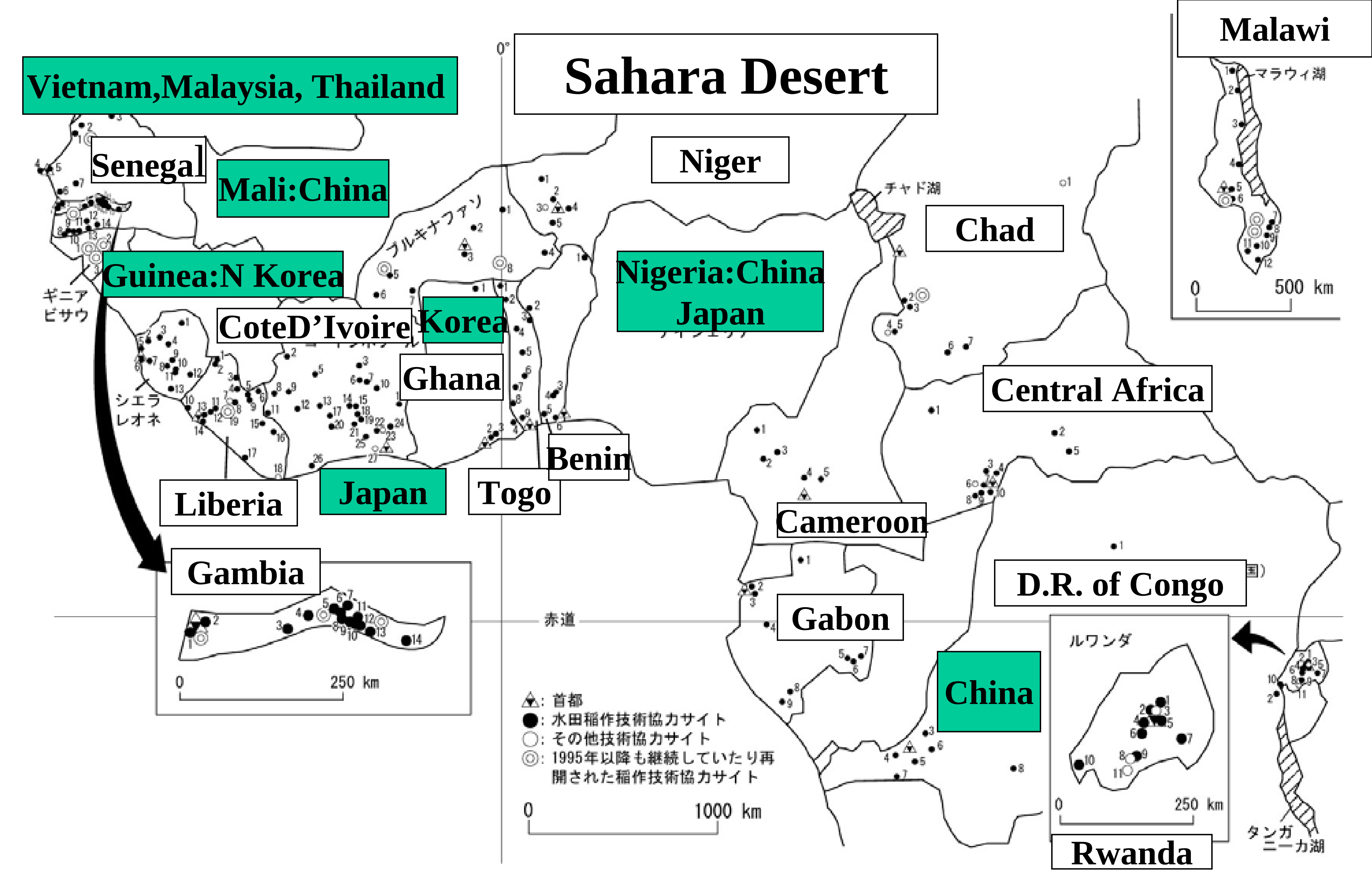



**Fig.Taiwan Project sites : ESAFS Pioneer for Sawah Ecotechnology transfer to Africa (Phase I:1960-75 and Phase II:1995-present)**

# Target 1:Field Facts and Impacts

1. Increase Sawah Farmers
2. Increase Leading Sawah Farmers Group, such as Amuni Club C and Achiber rice farmers group, 15-20 in 2010.
3. Inrease Sawah Area:100ha in 2010
4. Increase Sawah Based Paddy Production:400ton in 2010
5. Clear Publicity: Farmers' day, News paper, TV, and New Fund: IVRDP and UN Millennium village Project

# Tewiah site in CRI/JICA sawah project

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

Biemso No.1, Zongo site in 2002

Inland Valley Rice Development Project,
World Bank, 4500ha in 2004-2009
Biemso No.1, Ashanti, Ghana, Aug 2005

# Biemso No.1, Zongo site,New Sawah project, Sep.2007

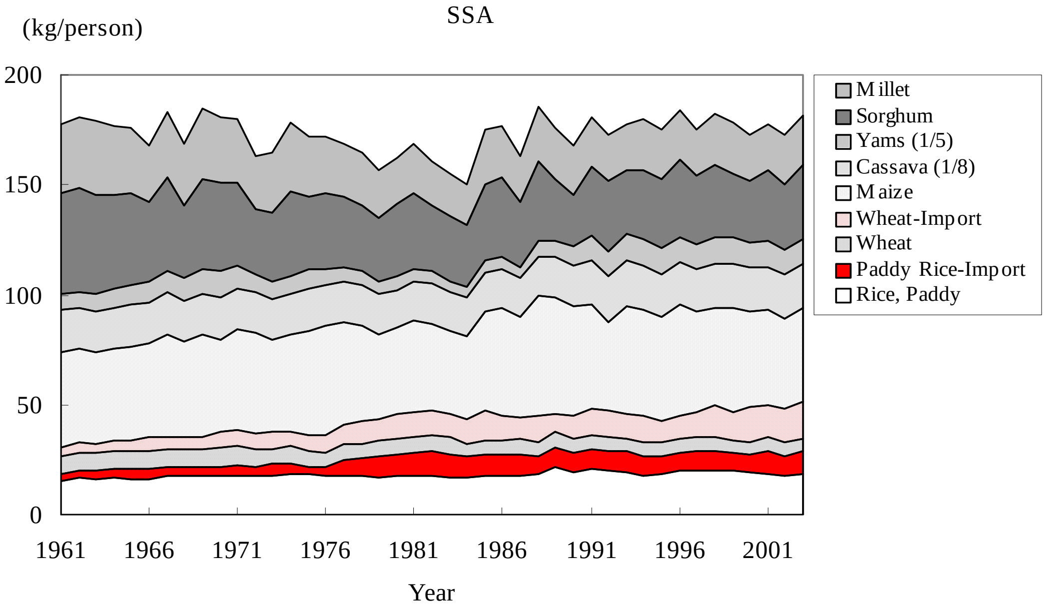
Tanokurom, Tepa, Sep. 2007

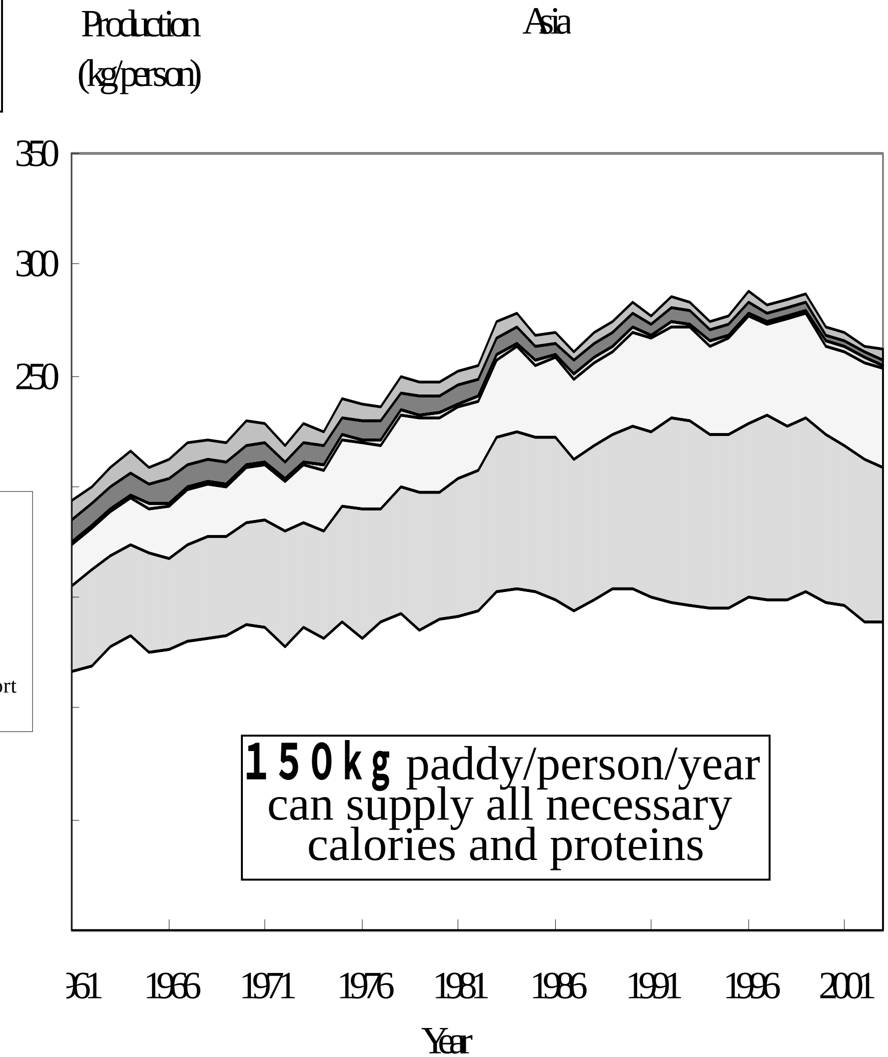
# Amakurom, possible New site by SRI in 2008

Mansokuwanta, UN Millennium village, possible new sawah Demonstration site in 2008

# Mr. Isaac and rice farmer, Mansokuwanta, UN Millennium village

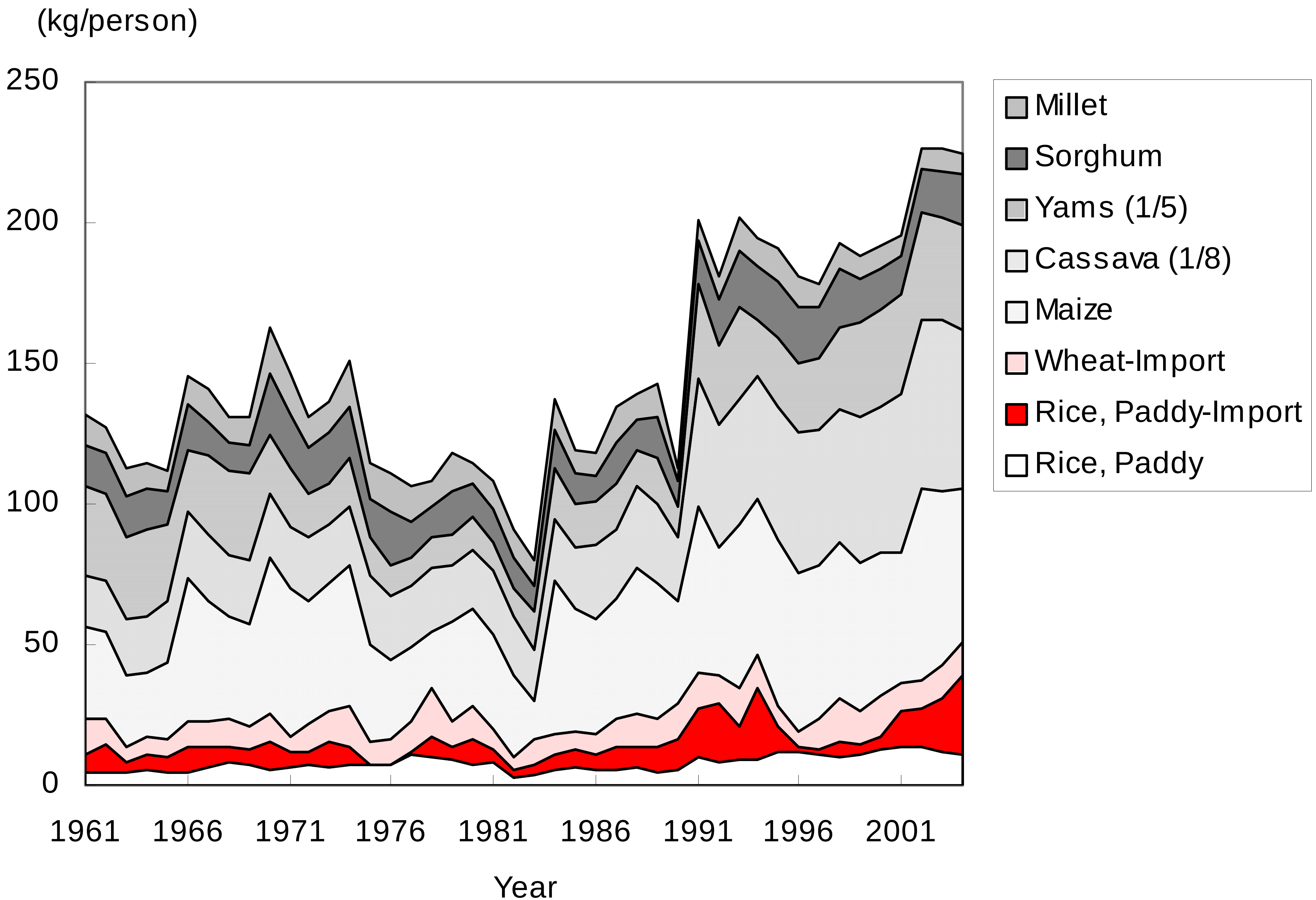
Production trend (kg/person) of diversified African crops in comparison with Asia

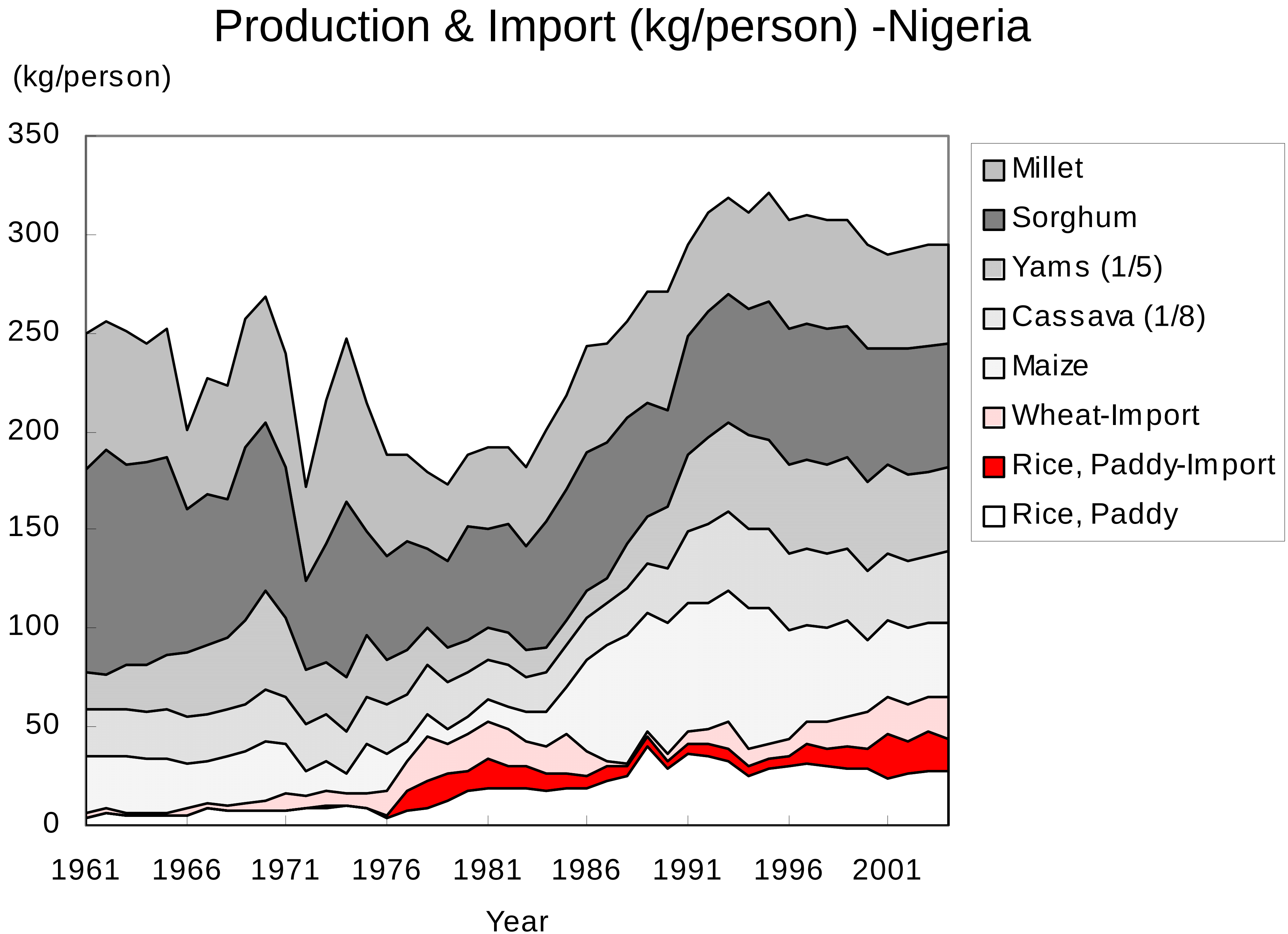


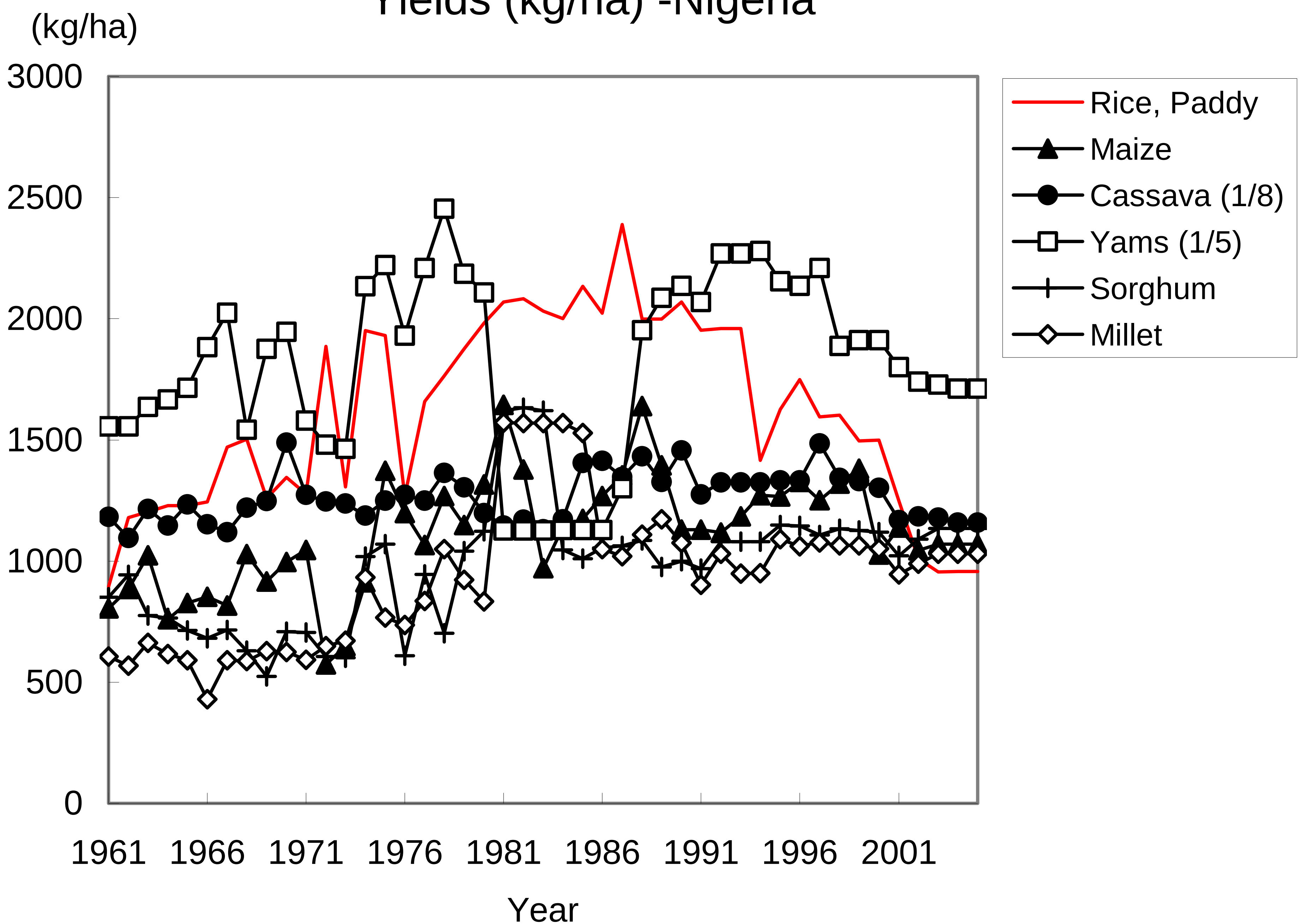

African crops are diverse, even production potential of rice is higher than demand, rice is importing. Wheat has not enough production potential in majority of SSA countries. Rice is also the highest quality cereals in terms of egg protein equivalent among the other 6 crops

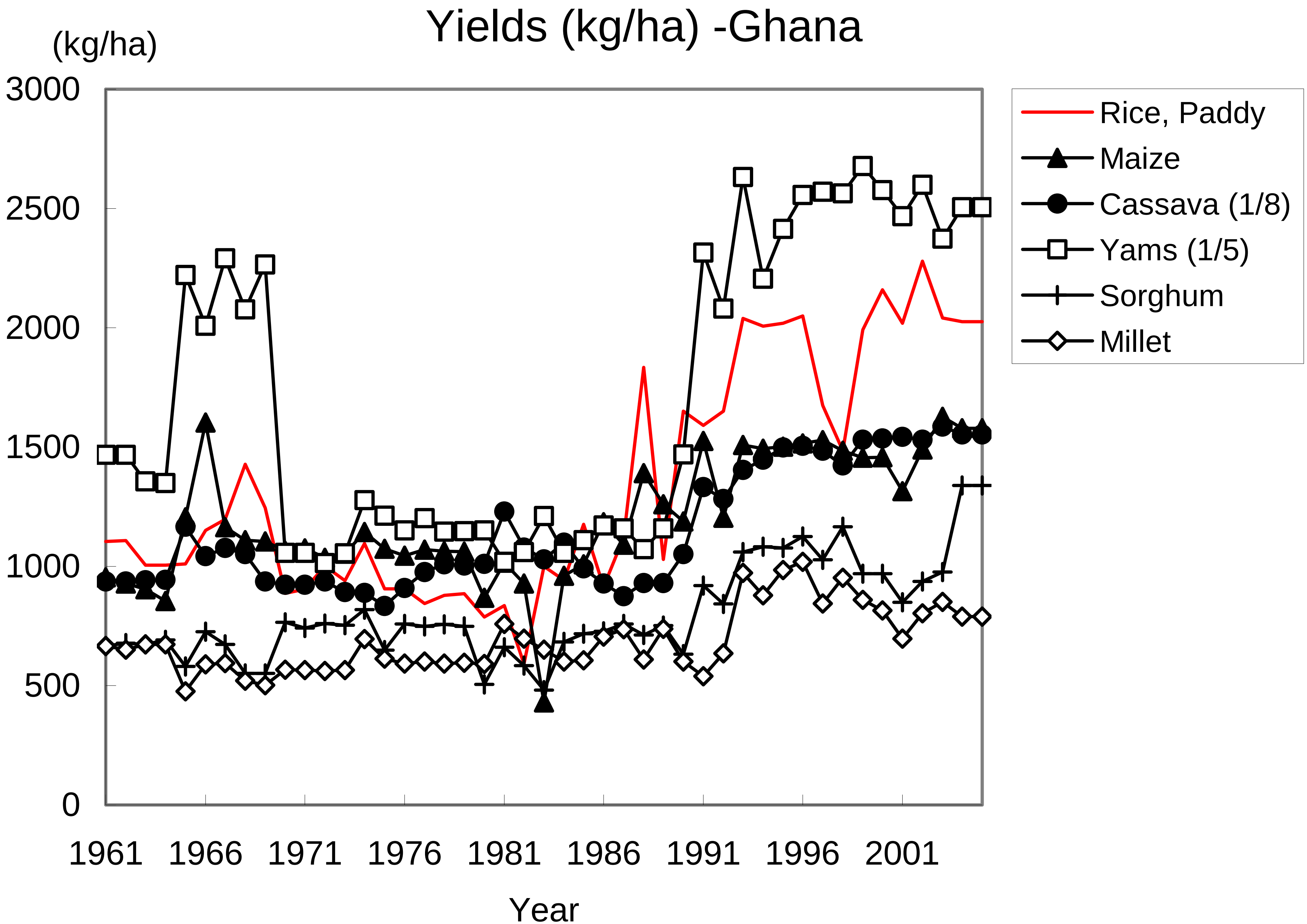
# Production & Import (kg/person) -Ghana




Production & Import (kg/person) -Nigeria
(kg/person)
350
300
250
200
150
100
50
0
1961
1966
1971
1976
1981
1986
1991
1996
2001
Year
Millet
Sorghum
Yams (1/5)
Cassava (1/8)
Maize
Wheat-Import
Rice, Paddy-Import
Rice, Paddy

## Yields (kg/ha) -Nigeria





Yields (kg/ha) -Ghana
(kg/ha)
3000
2500
2000
1500
1000
500
0
1961
1966
1971
1976
1981
1986
1991
1996
2001
Year
Rice, Paddy
Maize
Cassava (1/8)
Yams (1/5)
Sorghum
Millet

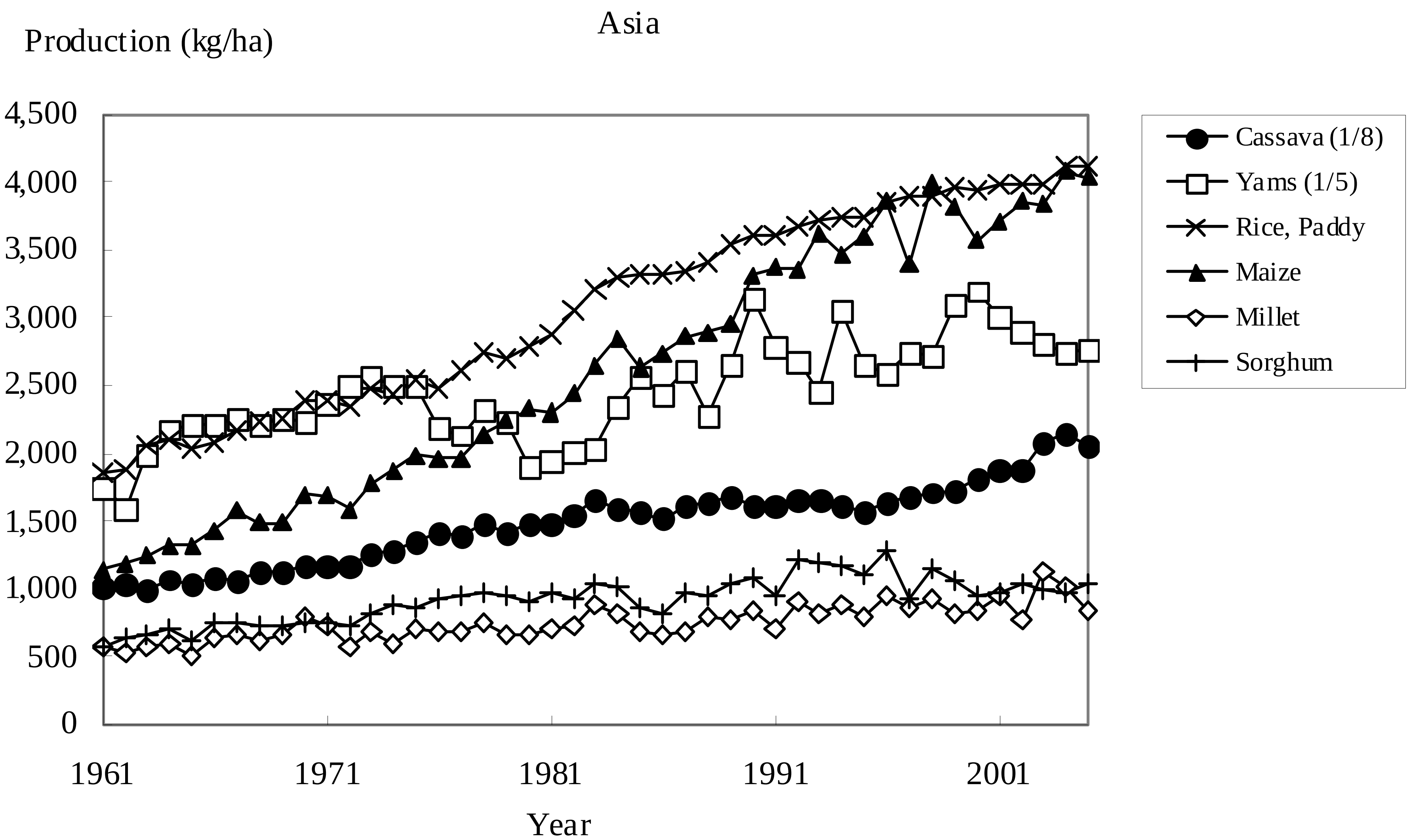



Fig. Asia, cereals production in kg per ha (FAOSTAT 2006)

# Target 2: Academic Publications

1. Number of Academic Papers per Year: 4-8
2. Number of Academic Paper per Scientist:1 per year
3. Number of Qualified International Conference Papers per Year: 4-8
4. Number of Citation Journal's Paper per Year : 2-4
5. Completion of Ph.D program: 5 by 2012

   E. Owusu Sekyere (2008), J. Opong, E. Boateng, G.K. Achempong, and M. Bandoh

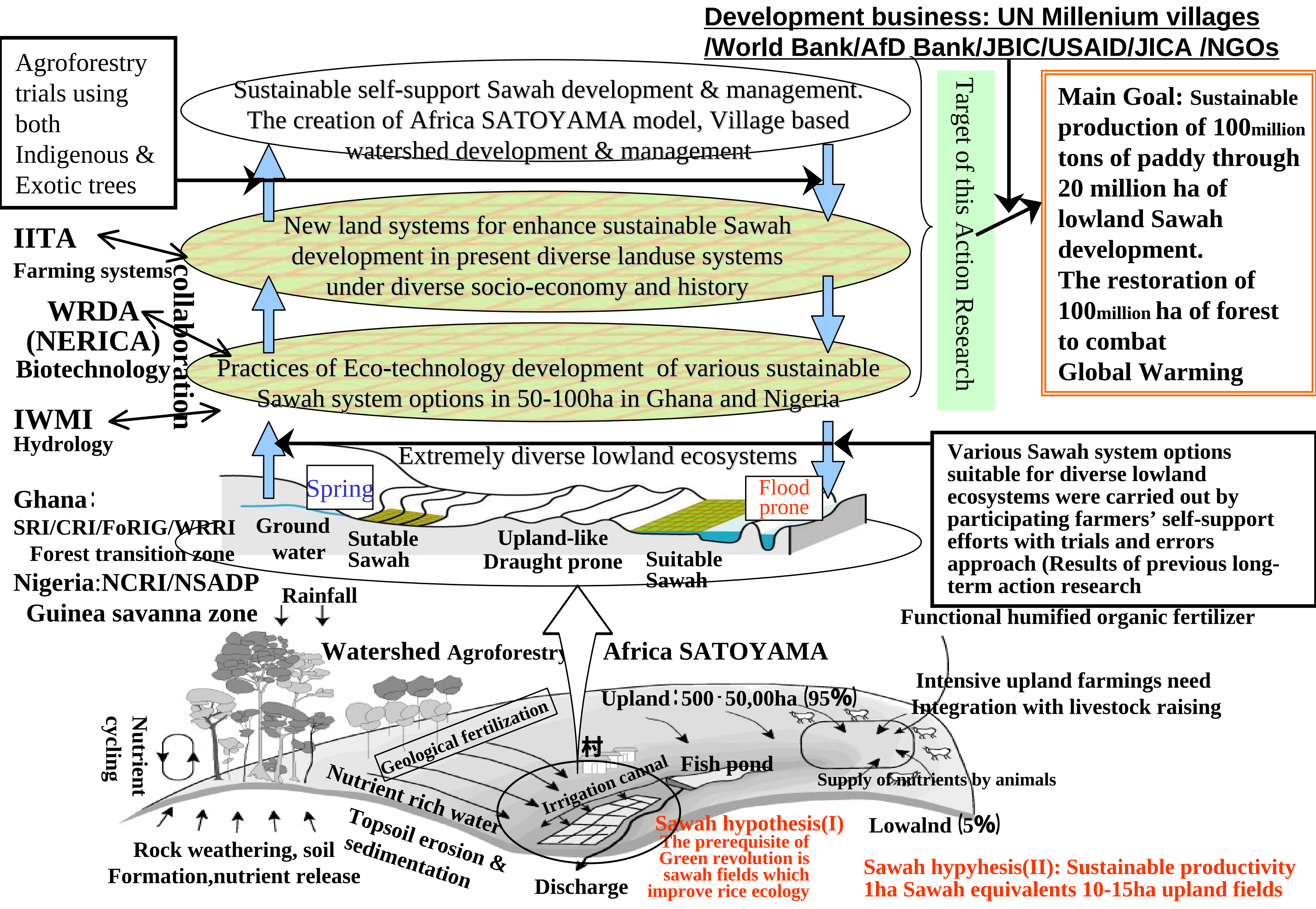



**Fig. Materialization of Green Revolution: Long-term Action Researches and the Creation of Africa SATOYMA watershed Model in collaboration with hundred farmers living in the two benchmark watershed in Ghana & Nigeria**

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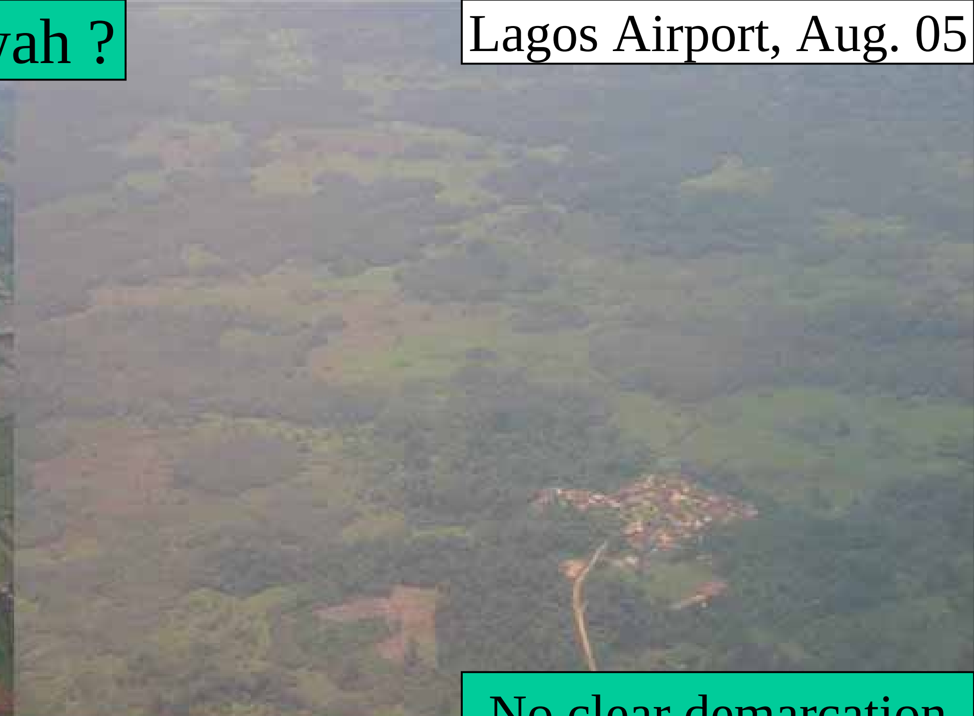
# What is Sawah ?

Bangkok Airport 05



Lagos Airport, Aug. 05

Farmers fields are demarcated

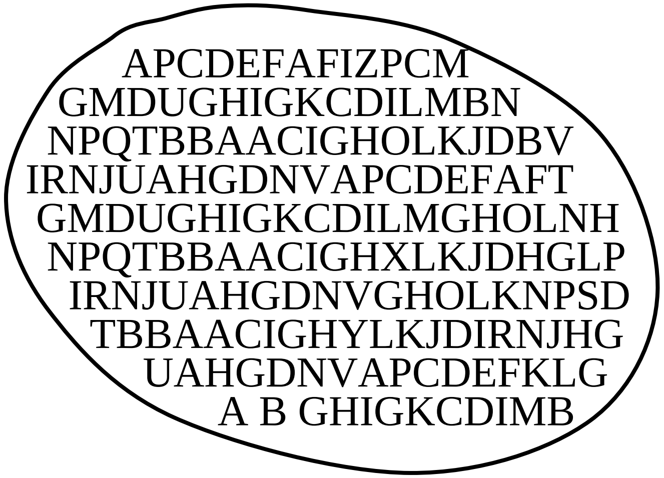
Northeastern plateau area in Thailand, July 06

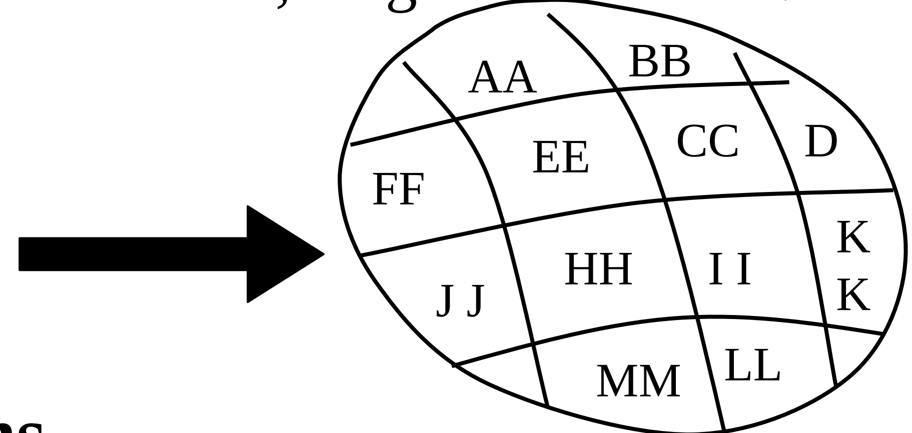
No clear demarcation

Dar es Salaam airport, July 06

**Farmers' Fields: Diverse and mixed up environment. No clear field demarcations**

**Sawah based eco-technology**: Diverse but well characterized and demarcated fields, which are prerequisite to improve rice environment, especially for water control. Green revolution technology of fertilizer, irrigation and HYV are useful.




**Mixed farming systems,**
**Diverse crops,**
**Mixed up varieties:A B C D E……**

**Fertilizer, Irrigation, and HYV are not effective**
**No Green Revolution possible**

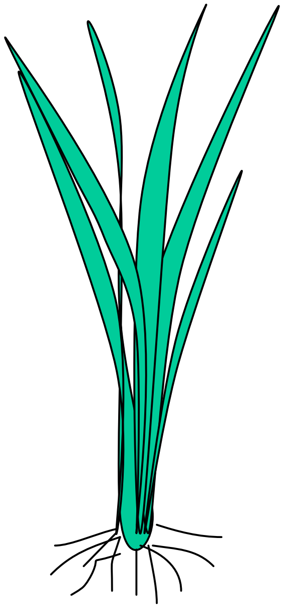
**pure variety A**
**pure variety B**
**pure variety C**
**pure variety D**

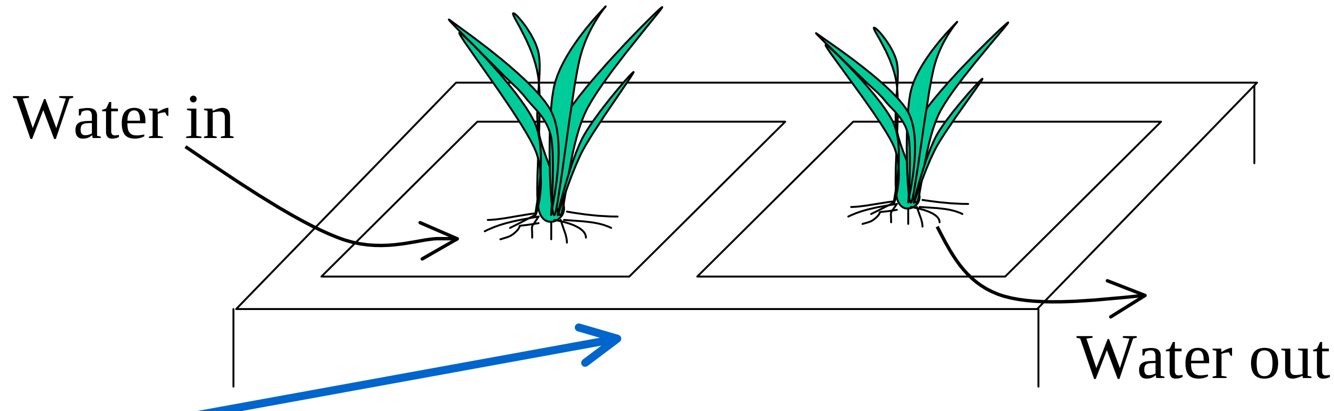
Sawah based Farming system

Fig. 6. **Successful Integrated Genetic and Natural Resource Management 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.**

**Fig.2 Rice (variety) and environment (Sawah) improvement Both Bio & Eco-technologies must be developed in balance**

# Comparison between Biotechnology and Ecotechnology Options for Rice Production

(1) Water shortage：Genes for deep rooting、C4-nature、and Osmotic regulation. Eco-technology of Sawah based soil and water management, bunding, leveling, puddling, well, weir,tank irrigation, System rice intensification

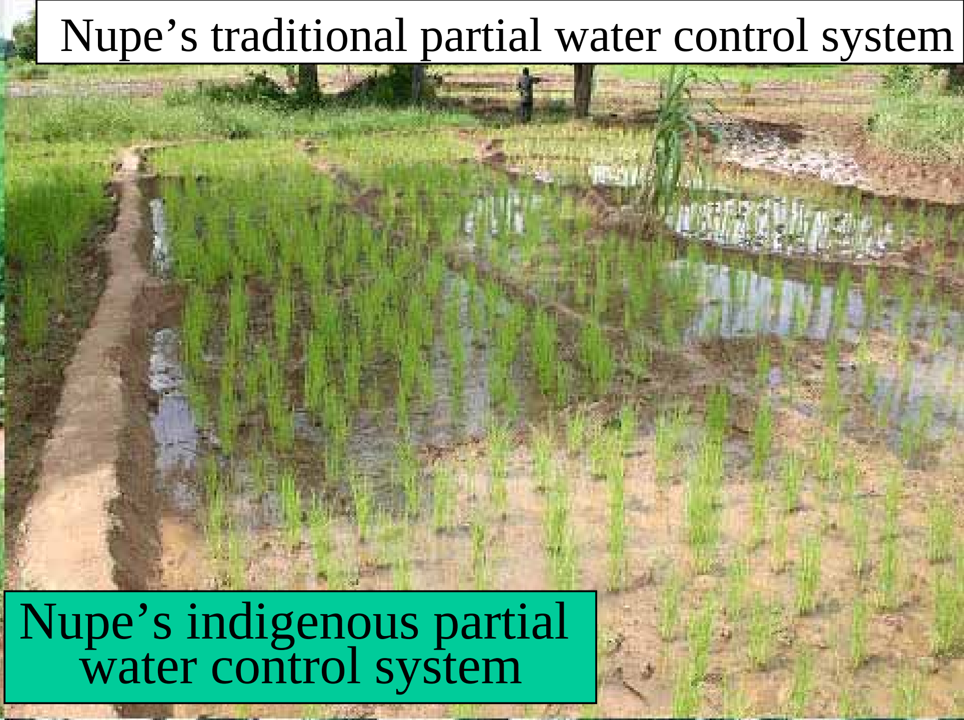
(2) Poor nutrition, acidity and alkalinity:Gene of Phosphate and micronutrient transporter. Eco-technology of Sawah based N fixation, increase P availability and micro- as well as macronutrient. Geological fertilization, Watershed agroforestry, organic matter and fertilization. Bird feculent are rich in P.

(3) Weed control:Gene of weed competition, rapid growth. Eco-technology of Sawah based weed management through water control. and tans-planting. Leveling quality of sawah is important. Duck and rice farming.

(4) Pest and disease control: Resistance genes. Eco-technology of Sawah based silica and other nutrients supply to enhance immune mechanisms of rice. Mixed cropping.

(5) Food quality: Vitamine rice gene. Sawah based nutrition control. Fish, duck and rice in sawah systems

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

Top-survey, Inland valley, Ashanti, Ghana

Canal construction by farmers

Simple barrage by farmers' efforts

Spring Irrigated Rudimentary Sawah, Nupe

## 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

BIOTECHNOLOGICAL IMPROVEMENT

| Entry No. | Cultivar | Irrigated Sawah HIL (t/ha) | Irrigated Sawah LIL (t/ha) | Rainfed sawah HIL (t/ha) | Rainfed sawah LIL (t/ha) | Upland like fields HIL (t/ha) | Upland like fields LIL (t/ha) |
|---|---|---|---|---|---|---|---|
| 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

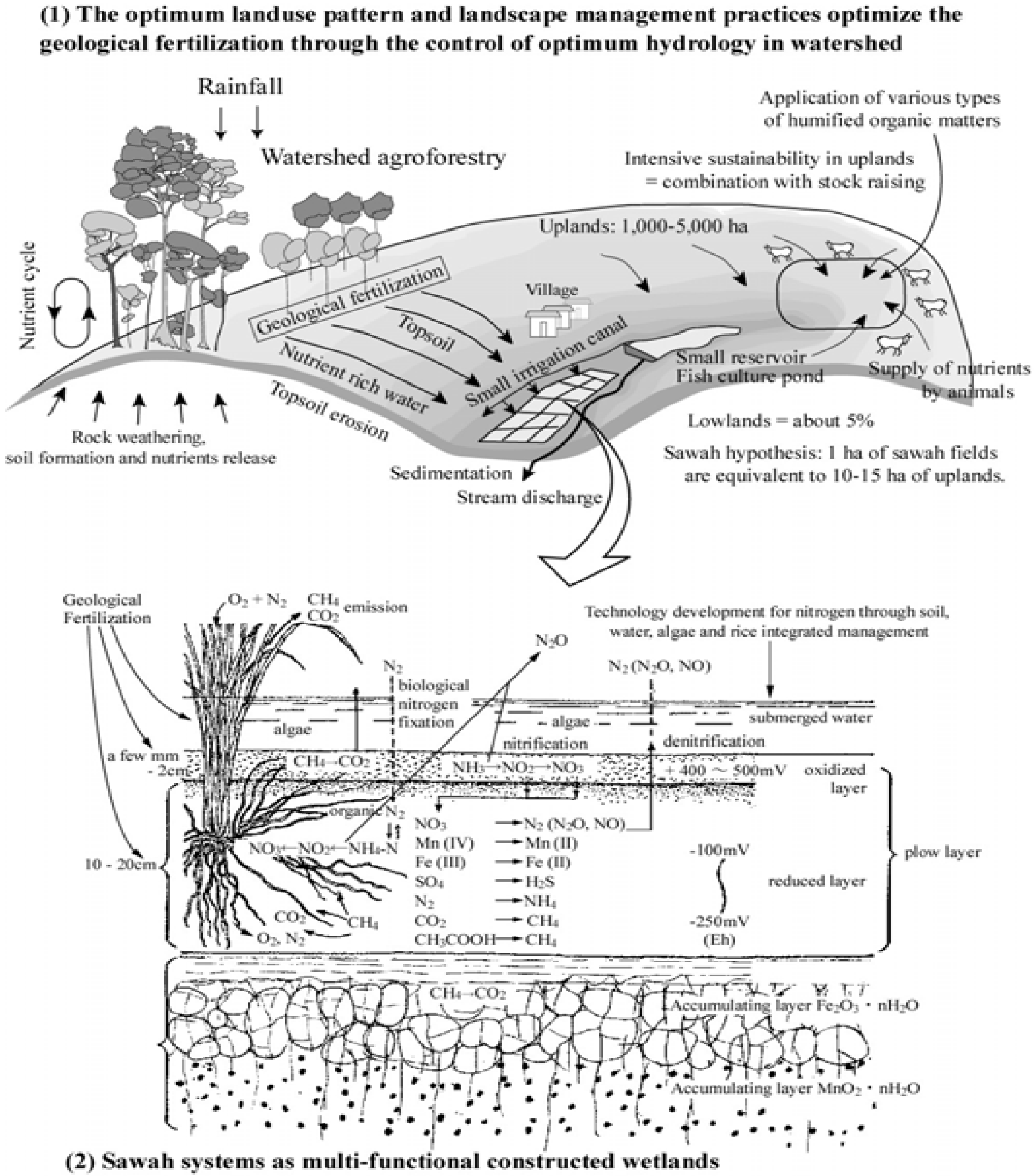
# Table 4: Sawah hypothesis(II): Sustainable Productivity of lowland Sawah is more than 10 times than Upland Field

1ha sawah is equivalent to 10-15ha of upland

| | Upland | | Lowland(Sawah) |
|---|---|---|---|
| Area (%) | 95 % | | 5 % |
| Productivity (t/ha) | 0.5-3 1** | | 3-8 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

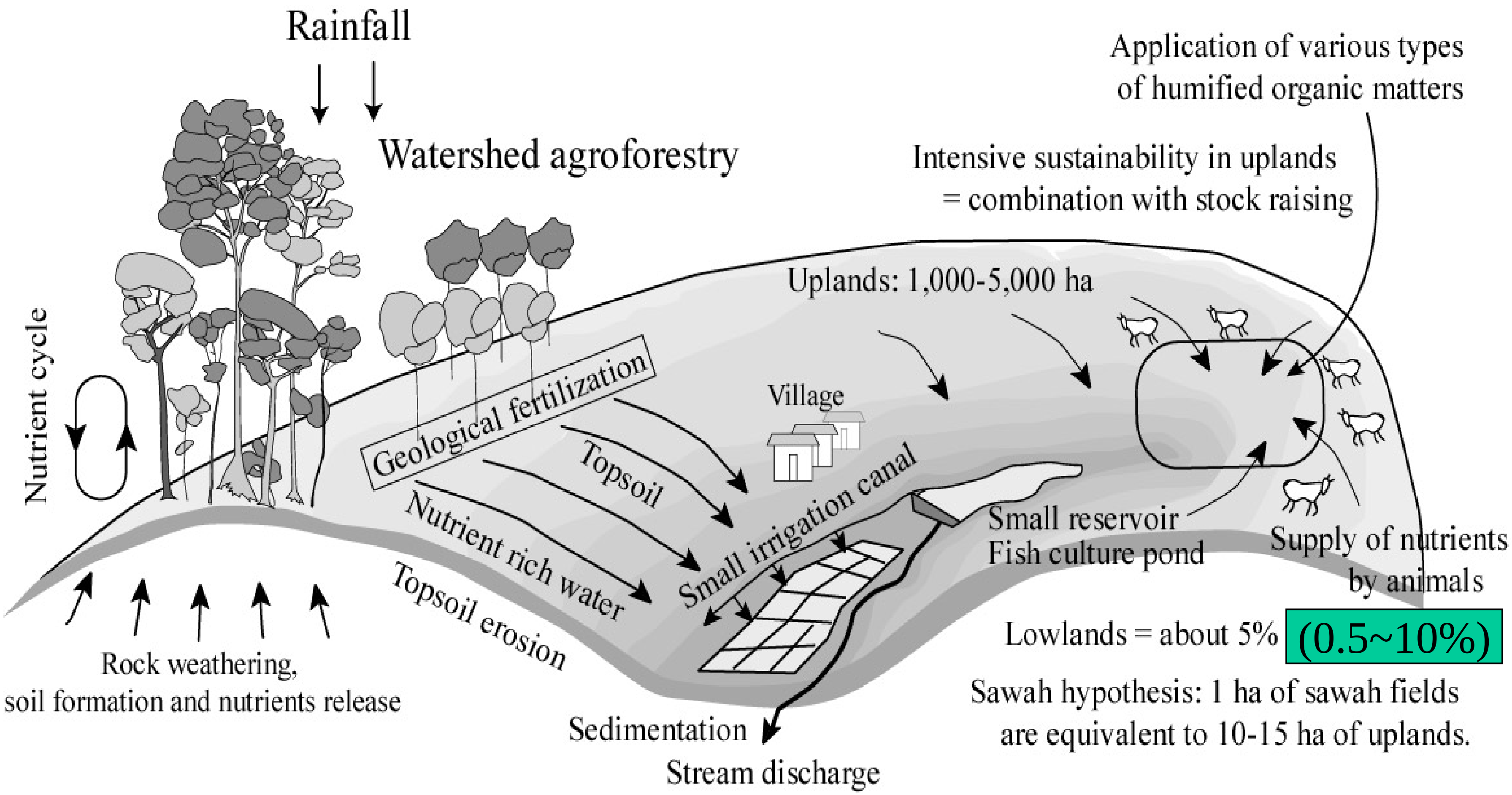



# Macro- and Micro-scale Ecological Mechanisms of Intensive Sustainability of Lowland Sawah Systems

(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**

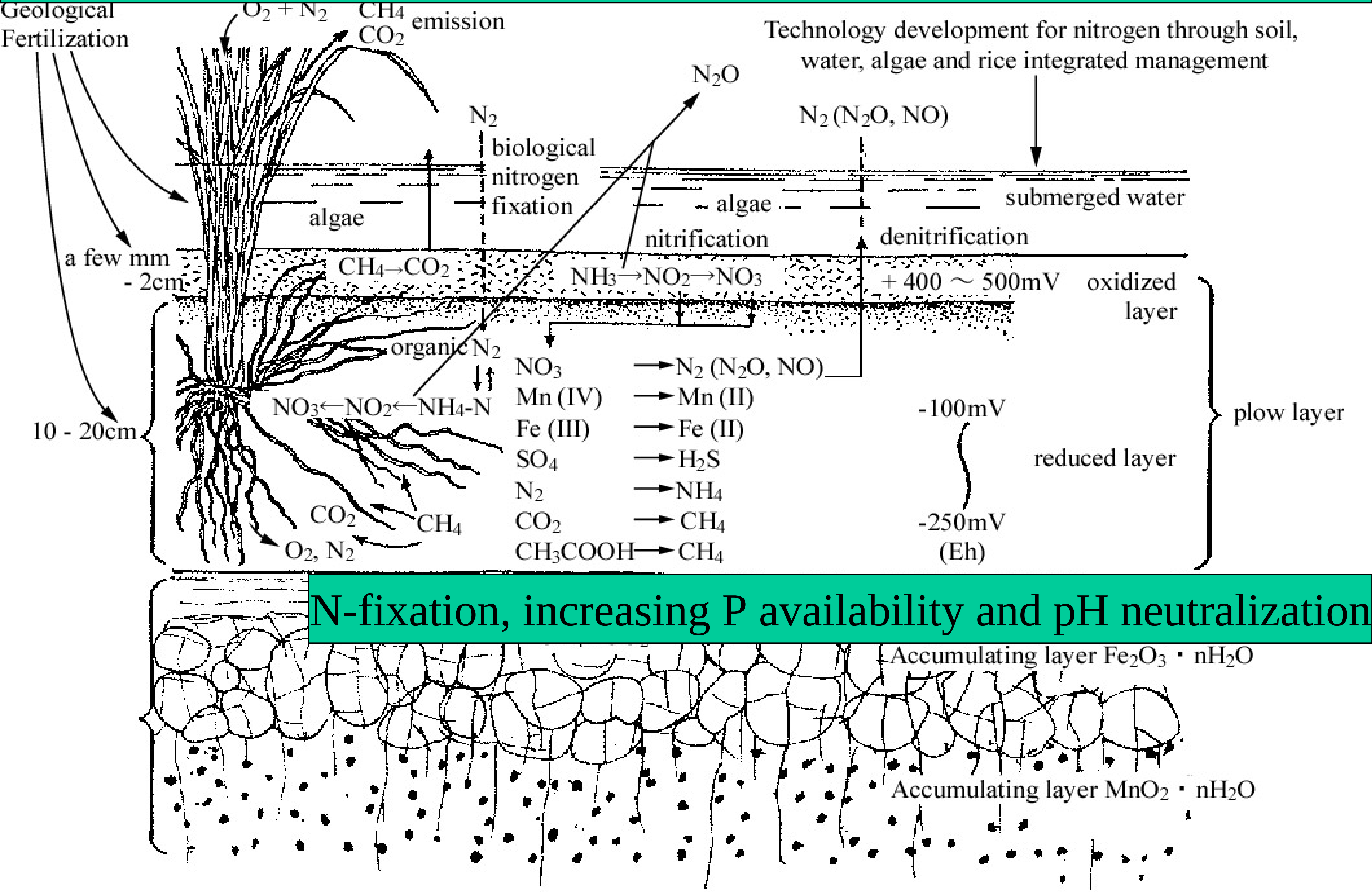



Concept of Watershed Eco-technology, i.e.,(1)Watershed Agro-forestry and (2)Multi-functional Sawah type wetland are key components

# 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**

**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 in comparison with Asian watersheds: Ecological Balance studies are necessary**

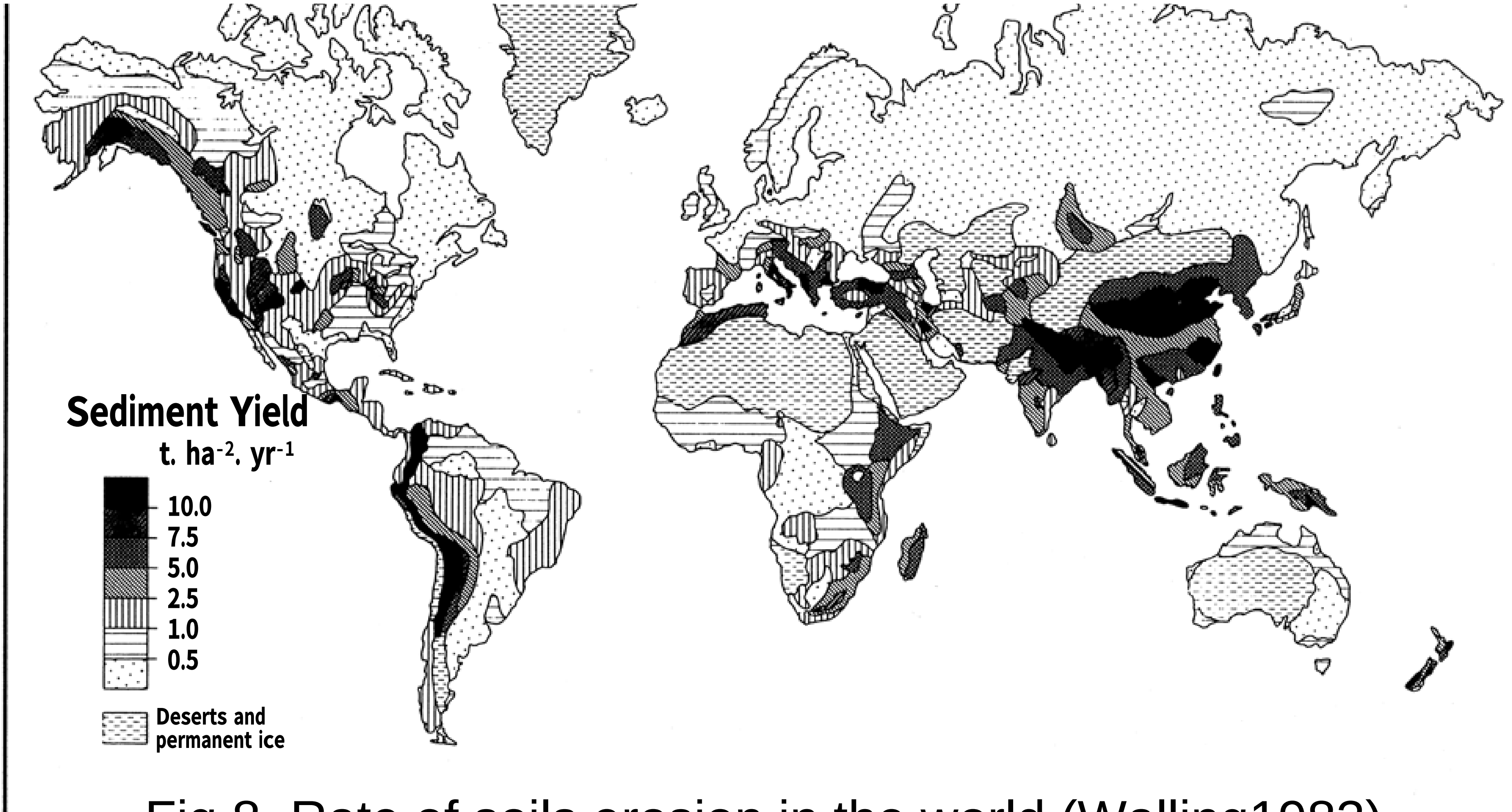
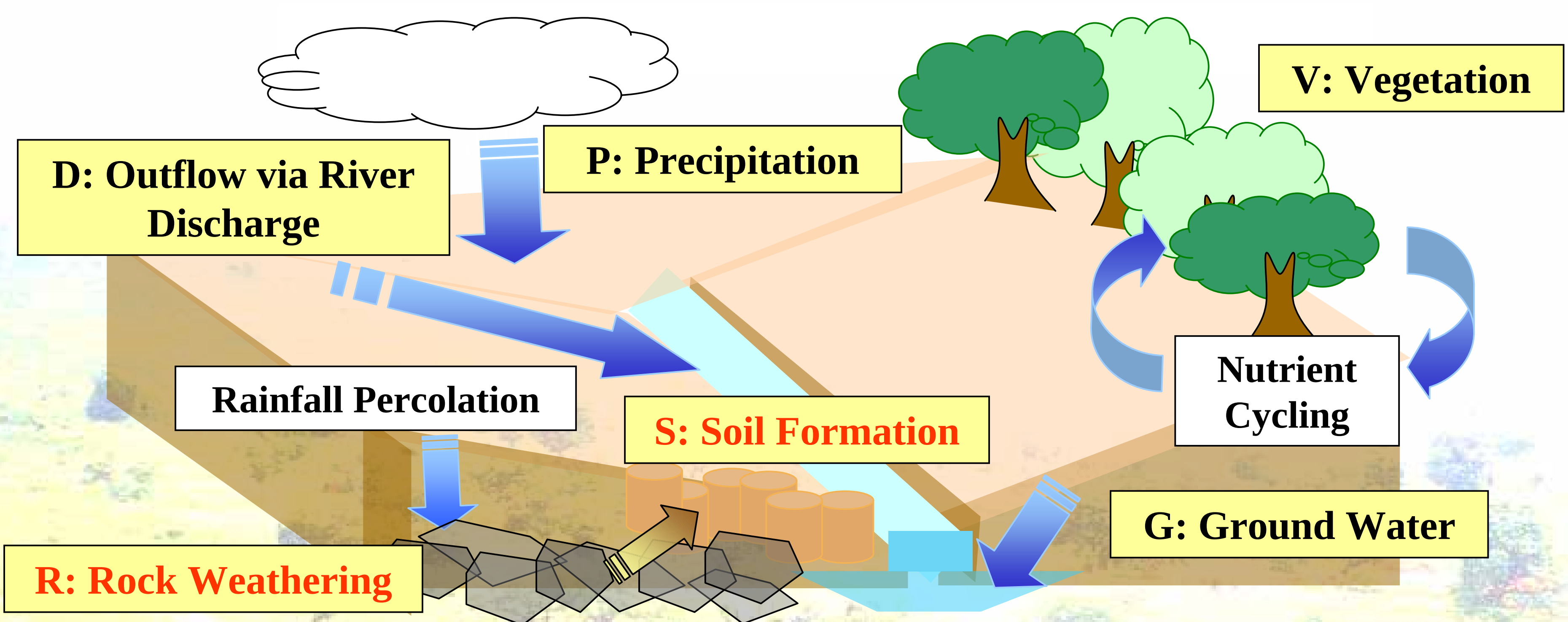



Fig.8. Rate of soils erosion in the world (Walling1983)

# Dynamics of Elements in Watersheds




**Geo-chemical Element Distribution in Watershed :**

**Rainfall + Rock == Soil + River + Ground Water + Vegetation**

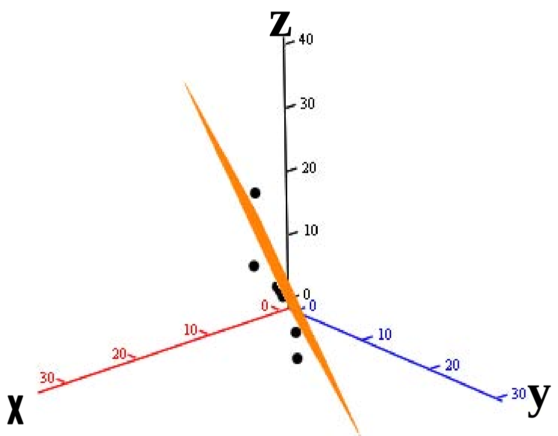
**Geo-chemical Mass Balance in Matured Mountain Forest :**

**River-Rainfall = Rock – Soil**

# Multiple regression method for estimating rates of weathering and soil formation in water sheds.

R: Rate of rock weathering (t / ha / y)

S: Rate of soil formation (t / ha / y )

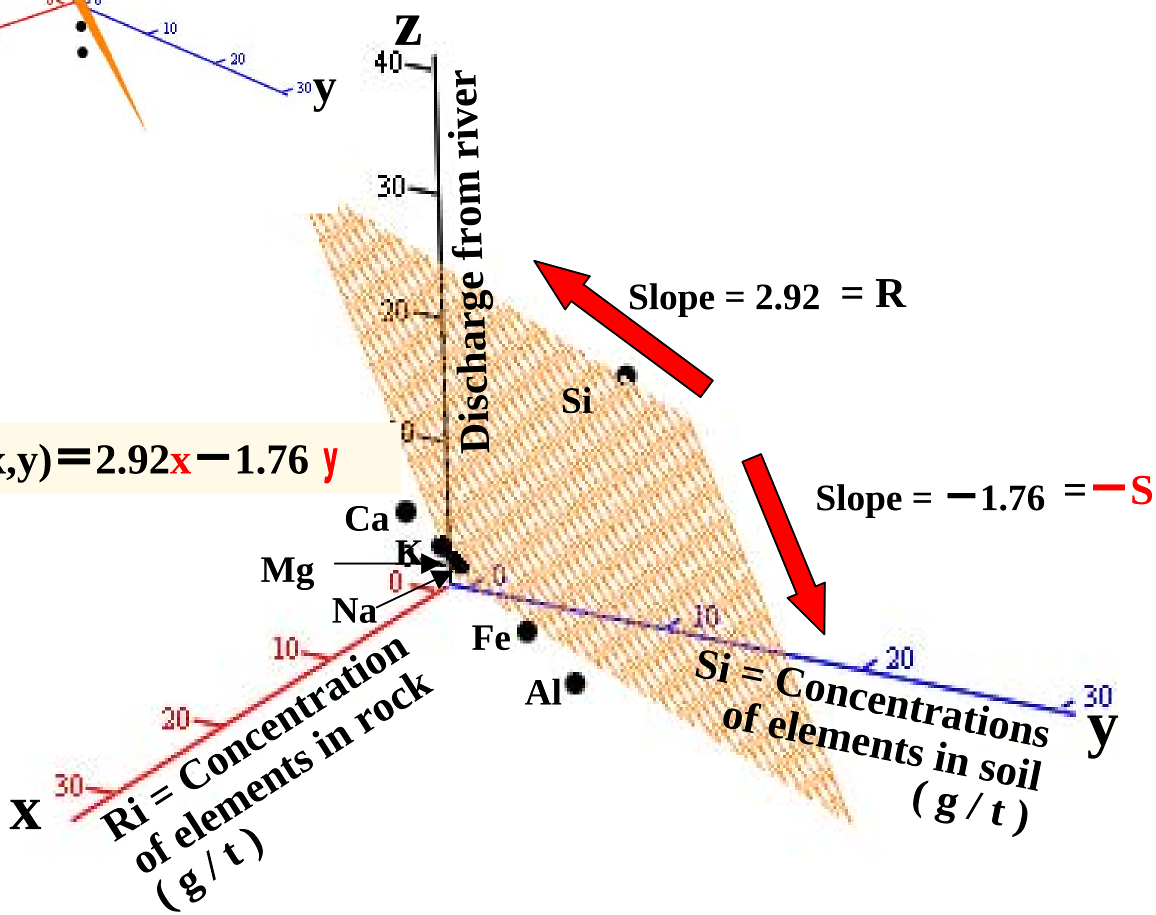



$$D\,D_i - P\,P_i = R_i \times R - S_i \times S$$

(D Di: river; P Pi: precipitation; Ri: rock; Si: soil)

G.Gadut (Indonesia) watershed

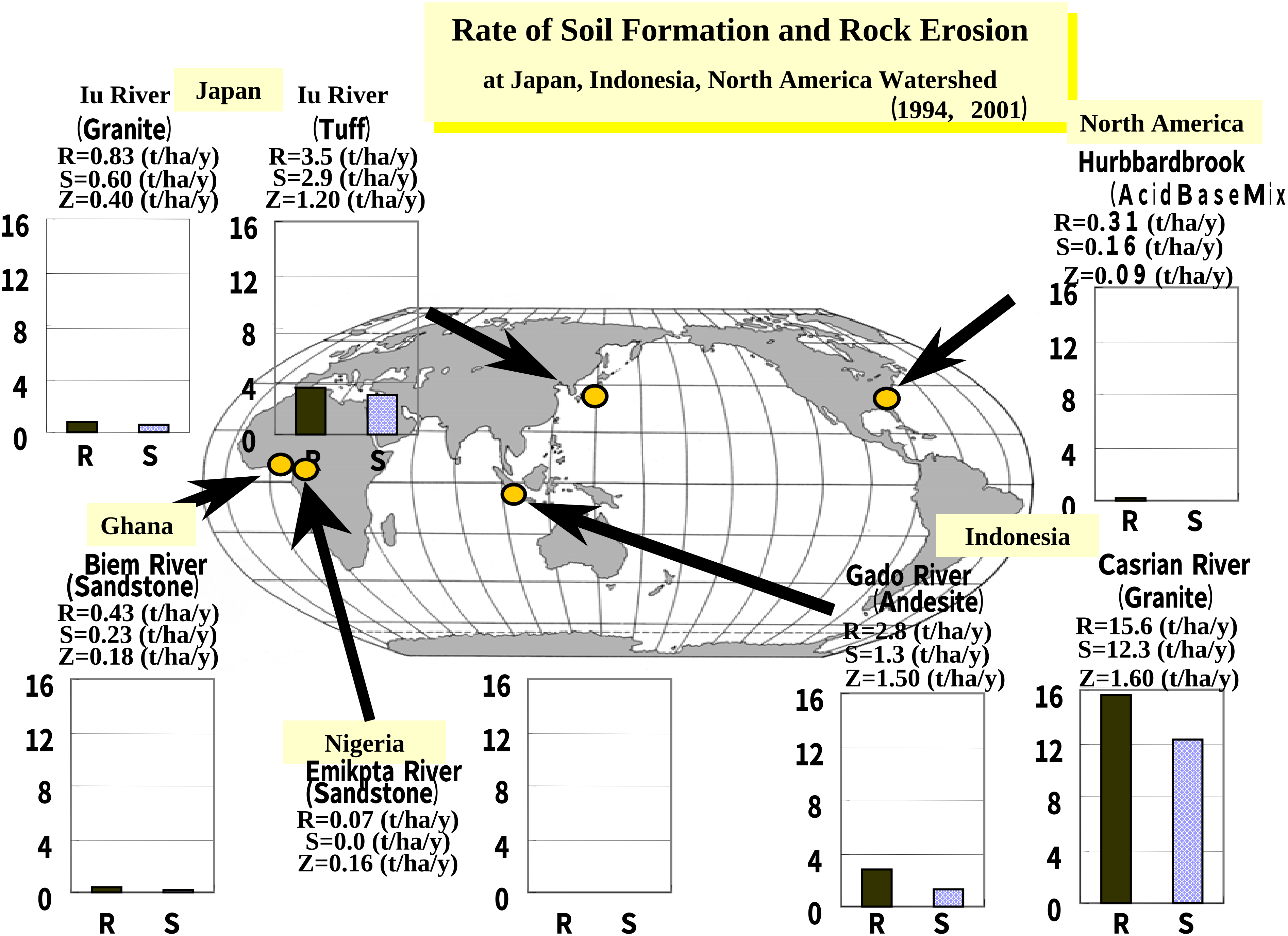
R=2.92 S=1.76 (t/ha/y)




$$Z(x,y) = 2.92x - 1.76\,y$$

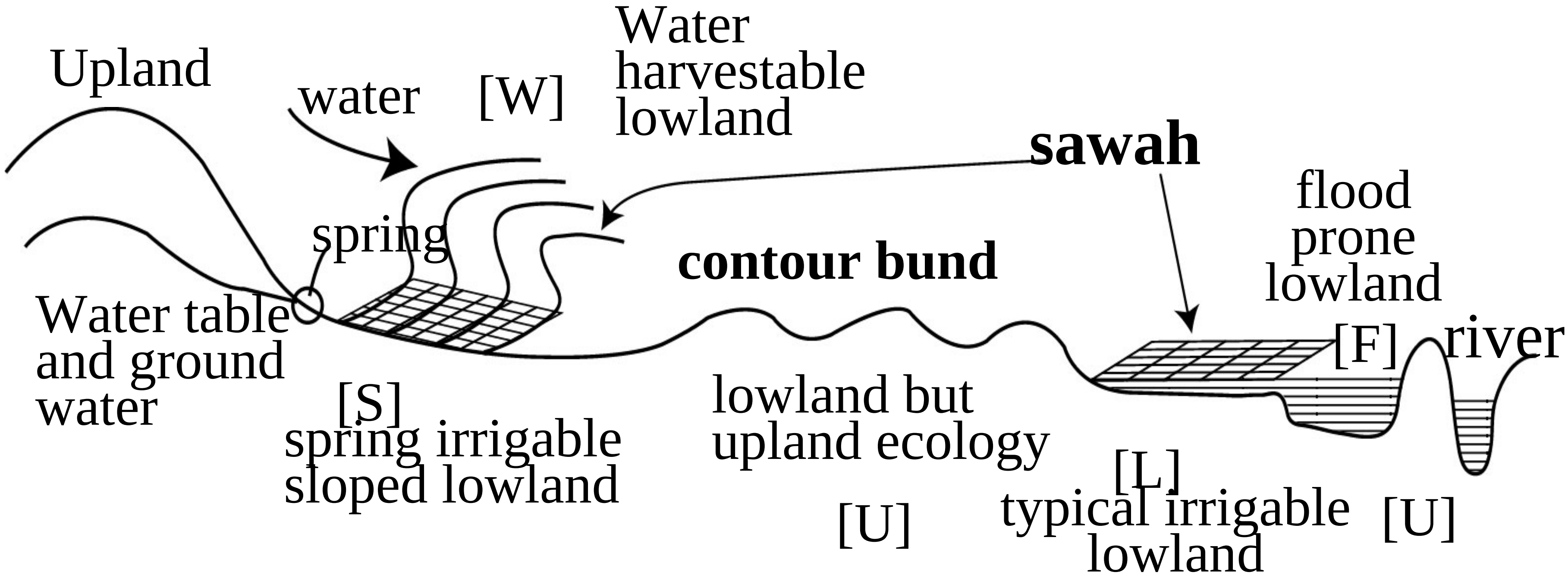
$$R = \frac{\begin{pmatrix} Na \\ K \\ Ca \\ Mg \\ Al \\ Fe \\ Si \end{pmatrix}_{Si} \times S + \begin{pmatrix} Na \\ K \\ Ca \\ Mg \\ Al \\ Fe \\ Si \end{pmatrix}_{DDi-PPi}}{\begin{pmatrix} Na \\ K \\ Ca \\ Mg \\ Al \\ Fe \\ Si \end{pmatrix}_{Ri}}$$

$$-S = \frac{-\begin{pmatrix} Na \\ K \\ Ca \\ Mg \\ Al \\ Fe \\ Si \end{pmatrix}_{Ri} \times R + \begin{pmatrix} Na \\ K \\ Ca \\ Mg \\ Al \\ Fe \\ Si \end{pmatrix}_{DDi-PPi}}{\begin{pmatrix} Na \\ K \\ Ca \\ Mg \\ Al \\ Fe \\ Si \end{pmatrix}_{Si}}$$



Rate of Soil Formation and Rock Erosion
at Japan, Indonesia, North America Watershed
(1994, 2001)
Japan
Iu River
(Granite)
R=0.83 (t/ha/y)
S=0.60 (t/ha/y)
Z=0.40 (t/ha/y)
Iu River
(Tuff)
R=3.5 (t/ha/y)
S=2.9 (t/ha/y)
Z=1.20 (t/ha/y)
North America
Hurbbardbrook
(AcidBaseMix)
R=0.31 (t/ha/y)
S=0.16 (t/ha/y)
Z=0.09 (t/ha/y)
Ghana
Biem River
(Sandstone)
R=0.43 (t/ha/y)
S=0.23 (t/ha/y)
Z=0.18 (t/ha/y)
Nigeria
Emikpta River
(Sandstone)
R=0.07 (t/ha/y)
S=0.0 (t/ha/y)
Z=0.16 (t/ha/y)
Indonesia
Gado River
(Andesite)
R=2.8 (t/ha/y)
S=1.3 (t/ha/y)
Z=1.50 (t/ha/y)
Casrian River
(Granite)
R=15.6 (t/ha/y)
S=12.3 (t/ha/y)
Z=1.60 (t/ha/y)
16
12
8
4
0
R
S


Inland Valley Rice Development Project,
World Bank, 4500ha in 2004-2009
Biemso, Ashanti, Ghana, Aug 2005




**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]

**Fig. 2: 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**

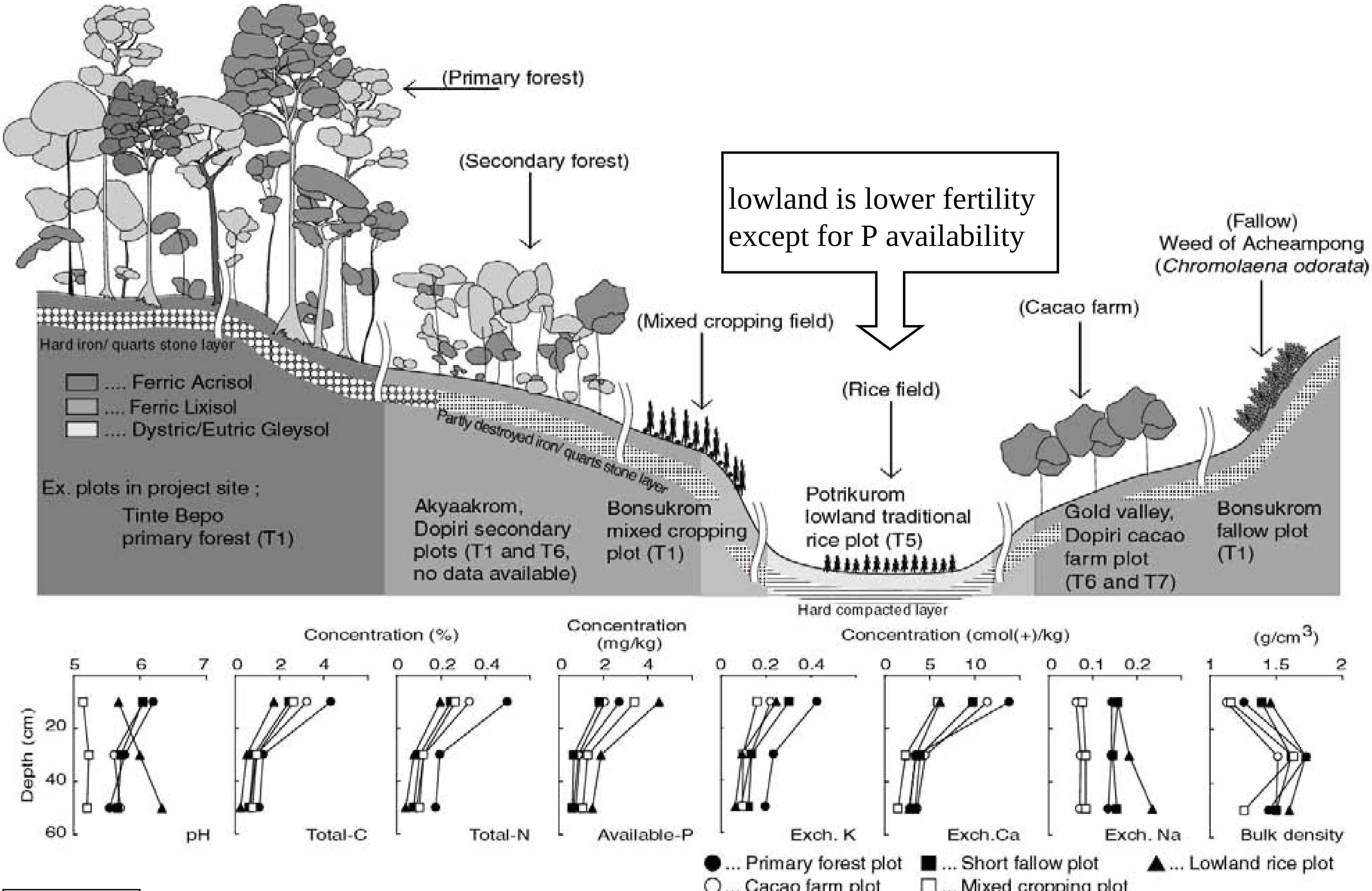
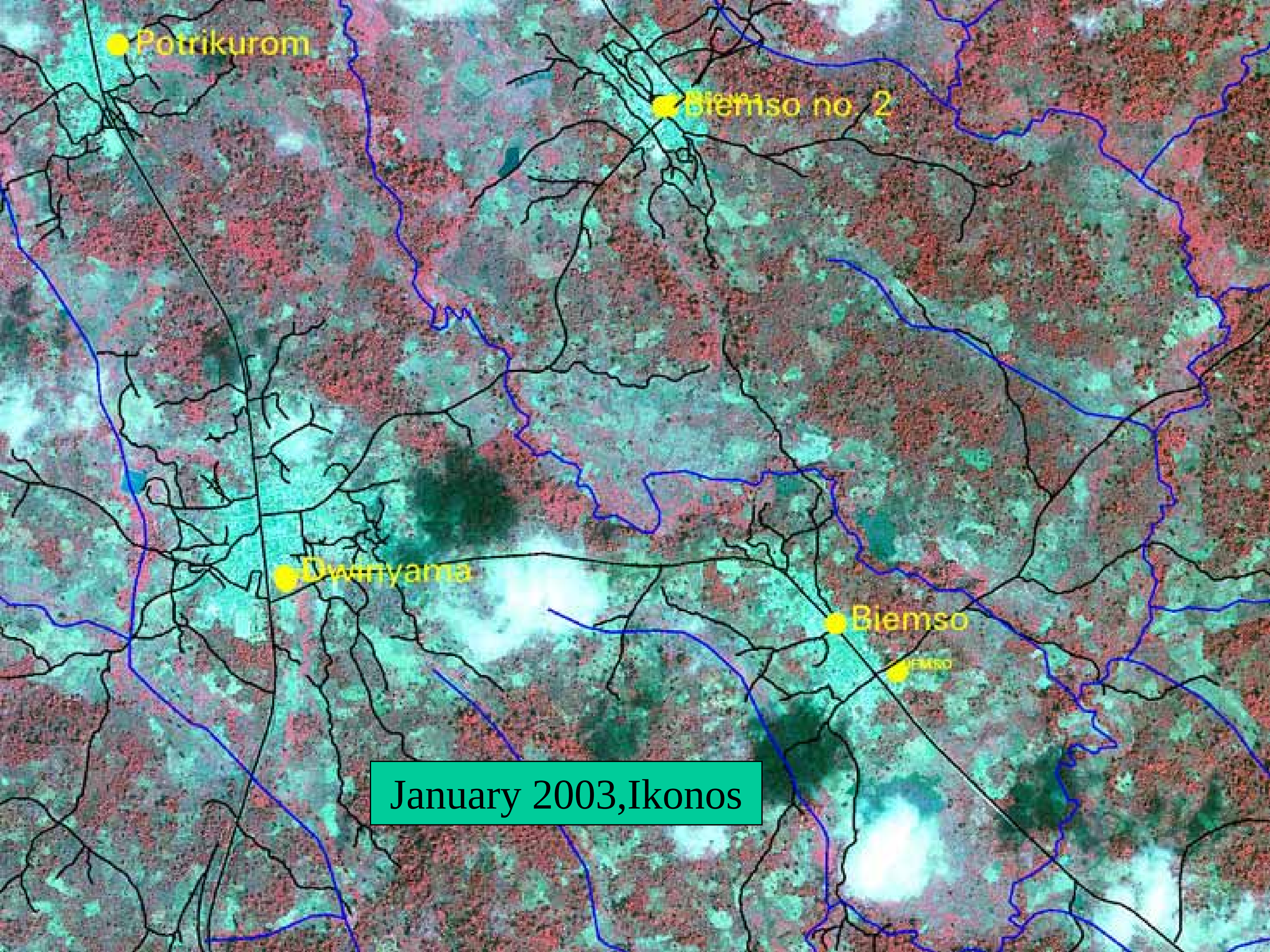
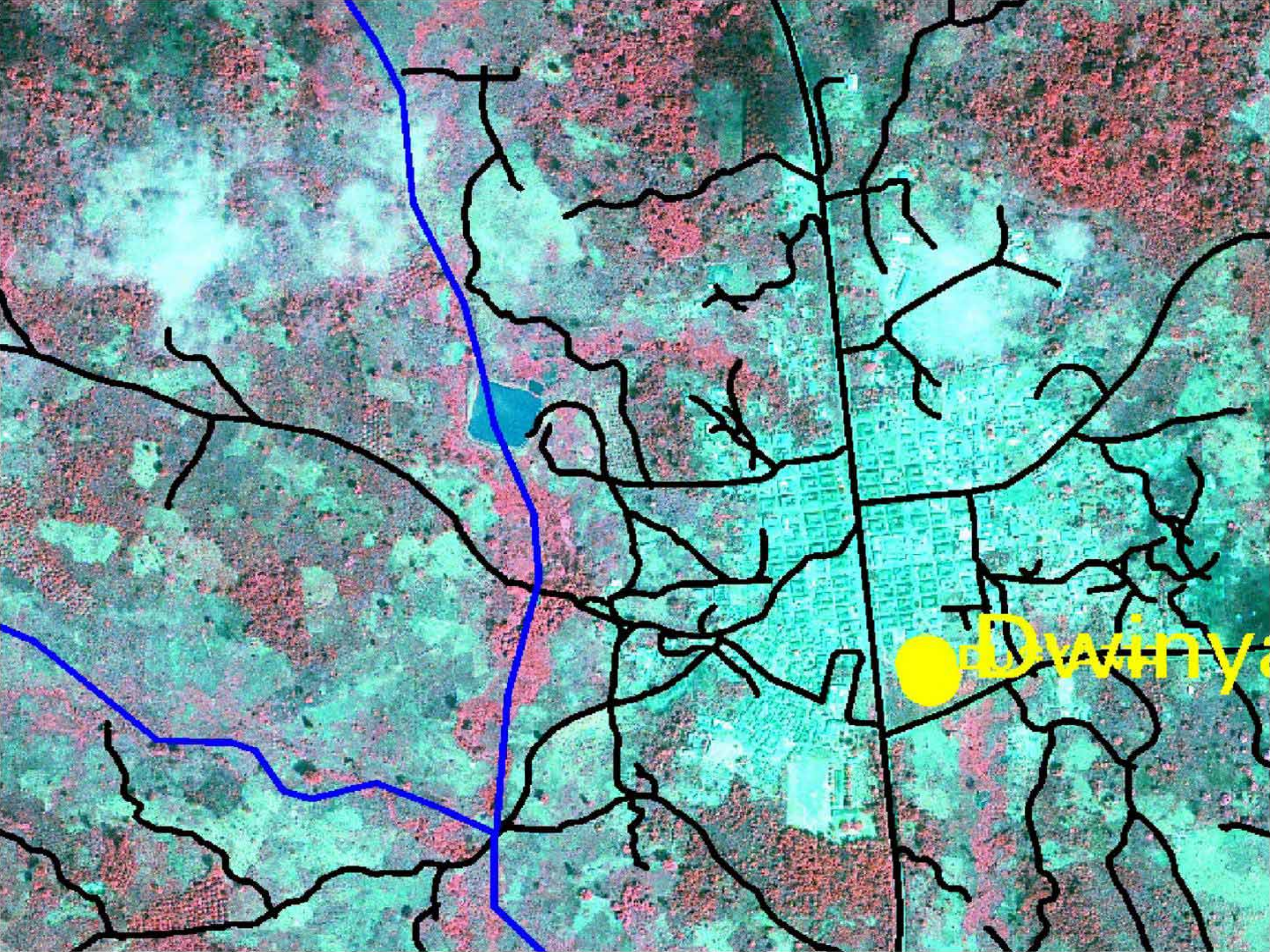
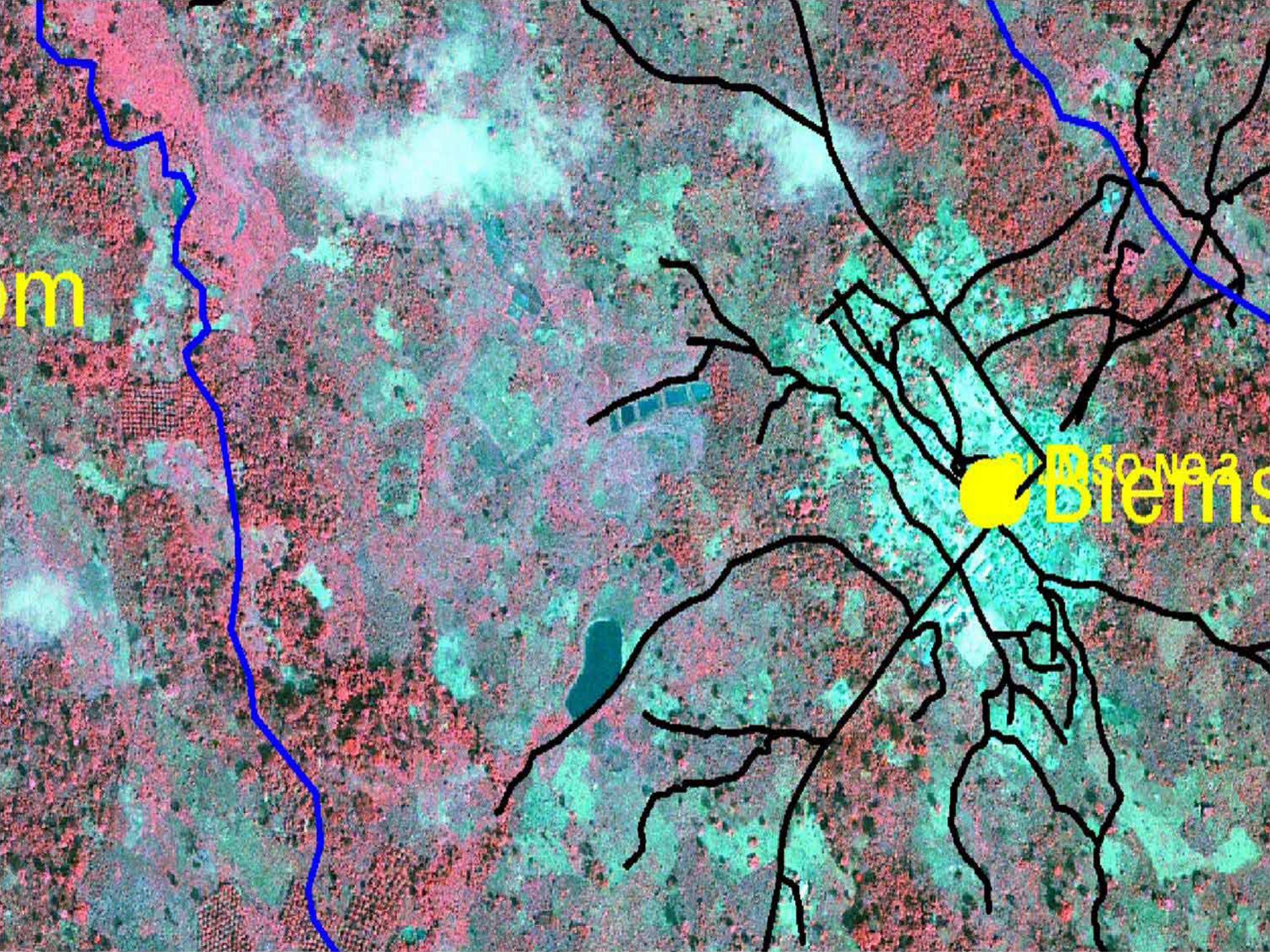


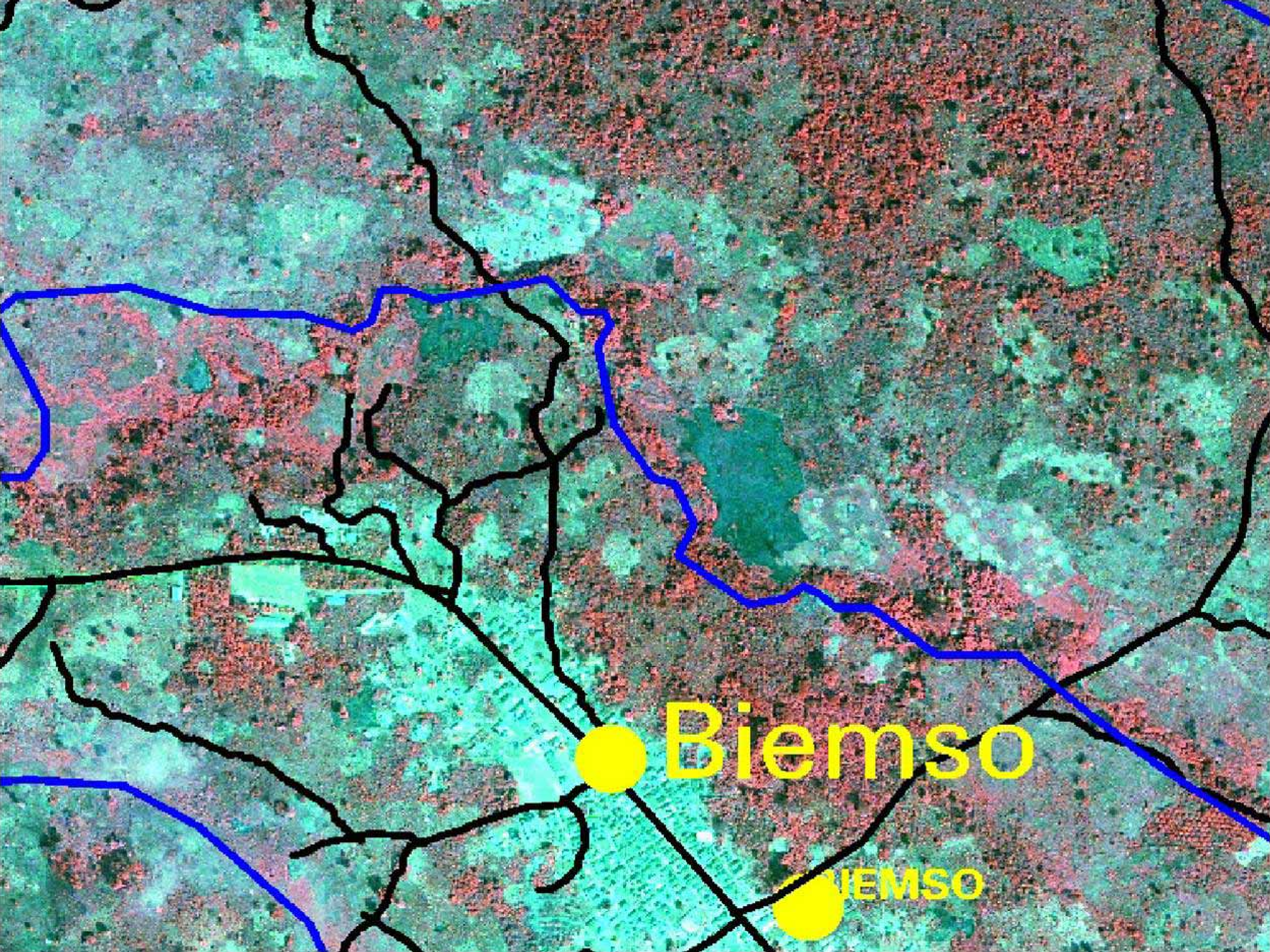

Fig.14 Typical soil type, land use (vegetation) and topography in benchmark inland valley watersheds. Profile characteristics of nutrients and bulk density are also shown in five land uses.




January 2003,Ikonos


Dwinya




Biemso
NEMSO

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

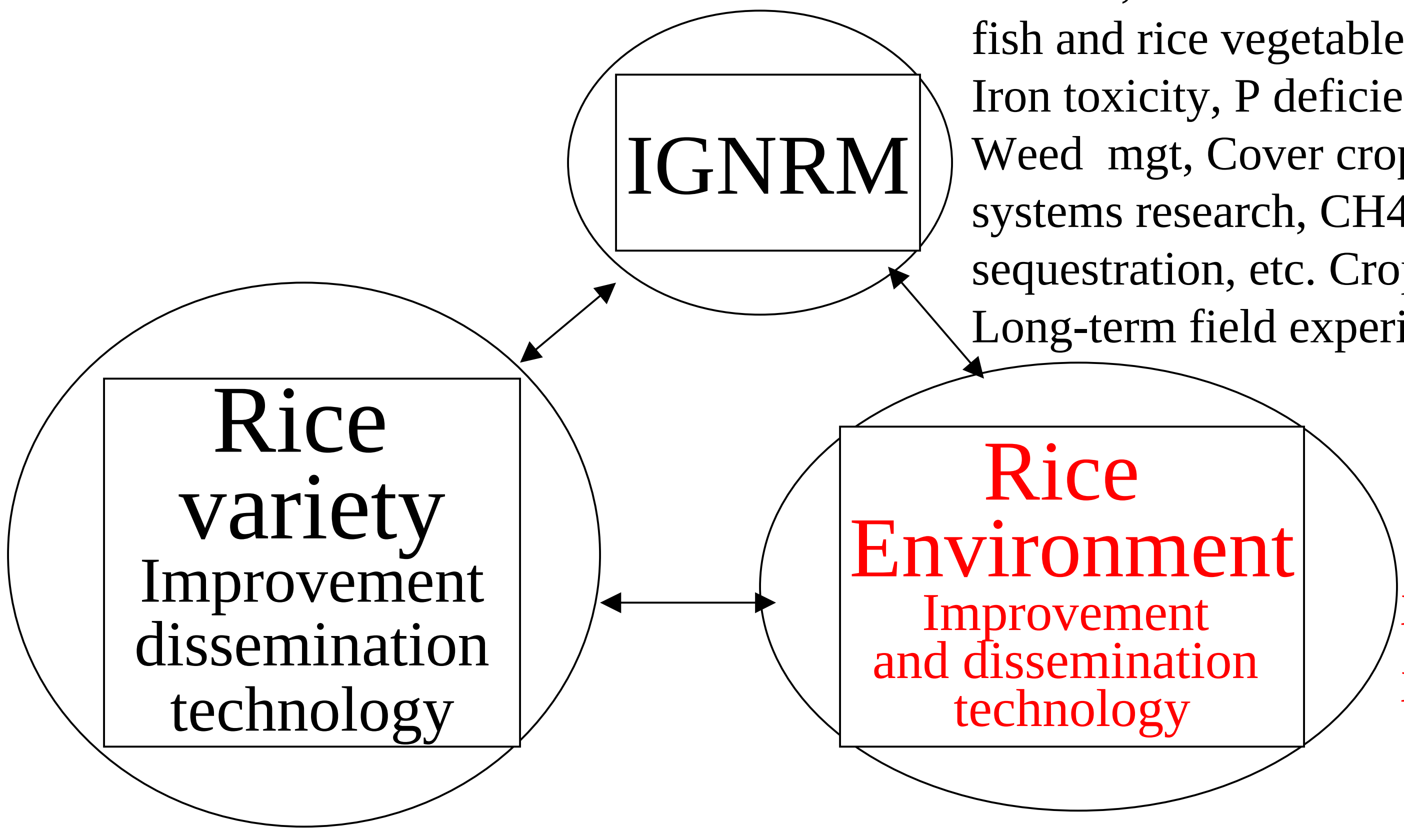
| Classification | Area (million ha) | | Percentage(%) |
|---|---|---|---|
| Coastal swamps | 16.5 | (3 ?) | 10-30% |
| Inland basins | 107.5 | (2 ?) | 1-3% |
| Flood plains | 30.0 | (6 ?) | 10-30 |
| Inland valleys | 85.0 | (10 ?) | 3-10 |

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)

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 )

**Fig. 8. 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**