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Volume 8

特集　第7回オープンフォーラム
アフリカにおける稲作振興の現状と今後の日本の役割
－NERICAの研究と普及を例として－

Special Issue: The Seventh Open Forum on
Recent Progress in Rice Promotion in Africa and Role of Japan
－NERICA as an example of research and dissemination－

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名古屋大学農学国際教育協力研究センター
International Cooperation Center for Agricultural Education
Nagoya University

Nagoya University
International Cooperation Center for Agricultural Education
7TH ICCAE OPEN FORUM
October 20th, 2006, Nagoya University, Japan

名古屋大学農学国際教育協力研究センター
第７回オープンフォーラム

Recent Progress in Rice Promotion in Africa and Role of Japan —NERICA as an example of research and dissemination—

アフリカにおける稲作振興の現状と今後の日本の役割 —NERICA の研究と普及を例として—

Proceedings

Published by
International Cooperation Center for Agricultural Education
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Nagoya University International Cooperation Center for Agricultural Education (ICCAE), one of the six research centers for international cooperation in education in Japan, is the center dedicated to agricultural education. ICCAE is aimed at being the leading center of international cooperation in agricultural education, with the missions:

1) as a national center, to contribute to human resource development for solving agricultural problems in developing countries;
2) as an international center, to coordinate international cooperative projects with other institutions;
3) to establish human resource database for the purpose of coordinating effective international cooperation; and
4) to work for researches on agricultural cooperative projects aimed at achieving the well-being of people in developing countries.

PROCEEDINGS
The proceedings included herein are the papers presented in the Seventh ICCAE Open Forum held in October 20th, 2006 at Nagoya University, Japan.

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巻 頭 言

農学国際協力第 8 号は、名古屋大学農学国際教育協力研究センター（以下、「農国センター」）が、2006（平成 18）年 10 月 20 日に、名古屋大学野依記念学術交流館で開催した第 7 回オープンフォーラム「アフリカにおける稲作振興の現状と今後の日本の役割—NERICA の研究と普及を例にして一（7th ICCAE Open Forum: Recent Progress in Rice Promotion in Africa and Role of Japan –NERICA as an example of research and dissemination-）」のプロシーディングとしてまとめたものです。ご承知のように、我が国のアフリカの稲作振興に向けての協力は、2008 年 5 月横浜で開催された第 4 回東京アフリカ開発会議（TICAD IV）で、国際協力機構（JICA）がアフリカ緑の革命のための同盟(AGRA)と共同で発表した「アフリカ稲作振興のための共同体（CARD）」のイニシアティブ以降、従前にもまして強化されてきています。

アフリカでの稲作振興には、JICA が得意とする技術普及や人材育成等に加え、稲作研究および研究を通じた稲研究者、特にアフリカ人研究者の育成もまた重要です。先に述べたように、ここに収録した第 7 回オープンフォーラムでの報告は 3 年前のものですが、その後のアフリカ稲作の状況の変化を踏まえましても、読者の皆様にとってたいへん有用な情報を多く含んでいます。

本号が、アフリカの稲作振興に興味や関心をお持ちの読者にとどまらず、実際に国際協力に携わっておられる方々、また様々な視点からアジアやアフリカの稲作研究に携わっておられる研究者や学生の皆さん等の今後の活動の参考になりますと望外の喜びでございます。

最後に、3 年前のオープンフォーラムでご講演いただいた皆様に対し、プロシーディングの刊行が遅れたことを深くお詫び申し上げます。

2010（平成 22）年 2 月

名古屋大学農学国際教育協力研究センター長
山内　章

Foreword

This eighth volume of "International Cooperation in Agriculture" is published as the proceedings of The Seventh ICCAE Open Forum held by International Cooperation Center for Agricultural Education (ICCAE), Nagoya University. ICCAE held the open forum at NOYORI Memorial Conference Hall, Nagoya University on October 20, 2006, with the theme, "Recent Progress in Rice Promotion in Africa and Role of Japan ―NERICA as an example of research and dissemination―".

Cooperation of Japan for the promotion of rice production in Africa has been increasingly strengthened especially since the initiative of the Coalition for African Rice Development (CARD) that was jointly announced by Alliance for a Green Revolution in Africa (AGRA) and Japan International Cooperation Agency (JICA) in the Fourth Tokyo International Conference on African Development (TICAD IV) in Yokohama, Japan, in May 2008.

For that purpose, in addition to the dissemination of technologies and human resource development that are specialty of JICA, research on rice, and capacity development of researchers, especially African researchers are quite important giving them chance to join the researches.

Even though the reports herein were given in the Seventh ICCAE Open Forum three years ago, and the circumstances of rice production in Africa have been changed since then, we are confident that the reports will offer valuable pieces of information that are beneficial to all those who are concerned.

It is our great pleasure if this volume of "International Cooperation in Agriculture" would be useful reference not only for those who are interested in rice promotion in Africa, but also for those who are actively involved in the international cooperation activities as well as for researchers and students working on rice production in Asia and Africa with various fields of expertise.

Finally, we have to express our sincere apology for the delay of this publication, to the speakers who had given their precious presentations in the open forum three years ago.

Akira Yamauchi
Director
International Cooperation Center for Agricultural Education
Nagoya University

February, 2010

開会の辞

名古屋大学農学国際教育協力研究センターは 1999 年の設立以来、アジアとともに、アフリカにおける農学分野の問題を実践的に解決する人づくり協力に力を入れて取り組んできております。当センターがここ数年、大学や JIRCAS など国内の研究機関、ならびに AICAD などアフリカの機関と連携して取り組んでいる NERICA 米の研究と普及にかかわる人づくり協力に関連して、第 7 回オープンフォーラム『アフリカにおける稲作振興の現状と今後の日本の役割　―ネリカの研究と普及を例として―』が 2006 年 10 月 20 日（金）、名古屋大学野依記念学術交流館において開催されました。本号はその発表と議論の内容をまとめたものです。

サブサハラアフリカの特に都市住民や若者を中心とする米消費の急激な増加を受け、各国は輸入依存からの脱却に向けて米の増産に力を入れてきています。我が国も 2003 年 9 月に開催された第 3 回アフリカ開発会議（TICAD III）を契機として、農業生産性の向上、ひいては食料輸入依存からの脱却に向けた国際協力をいっそう重視し、アジアの稲とアフリカの稲の長所を組み合わせた NERICA 米の研究と普及に力を注いでいます。TICAD III から3年、日本人研究者により取り組みの成果も出てきつつあるなか、ネリカ米の研究と普及を例にして、研究者、教育者、国際協力の専門家など関係者に本フォーラムにお集まりいただき、アフリカにおける稲作振興の現状を分析し、今後の日本の役割について活発な議論が行われました。

当センターは AICAD と 2002 年 3 月に学術交流協定を結び、2004 年 3 月にアクションプランを策定し、AICAD の中心メンバー、ならびに大学や試験研究機関の関係者を招聘して、またセンター関係者が AICAD を訪問するなどして、農学領域の問題解決にあたる人づくり協力、NERICA 米の共同研究や普及戦略構築の基盤調査、JICA プロジェクトの評価などに取り組んできました。第 7 回オープンフォーラムが、アフリカにおける稲作研究と普及に対し、到達点を確認し、今後の発展の方向と課題を明確化することに役立つことは言うまでもありません。

基調講演を賜りましたマセノ大学教授オニャンゴ先生をはじめ、ご参加いただきました皆様方に当センターを代表して厚く御礼申し上げます。また、本号が、当日ご参加いただけなかった方も含め、NERICA 米の研究普及などにかかわるアフリカ人づくり協力の取り組みを発展させる一助となりますよう心より願っております。

名古屋大学農学国際教育協力研究センター長
（2006 年 10 月当時）

竹谷　裕之

Opening Remarks

International Cooperation Center for Agricultural Education (ICCAE) of Nagoya University has been putting great deal of effort since its establishment in 1999, into international cooperation in human resource development as a practical solution to agricultural problems caused in African countries. Over the past few years, ICCAE has been engaging in capacity building cooperation activities concerning research and dissemination of NERICA (New Rice for Africa) a hybridized cultivar for favorable traits of both Asian rice *Oryza sativa* and African rice *O. glaberrima*, in cooperation with AICAD and concerned institutions in Africa and Japanese organization JIRCAS.

The Seventh ICCAE Open Forum was held at Noyori Conference Hall of Nagoya University in October 20th, 2006 on the theme of "Recent Progress in Rice Promotion in Africa and Role of Japan －NERICA as an example of research and dissemination－". The proceedings and discussion highlights of the forum are published herein, as the eighth issue of "International Cooperation in Agriculture".

Many African countries, particularly those in Sub-Saharan Africa, have been trying hard to increase their rice production to counteract the rather drastic increase of consumption. Since the Third Tokyo International Conference on African Development (TICAD III) in 2003, Japan has been promoting its cooperative activities aimed at leading African countries out of food import dependency, and concentrating on research and dissemination of NERICA. With the progress of such activities achieved by Japanese researchers in three years since TICAD III, ICCAE held this open forum as an occasion where we can evaluate and discuss the recent rice cropping situation in African countries.

ICCAE and AICAD have signed an academic exchange agreement in March 2002, and built its action plan in March 2004. Under the agreement, ICCAE and AICAD have visited each other and worked on their cooperative activities for agricultural capacity development such as joint researches on NERICA, conducting basic survey for NERICA dissemination strategies, and evaluating the JICA projects. The Seventh ICCAE Open Forum must have been a fruitful occasion for confirming those achievements and clarifying the issues to be addressed and the directions we should go towards.

I would like to convey my acknowledgement on behalf of ICCAE, to those who participated in this open forum, especially to Professor Onyango from Maseno University, Kenya, for giving us the key note address for this open forum. I hope the discussions and proceedings included herein could promote international cooperation in research and human resource development for disseminating NERICA.

Hiroyuki Takeya
Director
International Cooperation Center for Agricultural Education (ICCAE)
Nagoya University, Japan
(as of October 2006)

名古屋大学農学国際教育協力研究センター
第7回オープンフォーラム
アフリカにおける稲作振興の現状と今後の日本の役割
―NERICA の研究と普及を例として一

サブサハラアフリカの特に都市住民や若者を中心とする米消費の急激な増加を受け、各国は輸入依存からの脱却に向けて米の増産に力を入れてきている。我が国も、2003年9月の第3回アフリカ開発会議（TICAD III）前後を契機として、農業生産性の向上、ひいては食糧輸入依存からの脱却に向けた協力を一層重視し、アジアの稲とアフリカの稲の長所を組み合わせたネリカ米の研究と普及に力を注いでいる。

TICAD III から3年、日本人研究者による取り組みの成果も出てきつつある中、ネリカ米の研究と普及を例にして、アフリカにおける稲作振興の現状を分析し、今後の日本の役割について議論する。

日時：2006年10月20日（金） 開会 9:00 閉会 17:00
会場：名古屋大学 野依記念学術交流館（名古屋市千種区不老町）

Nagoya University
International Cooperation Center for Agricultural Education
The 7th ICCAE OPEN FORUM

Recent Progress in Rice Promotion in Africa and Role of Japan
- NERICA as an example of research and dissemination -

Many African countries, particularly those in Sub-Saharan Africa, have been trying hard to promote their rice production in order to counteract the rather drastic increase of consumption by young people and city dwellers. Over the past few years since the Third Tokyo International Conference on African Development (TICAD III) in 2003, Japanese researchers including those who of ICCAE have promoted in international cooperative activities aimed at human capacity development concerning the research on and dissemination of NERICA.

To confirm and evaluate the progress of such activities achieved by Japanese researchers in those three years, ICCAE held this Seventh Open Forum as an occasion where such progress is reported and shared among the concerned participants and the expected roles of Japan towards the future are discussed.

Date & Time: Friday, October 20th, 2006, 9:30 to 17:00
Venue: NOYORI Memorial Conference Hall, Nagoya University
Chikusa-ku 464-8601, Nagoya, Japan

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所属・職位は 2006 年 10 月 20 日第 7 回 ICCAE オープンフォーラム開催当時。
詳細については各プロフィールをご参照下さい。
The authors' affiliation and title are as of October 2006, at the time the 7th ICCAE Open Forum was held.
Please refer to the profile pages for their current affiliations and titles.

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第 1 章　基調講演

Chapter 1　Keynote Address

アフリカにおける米の生産： サハラ以南アフリカの食料安全保障を強化するためのキー

Rice Production in Africa: A Key to Promoting the Sub-Saharan Africa Food Security

ジョン・C・オニャンゴ　John C. Onyango
ケニア国立マセノ大学理学部長
名古屋大学農学国際教育協力研究センター客員教授*

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Maseno University, Kenya
Visiting Professor, International Cooperation Center for Agricultural Education (ICCAE),
Nagoya University, Japan*

要　約

アフリカ全体そしてケニアにおいて、農村住民の 60%以上が貧困であると言われている。貧困は通常、健康不良と栄養失調として現れる。深刻な食糧不足に加えエイズの流行が多くの農村地域の状況をさらに悪化させている。

アフリカ稲（*Oryza glabberima*）とアジア稲（*Oryza sativa*）の交配種である New Rice for Africa（NERICA）の利用は貧困を削減する方策の一つとして期待されている。西ケニアで実施された NERICA 品種の適応性試験では、1ヘクタール当り5トン以上の収量が示され、ケニア国内の水稲の収量を上回った。マセノ大学、アルペ研究センター、および SACRED-Africa（ブンゴマ）の適応性試験圃場で開催された農民の見学会で農民がこれを目にしてその事実に気づき、自分達の農地で NERICA を栽培したいと種子に対する要望が上がった。このことから、西ケニアで今後 NERICA 種子の需要が増えることが予想され、種子提供システムを整える必要性があると言える。

NERICA には実際 3,000 以上の品種があるが、西アフリカでは現在、約 25 品種しか利用されていない。ケニアで入手できる NERICA はわずか 20 品種であり、西ケニアの農地で適応性があると判明しているのはそのうちわずか 6 品種である。これらの推奨品種には共通する栽培特性があり、アフリカ大陸の厳しい環境条件下で長年にわたり進化してきたアフリカ稲品種の特性を持つ NERICA は、水不足や病虫害などのストレスに対する耐性が優れている。NERICA は親品種のいずれよりも収量が高い。1穂粒数は、*Oryza glaberrima* が約 100 粒、*Oryza sativa* が約 250 粒である一方、NERICA の1穂粒数は約 400 粒と多く、これが高い収量をもたらしていると思われる。また、NERICA のタンパク質含量は 10～12%で、親品種の約 8～10%を上回る。

コメはアジアで最もよく知られている穀物であり、世界人口の半分以上が数世紀にわたり食べ続けてきている。1980 年代にアジアで起こった緑の革命は、コメ研究の成功に拠るところが大きく、その研究は現在も続いている。この事実は、アフリカの食糧事情を解決する方策を探るうえで刺激となるものである。1991 年から

*2006 年 10 月講演当時。
At the time of presentation in October 2006.

数年を経て、NERICA は食糧保障および換金作物として西アフリカでよく知られるようになり、多くの農民女性グループが NERICA を主要穀物作物として栽培するようになった。食料生産と現金経済の観点から、NERICA が果たす役割は非常に大きいと考えられる。

これらのことを踏まえて今回の発表では、サハラ以南アフリカの作物生産に影響を与える重要項目について述べる。また、その影響下にある人々に寄与するために、それらの課題をどのように推進していくべきかについても述べる。研究によって解決策を探るという観点から、研究グループが早急に注目すべき課題に次のようなものがある。

耐旱性、肥料の利用効率、雑草管理、保証種子の生産、過去の降雨パターンのコンピュータ解析、病害虫管理、間作・輪作システム、水稲用 NERICA 品種、ポストハーベスト加工、付加価値付与・精米・マーケティング戦略、女性農民による土地所有、低金利融資など。

Rice Production in Africa: A Key to Promoting the Sub-Saharan Africa Food Security

John C. Onyango
Professor, Department of Botany and Horticulture, Dean of Faculty of Science, Maseno University, Kenya
Visiting Professor, International Cooperation Center for Agricultural Education (ICCAE), Nagoya University, Japan

Abstract

High poverty levels of over 60% have been reported in rural communities in Africa in general and in Kenya in particular. Poverty levels normally manifest themselves in poor health and malnutrition. There are high levels of household food insecurity and in most rural areas the situation is aggravated by the prevalence of HIV/AIDS. Some of the strategies that could contribute to poverty alleviation, food security and wealth creation have not been given due attention. These strategies include the use of NEw RIce for AfriCA, code named NERICA, which was developed by crossing the African rice (*Oryza glabberima*) and the Asian rice (*Oryza sativa*). Adaptability trials for the NERICA varieties in Western Kenya showed a yield potential of over 5 tons per hectare which is higher than the yields obtained in Kenya for irrigated rice. Farmers field days conducted at Maseno University, Alupe Research Center and SACRED-Africa in Bungoma adaptability trials sites have created awareness to the rural farmers and they have put in request for seeds of NERICA varieties to try on their farms. This implies that, there is demand for seed and therefore a need to set up seed support systems for NERICA in Western Kenya as the demand is anticipated to rise. NERICA is not just one cultivar, but there are actually over 3,000 different NERICA varieties, although farmers in West Africa currently are using only about 25 cultivars. In Kenya only about 20 cultivars are available out of which 6 varieties have been identified as promising in Western Kenya agro-ecological region. The preferred varieties share some common features of the rice growth cultures. Reflecting the characteristics of African rice varieties that have evolved over centuries in the continent's difficult environmental conditions, NERICA is very hardy, resistant to stresses such as water deficit, common rice diseases and pests. NERICA produces significantly higher grain yields than the two parent varieties. Each panicle of the *Oryza glaberrima* has about 100 grains and each panicle of *Oryza sativa* has 250. But NERICAs' panicles hold an average of 400 grains and this explains the high harvest observed. Each grain of NERICA has more protein than either of the parents: while the parents have a protein content of about 8-10 per cent, NERICA can reach 10-12 per cent.

Rice is a cereal crop best known in Asia and has fed well over half of the world's population for centuries. The success of the crop research led to the green revolution in Asia in the 1980's and is still strong. This can provide an incentive in finding a better solution for the African problem. Over the years from 1991 NERICA has become a household name in West Africa in terms of food security and cash crop in the region. Many women group farmers have adopted NERICA as their main cereal crop. The role NERICA plays in food production and cash economy cannot be over emphasized. This presentation is therefore, aimed at addressing the pertinent issues that affect the crop production in Sub-Saharan Africa and how it can be accelerated for the benefit of the affected population. Some of the factors which require urgent attention by scientific community in terms of solution exploration through research are: drought tolerance; nutrient use efficiency; weed control; production of certified seeds; computation of historical rainfall pattern; pests and diseases control; inter- and relay cropping systems; development of lowland NERICA varieties and buffer crops; post-harvest processing; value addition, milling and marketing strategies; land ownership by women farmers and availability of low interest credit facilities, among others.

1.0 Introduction

Farmers in most Sub-Saharan Africa produced enough food commodities for the continent's populations up to 1960s at the time of independence for most countries. After attaining independence from the imperial powers the Africa population started growing at a faster rate than food production. By 1980s most countries were pleading to the developed world for food aids. By 1985-88 the late photo journalist Mohammed Amin brought the plight of dying Africans especially the horn of Africa to the world attention and something had to be done. In most African countries over 60% of the population live in the rural areas with Agriculture as their main survival activity both for food security and economic empowerment. However, most governments have either given agriculture and rural development a low priority or pursued impractical policies to protect their stay in power. Investments in improved roads network, input delivery, value addition to agricultural produce and grain marketing systems also in agricultural research, extension and general education have been woefully in adequate. Cheap food policies to appease the politically informed urban dwellers have greatly distorted production incentives for framers.

The major development problem in Africa is infrastructure that is roads, dams, electricity and communication. These are areas which were ignored by the colonial powers as opposed to the development pattern in Asia and Latin America before the de-colonization era in those regions. The emerging African governments have not done much either and some have even worsen the situation; take the case of Zimbabwe in the recent years. All these have resulted in negative agricultural development in the continent giving way to starvation and rampant poverty. A concerted effort is needed within the continent to correct this situation before it explodes to the detriment of human kind. Africa needs assistance from development partners and best practices from outside the continent, however, the African government must understand that any sustainable success to these measures must be home grown and have the political good will. Strong economies and high quality of life are all integral part of good and responsive governance in terms of economic and development policies. It is important to take note that perfection is a peacock the academics chase and never catch. As researchers and intellectual think tanks we must undertake our share of the responsibility apart from advocating ivory tower autonomy.

Rice is known to be staple food for half of the world's over 6.5 billion people (International 2006). It is the cereal of choice and is produced and consumed in Asia in large quantity. In Sub-Saharan Africa the demand is increasing and has surpassed production leading to importation of about 46% in order to meet the region's demand but this is a drain to foreign reserve which is valued at more than US$1.5 billion per annum to most countries in the region (WARDA 2006). Rice has become a major source of calories not only for the affluent, but also for the urban and rural poor in many parts of the continent. Its availability and price have become major determinants of the welfare of the poorest African consumers. The notion that rice was only consumed by the urban affluent population does not apply any more since the consumption is actually dictated by availability and affordability of the cereal. It is the preferred food for the rural communities as well especially in regions where the crop is grown and therefore market price is affordable. To reduce rice import and achieve self-sufficiency in rice in most countries, the production of the crop in the sub-region will have to be increased and the quality of local rice must be comparable to the imported rice in order to maintain the market parity. To enhance the quality of local rice and its preference, improvements in both varietals' and value addition aspects must be taken into consideration in packaging. The current trends in rice production, particularly in Asia which has been the global rice basket is worrying due to respective governments' restrictions in their local rice production. This will definitely affect the rice net importers from Africa in terms of food security for their nationals. To mitigate against the expected out come, the Sub-Saharan Africa region must align itself into the promotion of rice production within the region. This is where the achievements which have been made in NERICA development since 1991 come into play.

Rice has been grown in East Africa for several centuries. In Kenya the crop is grown in the Lake Victoria basin in Nyanza and Western Provinces, in Central Kenya at Mwea Schemes and along the Indian Ocean coastal marsh areas. Over this period of time the crop has been subject to selection by farmers for performance in the rather dry climate of East Africa. The main rice growing regions in

Tanzania include Mwanza, Shinyanga, Mara and Kagera regions, which produce almost one third of the country's rice demand. Shinyanga, Mwanza and Mara do produce about 25% of the Country's total rice production. The main rice growing regions in Uganda, include Jinja, Mukono, Kampala, Mayuge and Bugiri districts while the upland rice and NERICA research activities is concentrated at Namulonge and other NARO research Centers. In Uganda there is increasing interest in rainfed rice cultivation by farmers. This interest has mainly been stimulated by sensitizing farmers on the importance of rice as an income generating crop and food security. The rice production is mainly done by farmers in groups in order to lower the cost of production. Over 60% of land being cultivated is under upland rice at the moment causing high demand for seed rice since 2000, unlike in the past years when demand for seed rice from the District farm institutes was rather low. The difference in maturity of the varieties, water condition in the fields and labour availability of the households determines the length of harvesting season that ranges from 145-175 days (Zuma, 2004). The rice yields ranges from 500 kg to 3,500 kg depending on the moisture availability, cultivars used, soil fertility and timeliness of field operations. No other crops are planted after rice harvesting although these relatively wet fields could be used for short season crops such as vegetables and legumes. Local communities are not aware of the utilization of the residual moisture after harvesting rice, or other sources of water.

NERICA has become so popular in certain districts of Uganda that some farmers are even abandoning other crops to produce rice. This change in trend and awareness has been increased by the dissemination of research through extension activities and political good-will by Uganda government officials. The crop has been reported to yield up to 4-5 tones per hectare in farmers' fields, which translates to US$ 2000 in local markets in terms of income to the farmer. NERICA is preferred in East Africa because of its short duration to maturity – about 90 – 110 days.

Rice is a cereal crop best known in Asia and has fed over half of the world's population for centuries. The success of the crop research led to green revolution in Asia in the 1970's and is still strong. This can provide a more vigour in finding a better recipe for the African problem. Over the years from 1991 NERICA has become a household name in West Africa in terms of food security and cash crop in the region. Many women-group farmers have adopted NERICA as their main cereal crop. NERICA produces significantly higher grain yields than the two parent varieties. Each panicle of the *Oryza glaberrima* has about 100 grains and each panicle of *Oryza sativa* has 250. But NERICA's panicles hold an average of 400 grains and this explains the high harvest observed. Each grain of NERICA has more protein than either of the parents. While the parents have a protein content of about 8-10 per cent, NERICA can reach 10-12 per cent (Fujii *et al.,* 2004). NERICA matures considerably faster within a period of 90-100 day after planting. This not only ensures food security among the farming communities, but also reduces poverty levels through sales of excess produce (Onyango and Onyango 2006).

The role NERICA plays in food production and cash economy cannot be over emphasized. This presentation is therefore, aimed at addressing the pertinent issues that affect the crop production in Africa and how it can be accelerated to the benefit of the sub-Saharan Africa population. Initial studies carried out in Western Kenya at Maseno, Kisumu district; Alupe, Teso district and Siritanyi, Bungoma district from 2004 to 2006 have given promising results in production. Farmers in these regions are demanding seeds of the NERICA cultivars to grow on their farms, mostly small scale farmers. Rice as a crop is generally grown in small plots of about one hectare blocks. This is because of its labour requirements. It is only in the six rice growing states of U.S.A. where large commercial farmers are found due to mechanization (Onyango 2006). In Africa the target farmers shall be the small scale farmers with low capital base at the initial stage. During the adaptability trials six NERICA cultivars have been identified for seed multiplication (production) for release to demanding farmers. The cultivars are NERICAs N1, N4, N6, N8, N10, and N11. Seed bulking of the above cultivars have been achieved and enough seeds for multiplication can be provided from the University Botanic Garden, Maseno NERICA seed stock. Further more training of adaptability trial researchers and technicians on harmonization of research and production operations have been achieved for the pilot group.

1.1 Problem statement

The role of NERICA is not only improving the food situation in Africa but also improves the livelihoods and the economic situation of the rural and urban poor has not been exploited. There is need to sensitize the communities on NERICA cultivation in East Africa. Nonetheless, there is no established seed support system for NERICA resulting in lack of quality seed. Inadequate Agronomic and physiological studies have been carried out. Limited research done has not been fully disseminated to farming communities there is therefore need for up scaling the known technical information to the wider farming communities in the region.

1.2

NERICA has been identified as one of the Africa's "best practices" worth up scaling. The development of NERICA was heavily funded by the government of Japan and IFAD with ARC Scientists producing desired results (WARDA 1999). NERICA adaptation and production in West Africa has played a key role in reducing poverty and malnutrition in the region. The expansion of NERICA cultivation throughout Sub-Saharan Africa has been hailed by NEPAD member countries because of its adaptability and high productivity. The aim of this presentation is therefore, to explore how NERICA can be integrated into the existing varietals' portfolio for Sub-Saharan Africa farmers with complementary technologies to maximize production at minimal input level. This will spirally lead to better natural resource management practices and improved rice marketing and availability to rural communities. The findings from the research strategies and up-scaling of production technologies will also be a resource and attribute to the performance and implementation by various Ministry of Agriculture extension services in different countries in the region. If coordinated well then this will enhance the role of NERICA in food security and poverty reduction in Africa.

Detailed analysis of limiting factors

NERICA varieties were developed for rainfed or upland conditions; however, there is need to quantify the spectrum of several varieties in cultivation with regard to their water requirements for effective production. From previous experiments it has become clear that there are some NERICA lines that show high growth with low uptake of water and they seem to be appropriate for long periods of cultivation in low precipitation conditions (Fujii *et al.,* 2004). This is because high dry matter accumulation during drought by drought tolerance cultivars is due to their ability to absorb soil water. However, physiological characteristics of NERICA are not fully known and there is an urgent need to conduct research in NERICA physiological parameters geared to high productivity under limiting water availability. The trend of rice cultivation is going towards the upland production rather than irrigated. The kind of infrastructure which goes with the paddy rice production is rather expensive for most small holder farmers. Because of these problems, most farmers tend to go for upland rice production, based on rainfall but if there is any irrigation, it will be by gravity from rainfall harvested water or from small streams. The are three rice irrigation systems for lowland rice in Kenya which are situated in Ahero, West Kano and Bunyala in Western Kenya, Mwea Tabere in Central and Bura in North Eastern Kenya, but all of the are performing under capacity. In Western Kenya electricity is used to pump water and as the cost of electricity goes up, it becomes expensive to supply water while in Central and North Eastern Kenya, gravity irrigation is used but during droughts the level of rivers go down.

Establishing seed banks requires elaborate information on the ecophysiology of the donor plants, especially with regard to overcoming environmental constraints, since stress is a major limitation to crop production worldwide. This will ensure that well adapted germplasms are established, which are able to survive and achieve acceptable levels of bio-productivity. The Western parts of Kenya for example, are faced with intermittent dry spells accompanied with high rates of evapo-transpiration, more negative soil–water potentials and decreasing soil–water supply capacity to the plants. Plants in such environments must therefore, posse's adaptable strategies (Kramer 1980), which will enable them achieve their water requirements for maximum rates of shoot growth and transpiration, without undergoing cavitation (Sperry 2000). Such plants must attain a balance between shoot and root activities in order to ensure productivity without compromising survival (Otieno et al. in press). Understanding soil water uptake patterns by of the NERICA varieties and the associated shoot responses to water loss under limited water supply will help explain differences in productivity, survival and distribution among species and varieties as well as provide selection criteria for the preferred gene banks. Few studies exist on the eco-physiological responses of the NERICA varieties. This information is however required to further our understanding of their autecology in natural or agro-ecosystems. There is growing interest in identifying and selecting genotypes that will maintain growth and productivity under limited water conditions.

- Although the breeders credit NERICA with low nutrient demand, no results are available to quantify the requirement in the various African agro-ecological regions where the crop is grown. NERICA may need the shuttle breeding approach in order to produce varieties which are adaptive to several regions of different agro-ecological structures. Through this process varieties which can perform well in the Sub-Saharan Africa can be produced or selected within a short time, thereby reducing the breeding programme period. The fertilizer use has been in high debate for a very long time as a factor in improving crop production. Actually, even the Green Revolution in Asia that is, India and Pakistan, the fertilizer was a problem and so was the crop production. But I think the scientists who were dealing with the crop at that particular time made the governments realize that if the aim was to increase production then fertilizer had to be involved. If that (increased use of fertilizer) is going to be the case, even though the farmers are poor, they are ready to offer labor on their farms, so the government should come up with subsidy to bale them out to increase NERICA production. The problem with the fertilizer is still there as at now we also have environmentalists who are concerned with pollution factors caused by fertilizer run-off from farm lands. However, this can be mitigated by having buffer crops to take up run-off nutrient load before discharge into water bodies. Since the subsidy worked for Green Revolution it is possible to employ the same method to increase production. The countries affected with low rice production spends about US$ 1.5 billion to import rice, it follows that, if they spend a fraction of that money to access fertilizer for farmers then they can assist small holder producer increase production. The agricultural extension staff will also help with safe environmental management of fertilizer usage.

- Weed control has been identified as a factor, reducing NERICA production in East Africa, especially the *Striga hermonthica* which causes up to 70% loses in cereals. Identification of NERICA varieties that can withstand the weeds effect will be desirable to promote production. Striga is the main parasitic weed devastating NERICA production in Sub-Saharan African. Striga compensates for lack of its own root system by penetrating the roots of rice, diverting essential nutrients from them, and stunting their growth. Striga infests an estimated half of the 8.5 million hectares devoted to rice in Africa, resulting in crop losses of up to 60% among rice farmers. Striga is considered to be the main obstacle to sufficient food production in Africa. Most farmers have been using cultural method of weed control through crop rotation with cultivars that encourage suicidal germination of *striga* seeds but the methods is too slow for effective land use. Other modern method such as the use of Fungus (*Fusarium oxysporum*) is rather expensive to the target farmers (Ciotola *et al.,* 1995).

- In recent Africa Rice Congress (ARC) in Tanzania, it was realized that Sub-Saharan Africa has the lowest number of available scientific expertise which is about 83 scientists per million people, compared to 1100 scientist per million in industrialized countries and 785 per million in Asia. At this level of scientific expertise in Africa, it is paramount that capacity-building programme focusing on the development of a multi-disciplinary researchers and extension staff is urgently needed.

- Lack of certified seeds is the main draw back to releasing some of the high potential NERICA varieties in Kenya. Efforts are now being made to bulk the seeds of selected NERICA lines for release to farmers by 2008 long rains season but there is also a need to bring in private sector stakeholders in certified seed production and marketing. Sasakawa-Global 2000 has played the role of seed production successfully in Asia and Uganda. Their role lead to successful green revolution in Asia and rapid dissemination of NERICA production in both East and West Africa and involvement of selected farmers in the informal seed multiplication. African Rice Congress took the cognizance of the importance of NERICA seed production in Africa and recommended that farmers adoption of NERICA should be accelerated and other improved technologies, concerted action by partnership including governments, research institutions, the private sector, local, regional and international organizations are needed (ARC 2006).

- Intercropping NERICA with maize and sorghum is a common practice in upland cultures in Sub-Saharan Africa for various reasons. To enhance this practice we are investigating the intercropping or relay cropping NERICA with leguminous pulses for soil improvement at Maseno University. Good adaptive technology researchers must know how to implement the technologies themselves without relying on the technicians to do the work. It is more difficult to inculcate what one knows only in theory. The practical aspect is very important and should be master right from the laboratory and experimental field. Intercropping of NERICA with legumes is being experimented in Western Kenya (Maseno University) with the main purpose of replenishment of the soil nitrogen, because the two crops are legumes, hence good in nitrogen fixation at scientific level. But at community level, most farmers we are dealing with are already intercropping Soya beans and Bambara groundnuts with maize. Our experiments are therefore aimed at developing a package for technology transfer. We want to have enough information for this transfer so that we can win farmers' confidence in using rice instead of maize thereby increasing the production.

- Value addition and milling requires quick access to good quality mills to enhance profitability of the rice produce by farmers in contrast to the middle traders. Market surveys and identification of ready market for the produce will also entice more small-holder farmers to continue with rice production both for food security and cash crop. In Uganda farmers have earned up to Ush. 3,740,000 (about US$ 2,000) for NERICA production per hectare. This earning has enables NERICA farmers to meet several of their family obligations.

- Women have been identified to be key players in NERICA production in Africa and yet they do not own land. Sustainable production will therefore require a review of land tenure system in most countries to allow women to acquire and own land as a natural resource base for rice production. Actually the problem we have is that, it is the women who are actually more active in agriculture. The women according to our statutory set up do not own land. In other words you might have group of women who want to participate in NERICA cultivation. Since they don't have land, they have to get permission from their husbands.

Concluding remarks

It is a clear knowledge that the Japanese Government made a very strong promise to the African governments; this was at the World Summit on sustainable development in Johannesburg, South Africa in the year 2002 that was followed by NEPAD and the involvement in the NERICA production. I understand that the third TICAD is coming in two years time and we would like to learn about the success story on the Japanese government contribution in NERICA production in Africa. From the contributions presented in this Open Forum it is clear that there are several aspects of NERICA production, in Africa and all of them are geared towards sorting out food shortage in Africa. I think it is only the last presentation by Sasakawa 2000 which mentioned that in case of Uganda, NERICA is actually not being produced to sort out the food problem it is being produce as a cash crop, and if that is a case it is still a contribution because that will be alleviating the foreign currency balance from the Uganda government, therefore, we are still in the right direction.

In my prioritization brief we are talking of the upland conditions of rice production. When we talk of upland situation, it is soil moisture which keeps fluctuating and we need to arrest it. Most of us plant scientists are very quick at looking at what is happening above ground which everyone can observe. But what happens below ground which is being expressed by the above ground characters we don't know, this is where precipitation or water requirement under upland conditions comes in handy and we need to look at that. I would not like to go GMO direction, I would like to go through the conventional breeding if at all we can identify the markers which code for less water usage and that will definitely be tied to water use efficiency among the various NERICA. If we can identify this we will have made more or less 50 % contribution towards promotion of NERICA production in Africa, given the fact that agro-ecological situation is very fragile. That is my first line, looking at the water requirement and that will entail looking at below and above ground structures of NERICA varieties. One advantage we have is that there are several NERICA varieties and it seems that the regions in Africa have already identified which lines they want to use and therefore those lines should be investigated for desirable traits. The other aspect which came out very clearly is the question of availability of certified seed. The contribution of double naming of NERICAs' seeds in Uganda is real. There is a variety which is NERICA 4 which one commercial seed firm calls it Suparica 2 while National Agricultural Research Organization (NARO) also in Uganda calls it Naric 3. This creates confusion to farmers. They are growing same variety but depending on where they sourced the seed they think the varieties are different. Therefore we need to look at the seed aspect and harmonize it. This would ensure seed purity which is very fundamental in genotype research. From those two main points, there should be some socio-economic activities which prepare farmers at the farm level to receive some of the NERICA technology which can complement lack of greenhouses.

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RICE PRODUCTION IN AFRICA:
A KEY TO PROMOTING THE SUB-SAHARAN AFRICA FOOD SECUTY

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BY

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7TH ICCAE OPEN FORUM AT NOYORI Memorial Conference Hall, NAGOYA UNIVERSITY
20TH OCTOBER 2006

1

KEYNOTE ADDRESS

Introduction

- Rice is a crop that is currently feeding over a half of the world's 6.5 million population and doubles as both subsistence and export cereals.
- Rice production is increasingly becoming a key issue in cereal growth and development in the Sub-Saharan Africa region.
- The increasing consumer preference has pushed rice into the list of most important crops that requires concerted effort in production.

2

Food Production by Independence

- Farmers in most Sub-Saharan Africa produced enough food commodities for the continent's populations up to 1960s at the time of independence for most countries.
- After attaining independence from the imperial powers the Africa population started growing at a faster rate than food production.
- By 1980s most countries were pleading to the developed world for food aids.

3

Infrastructure constraint

- The major development problem in Africa is infrastructure that is roads, dams, electricity and communication.

- These are areas which were ignored by the colonial powers as opposed to the development pattern in Asia and Latin America before the de-colonization era in those regions.

4

Governance and Development

- Strong economies and high quality of life are all integral part of good and responsive governance in terms of economic and development policies.
- It is important to take note that perfection is a peacock the academics chase and never catch.
- As researchers and intellectual think tank we must undertake our share of the responsibility apart from advocating academic freedom.

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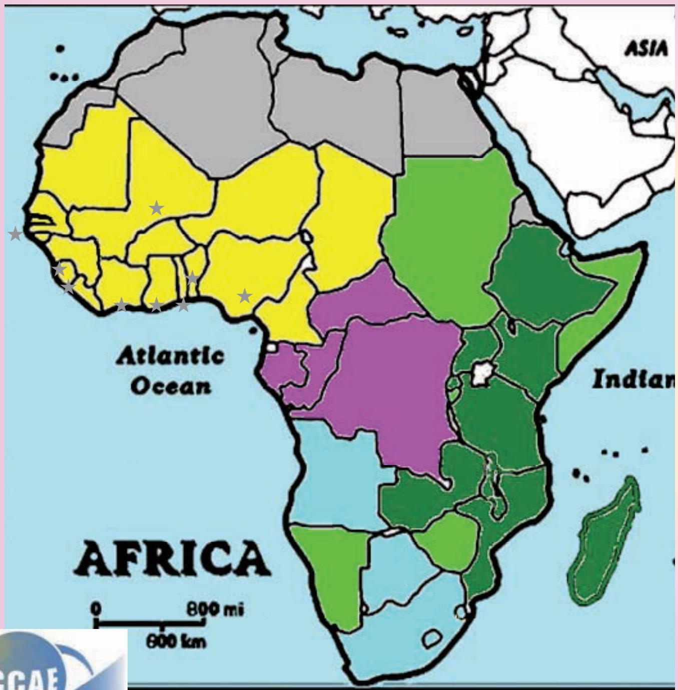
5

WARDA's involvement in Sub-Saharan Africa



- WARDA Members States and ARI
- ★ : ARI pilot country
- ARI & INGER-Africa
- ROCARIZ & INGER-Africa
- INGER-AFRICA only
- Non-affiliated countries
- Others

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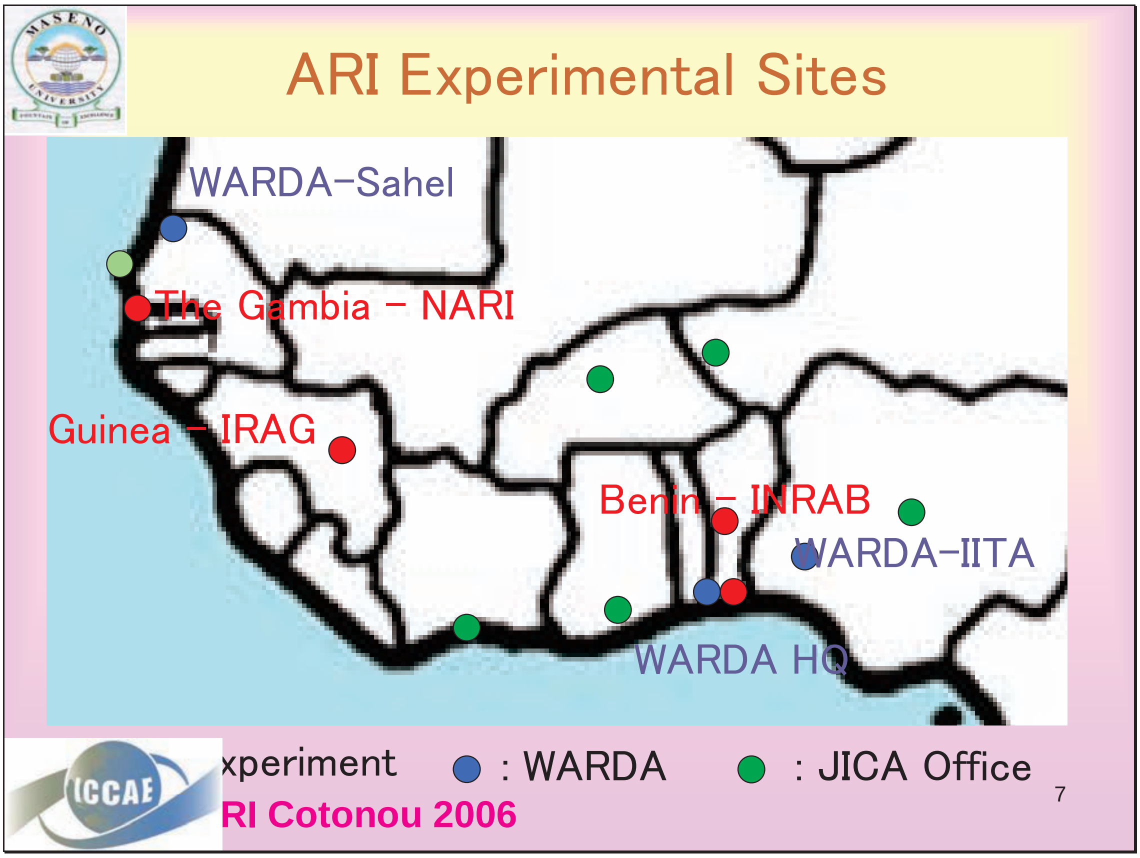
Source, ARI Cotonou 2006

6


ARI Experimental Sites
WARDA-Sahel
The Gambia – NARI
Guinea – IRAG
Benin – INRAB
WARDA-IITA
WARDA HQ
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: WARDA
: JICA Office
RI Cotonou 2006
ICCAE
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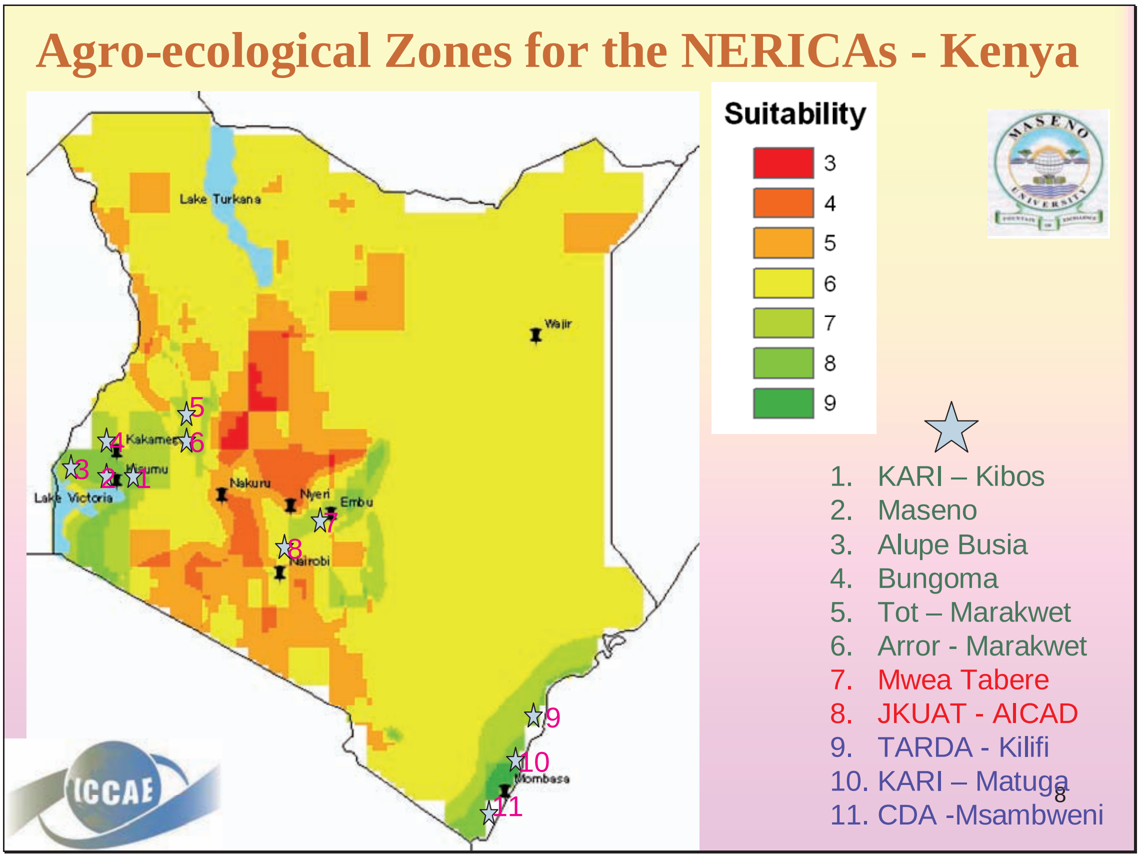
Agro-ecological Zones for the NERICAs - Kenya
Suitability
3
4
5
6
7
8
9
Lake Turkana
Wajir
Kakamega
Kisumu
Lake Victoria
Nakuru
Nyeri
Embu
Nairobi
Mombasa
1. KARI – Kibos
2. Maseno
3. Alupe Busia
4. Bungoma
5. Tot – Marakwet
6. Arror - Marakwet
7. Mwea Tabere
8. JKUAT - AICAD
9. TARDA - Kilifi
10. KARI – Matuga
11. CDA -Msambweni
ICCAE
8

NERICA Potential

- In Sub-Saharan Africa the demand for rice is increasing and has surpassed production leading to importation of about 46% in order to meet the region's demand.
- This is a drain to foreign reserve which is valued at more than US$1.5 billion per annum to most countries in the region.

9

Global Rice Production Trend

- The current trends in rice production, particularly in Asia which has been the global rice basket is worrying due to respective governments' restrictions in their local rice production.
- This will definitely affect the rice net importers from Africa in terms of food security for their nationals.

10

Hunger Alleviation in Africa

- To mitigate against the expected out come, the Sub-Saharan Africa region must align itself into the promotion of rice production within the region.
- This is where the achievements which have been made in NERICA development since 1991 come into play.

11

Rice Cultivation regions in East Africa

- Kenya: Nyanza and Western Provinces, Marakwet, Kirinyanga, Kilifi, Mombasa and Kwale.
- Tanzania: Mwanza, Shinyanga, Mara and Kagera regions.
- Uganda: Jinja, Mukono, Kampala, Mayuge and Bugiri districts.

12

NERICA Yields in East Africa

- The rice yields ranges from 1500 kg to 5,000 kg depending on the moisture availability, cultivars used, soil fertility and timeliness of field operations.
- No other crops are planted after rice harvesting although these relatively wet fields could be used for short season crops such as vegetables and legumes.
- NERICA has become so popular in certain districts of Uganda that some farmers are even abandoning other crops to produce rice.

13

NERICA Dissemination and Economy

- The change in trend and awareness has been increased by the dissemination of research through extension activities and political good-will by Uganda government officials.
- The crop has been reported to yield up to 4-5 tones per hectare in farmers' fields, which translates to US$ 2000 in local markets in terms of income to the farmer.
- NERICA is preferred in East Africa because of its short duration to maturity – about 90 – 110 days.

14

NERICA Best Practices

- NERICA has been identified as one of the Africa's "best practices" worth up scaling.
- The development of NERICA was heavily funded by the government of Japan and IFAD with ARC Scientists producing desired results.
- NERICA adaptation and production in West Africa has played a key role in reducing poverty and malnutrition in the region.

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15

Need to Increase NERICA Production

- There is need to sensitize the communities on NERICA cultivation in East Africa. Nonetheless, there is no established seed support system for NERICA resulting in lack of quality seed.
- Inadequate Agronomic and physiological studies have been carried out.
- Limited research done has not been fully disseminated to farming communities therefore, there is need for up scaling the known technical information to the wider Farming communities in the region.

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16

Role of Japan and NEPAD

- The expansion of NERICA cultivation throughout Sub-Saharan Africa has been hailed by the Government of Japan and NEPAD member countries because of its adaptability and high productivity.
- The aim of this presentation is therefore, to explore how NERICA can be integrated into the existing varietals' portfolio for Sub-Saharan Africa farmers with complementary technologies to maximize production at minimal input level.

17

Production Constraints in Ethiopia

- Introduction of breeding materials and commercial varieties for different rice ecosystems
- Variety development for different ecosystems
- Developing suitable agronomic practices for different ecosystems
- Post –harvest management
- Food science research
- Marketing channel
- Capacity building
- Creating strong linkage with International Rice Research Institutions, Private Investers, governmental and non-governmental organizations.

18

Rice Field Day in Ethiopia

- Farmers appreciated the candidate varieties (NERICA-3, NERICA-4 and Suparica-1 for their:

✓ early maturity
✓ ability to grow on drained soil and low water requirement.
✓ disease resistance
✓ non-shattering nature
✓ seed quality such as seed size, seed color
✓ Long panicle.

19

NERICA 4 SEED MULTIPLICATION PAWE ETHIOPIA, OCTOBER 2005

NERICA 4 AT 1200 masl = 110-120 DAYS TO MATURITY

20

Mozambique Rice Production

- Agriculture contributes 25.9% of total GDP.
- Rice is 6th main crop in Mozambique.
- Rice production areas - Central region – 62 %, North region – 31 % and South region – 7%.
- Rice is cultivated in 182,000 ha and production was 187,000 tons in 2005.
- Rice import is 340,000 tons at a value of US$70 million to meet a demand of 527,000 tons in 2005.
- Calories based consumption – Rice is 3rd - 234 calories, after Cassava-718 and Maize-534.

21

NERICA in Zambezia Region

NERICA Growing under irregular rainfed
3 months after germination

NERICA 4 varieties – Different Stages
One Local variety – still Catching Up


Insect Rice pests in Mozambique
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23


Insect pests in rice field in Arror Marakwet, Kenya
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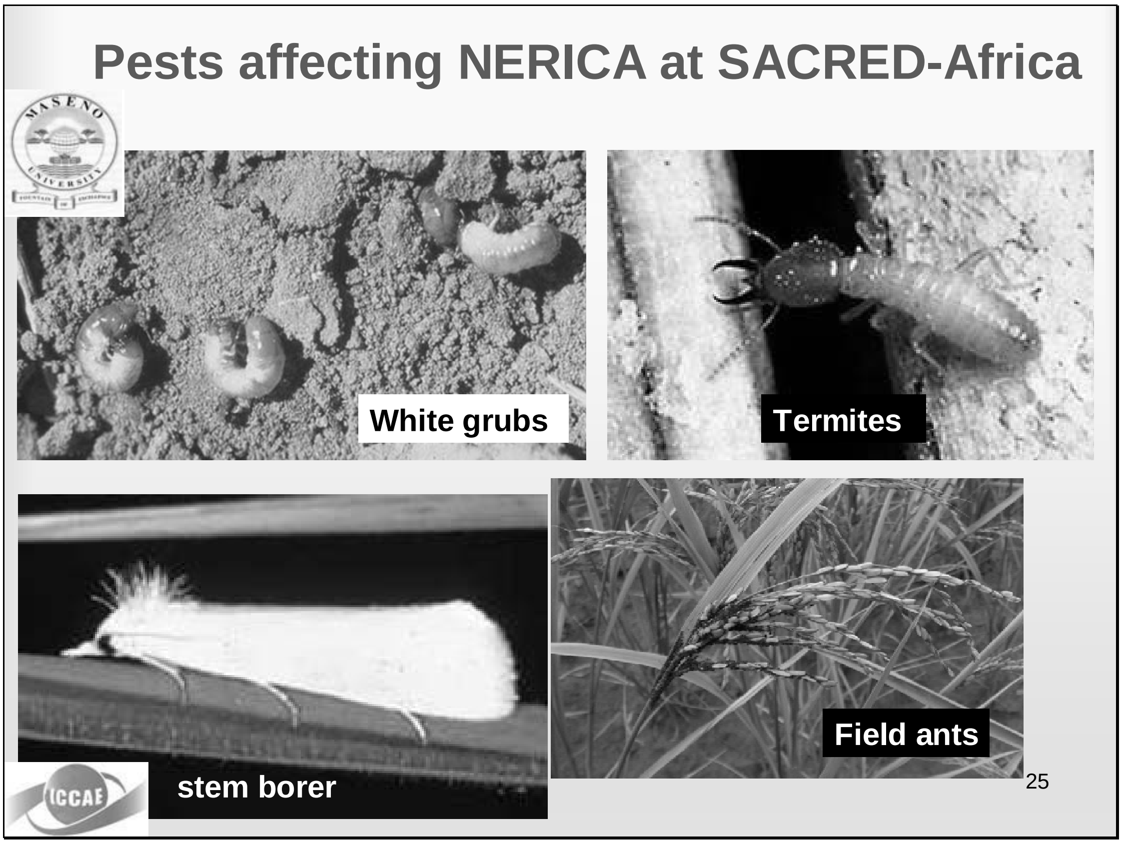
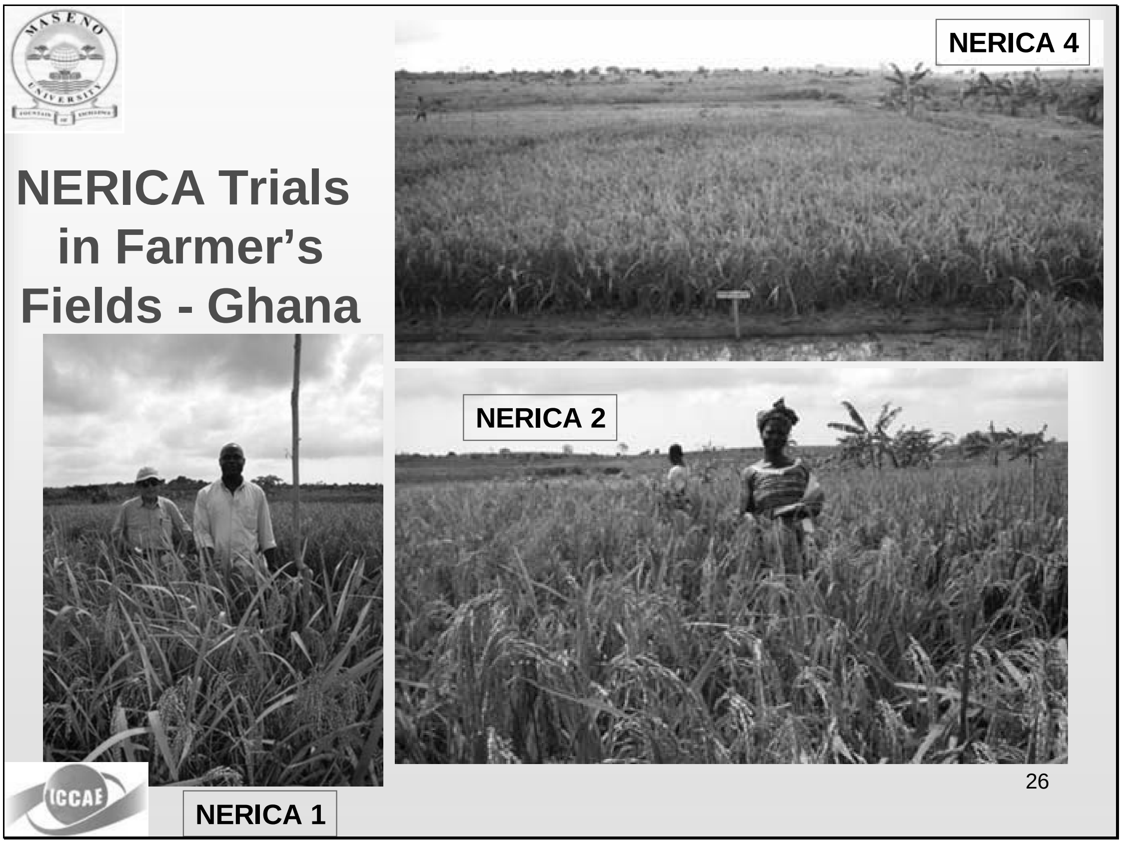

Pests affecting NERICA at SACRED-Africa
White grubs
Termites
Field ants
stem borer
25


NERICA Trials in Farmer's Fields - Ghana
NERICA 4
NERICA 2
NERICA 1
26

NERICA Production by Farmers in Ghana

NERICA 3

NERICA 1

27

Grain Yield for some NERICAs in Ghana

Days from seeding to maturity

Variety	I	II	III	IV	Mean
N-1	118	106	106	115	111
N-4	118	106	106	115	111
N-6	122	111	111	117	115

Yield ($Kg.ha^{-1}$)

Variety	I	II	III	IV	Mean
N-1	2576	4982	3288	1235	3020
N-4	2531	3653	2384	1456	2506
N-6	3171	4955	3593	1951	3418

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Rice seed multiplication field in Kilobero region, Tanzania

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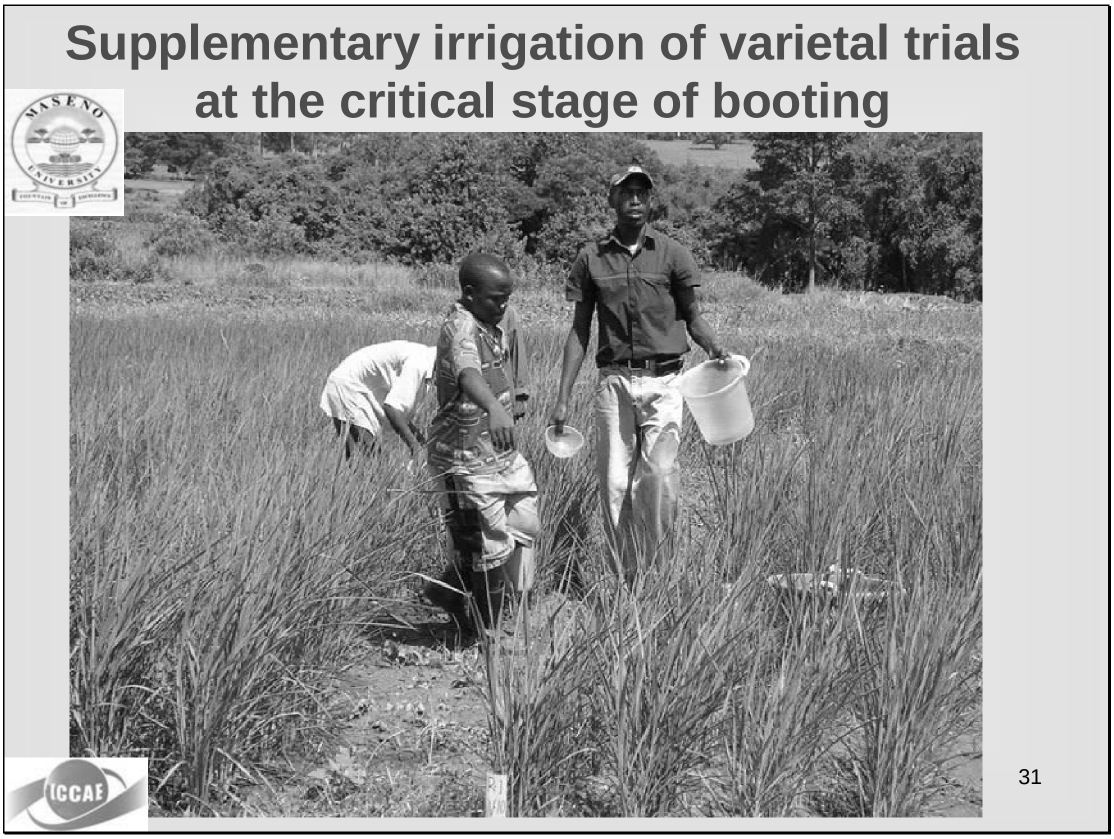
VARIETAL TRIAL NAMULONGE UGANDA

NERICA-5: HIGHEST YIELDING CULTIVAR

Maturity: 120 DAS
Yield t/ha: 4.42
Shatter habit: VD

30


Supplementary irrigation of varietal trials
at the critical stage of booting
31


LONGTERM FERTILITY TRIAL
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NERICA 4 in Farmer's Field Near Namulonge, Uganda

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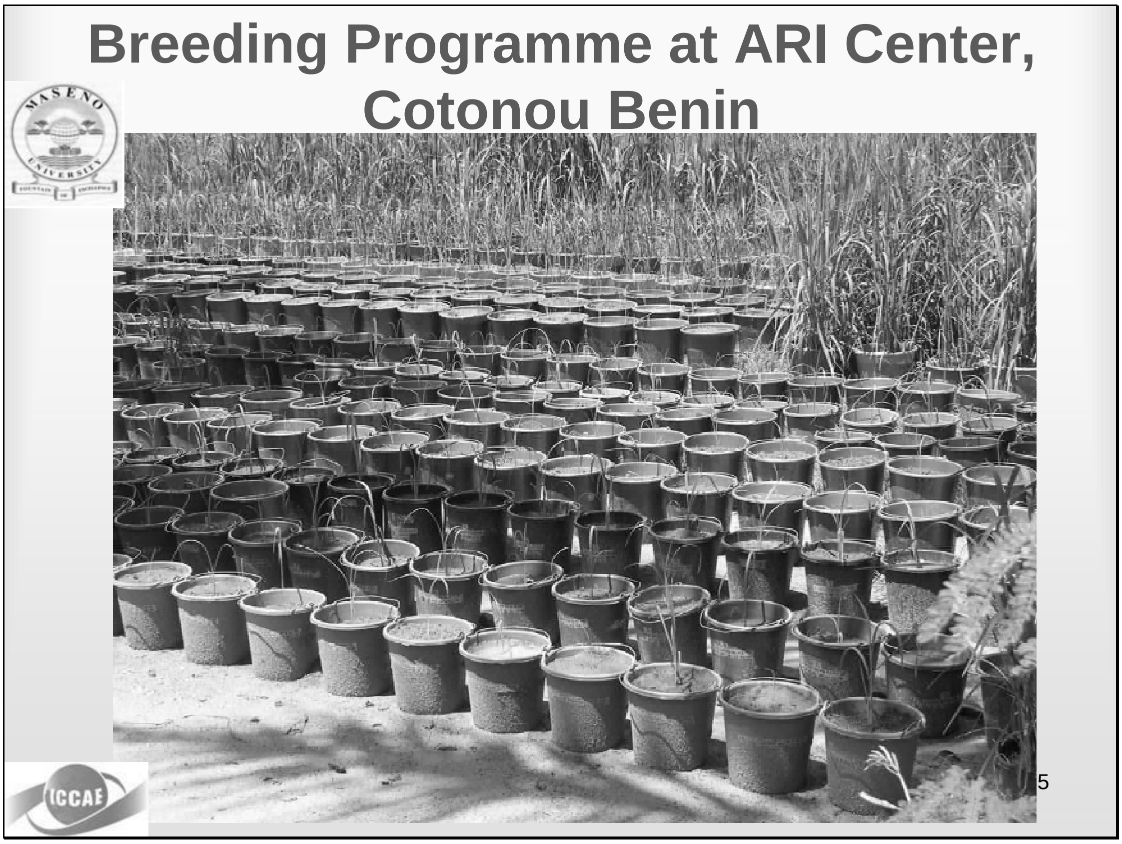
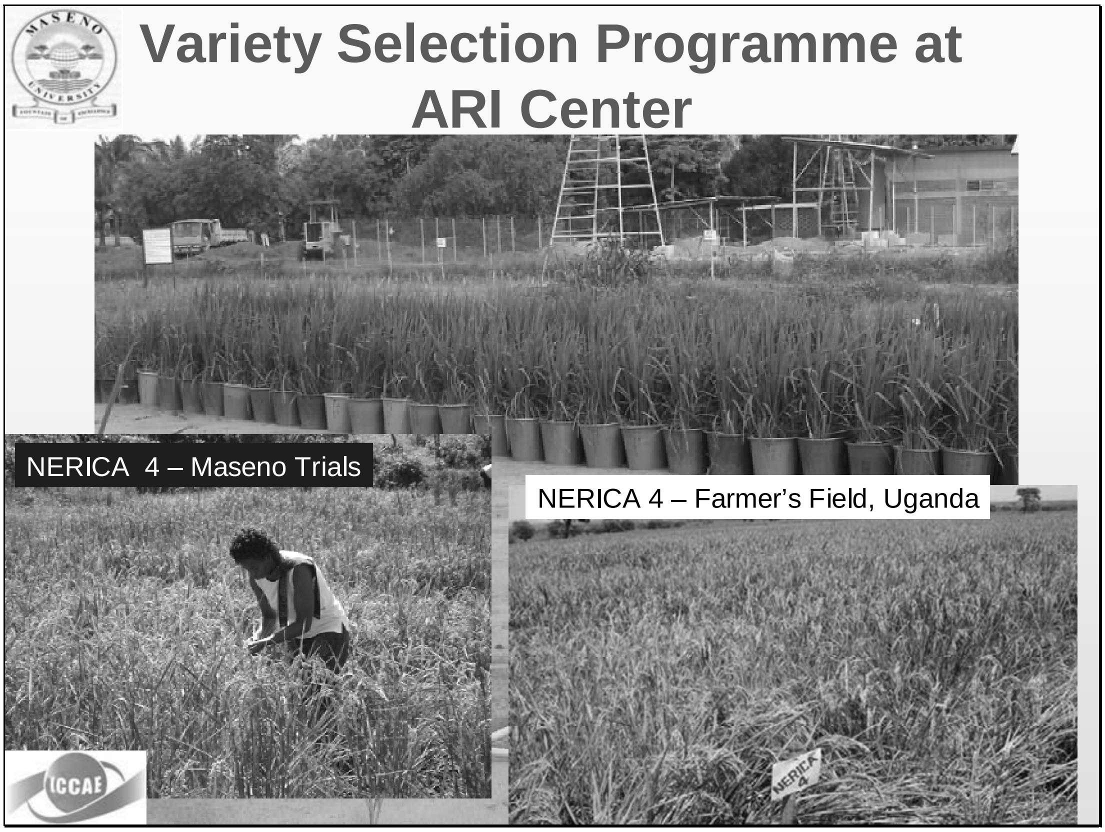
Drought Tolerance Trials at ARI Center


Breeding Programme at ARI Center,
Cotonou Benin
ICCAE
5


Variety Selection Programme at
ARI Center
NERICA 4 – Maseno Trials
NERICA 4 – Farmer’s Field, Uganda
ICCAE

NERICAs in Kenya

- NERICAs have been tried in Kenya for last three years.
- Yields obtained from the trials have been promising.
- The NERICAs have proved to be superior than the local varieties
- From the 3 years results: -NERICAs have been developed for various agro-ecological zones.

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Research hypothesis to be tested

- Low and unstable yields of NERICA cultivars is caused by the unreliable rainfall in Sub-Saharan Africa's arable areas.
- Increased rice productivity will solve the problem of household food insecurity, wealth creation and poor natural resource management affected by increasing population.

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Rain Water pool in NERICA Field

Student Taking Florescence Measurements

POT EXPERIMENTS FOR WATER REGIME EVALUATION

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GREENHOUSE EXPERIMENTS: Some growth parameters

CULTIVARS	Height (cm)	Root Length (cm)	Panicle Length (cm)	Days to Harvest (dae)
T1	104bc	18b	25a	115bcd
T2	104bc	17bc	24abc	114cd
T3	102bc	14b-e	24abc	115bcd
T4	93bc	12de	23a-d	121a
T5	87c	18bc	25ab	113d
T6	106bc	14cde	25a	118a-d
T7	105bc	14b-e	24abc	119abc
T8	89	10e	21d	122a
T9	131	26a	25a	104e
T10	117	17bc	24abc	105e
T11	111bc	15bcd	22bcd	117a-d
T12	109bc	12de	22cd	120ab
LSD (0.05)	22.1	3.87	1.91	4.9
Standard Dev.	15.3	2.68	1.32	3.78
CV	14.6	17.27	5.6	2.93

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GREENHOUSE EXPERIMENTS: Some growth parameters

CULTIVARS	1000 Grain (g)	Filled Grain (%)	Yield 14% M.C. (Kg/ha)	Yield Component (Kg/ha)
T1	25.2cd	91a	610a	4069a
T2	24.8cde	88a	380b	2494bc
T3	24de	71c	272bc	1824bcd
T4	24de	71c	203cd	1501cde
T5	27bcd	91a	541a	3809a
T6	24.8cde	71c	356b	2380bcd
T7	26.9bcd	74bc	304bc	2031bcd
T8	21.5e	56d	123d	817e
T9	36.9a	85ab	641a	4285a
T10	34.7	80abc	380b	2551
T11	29.4b	56d	200cd	1385de
T12	27.8bc	42e	110d	736e
LSD (0.05)	3.22	11.5	119.3	899.2
Standard Dev.	2.23	7.97	82.6	622.8
CV	8.19	10.92	24.0	26.8

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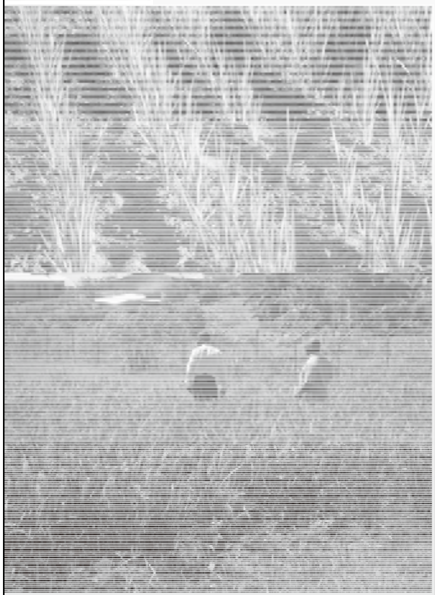
Rainfall and Temperature Data during NERICA Cultivars Trial – Short rains 2005



Months	Rainfall (mm)	Temperature (⁰C) Min.	Max
• August	143	21	28
• September	167	20	30
• October	353	18	28
• November	96	19	31
• December	83	22	31
• January	64	21	28

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NERICA at Flowering – Maseno Site

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NERICA 11 AT MATURITY

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NERICA DISSEMINATION FIELD DAY AT BUNGOMA, KENYA

46

NERICA Growing in The Farmer Field in Bungoma, Panicle Harvesting

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Response of NERICA Cultivars to Field Water Deficit

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Grain filling during drought stress

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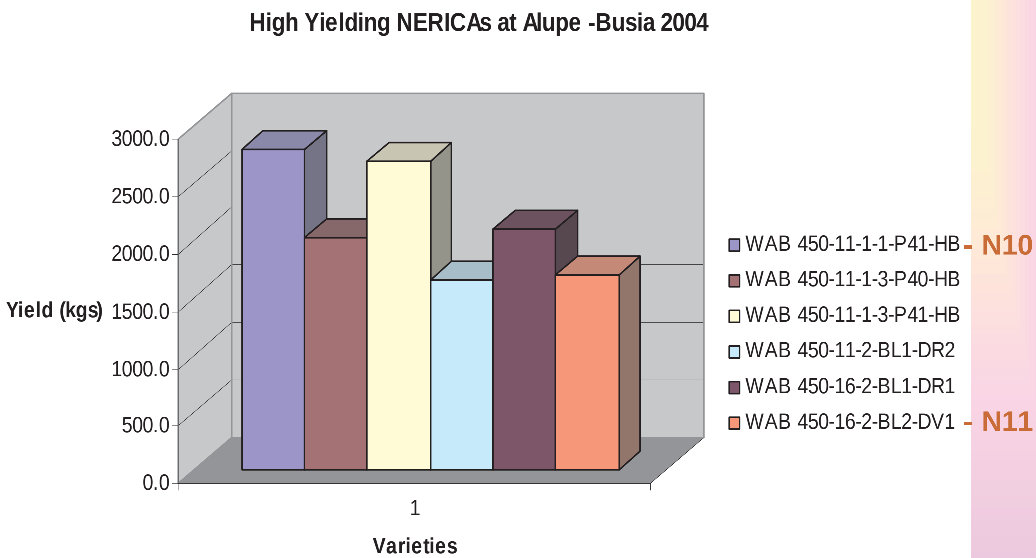
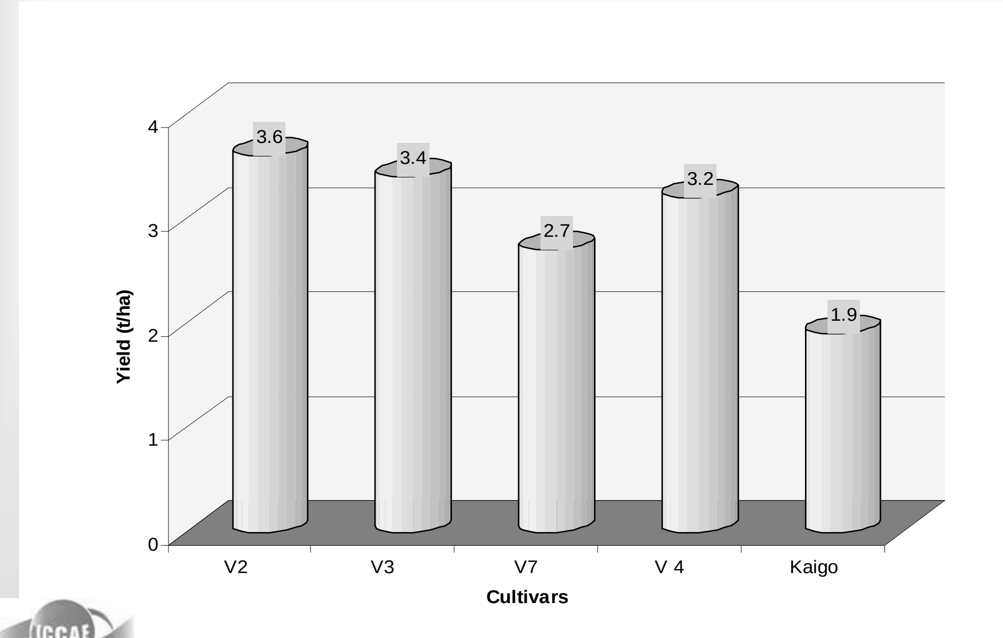
NERICA Yield 2005 at LBDA



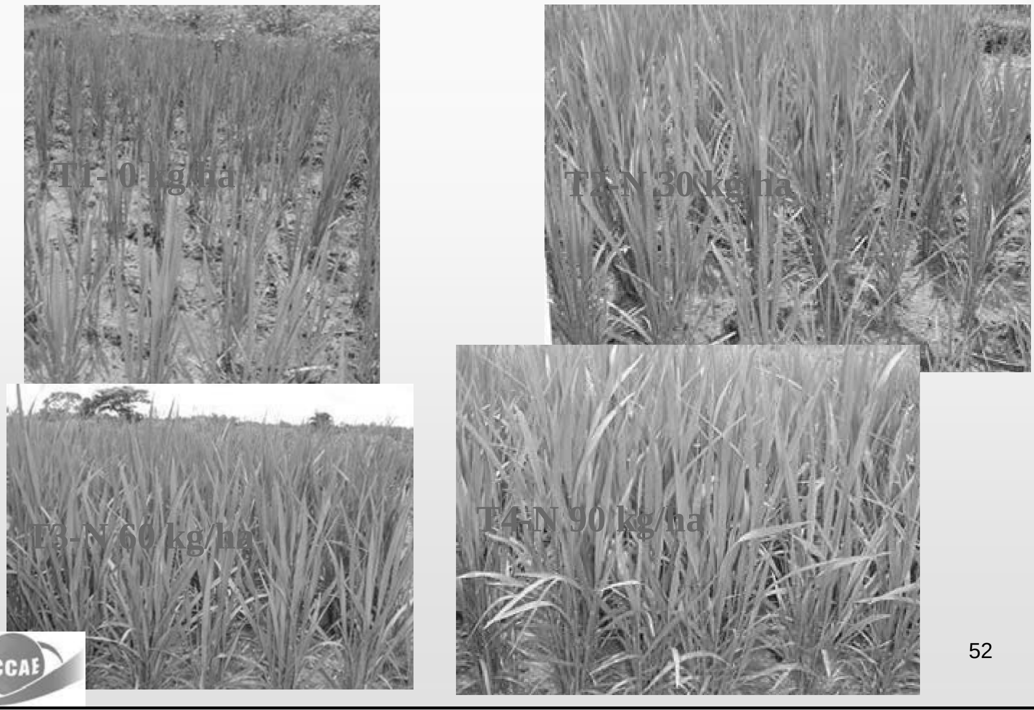
50

Yield of the NERICAs at the Farmers Field in Teso District



51

NERICAs at 52 DASE at LBDA Alupe grown under different treatment of N



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High Yielding NERICAs

Maturity – 100 days

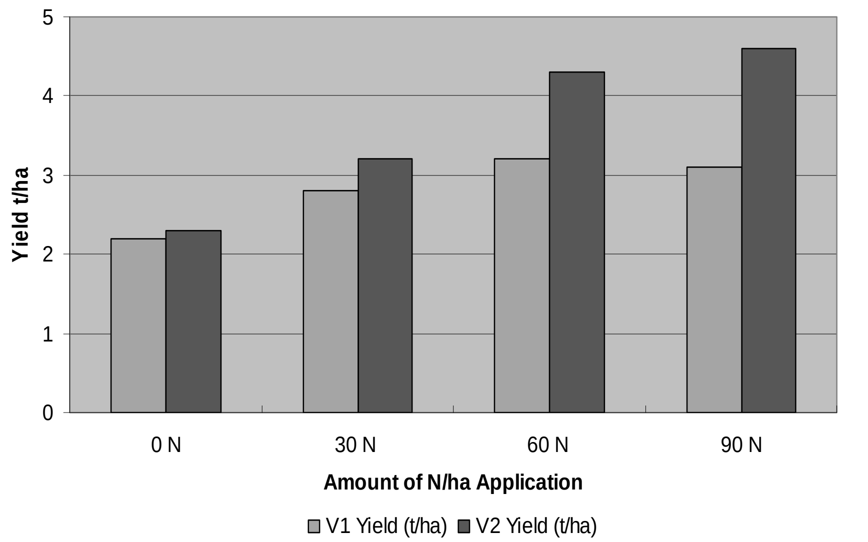
Yield – more than 4.0 t/ha

450-11-1-3-P40-HB

WAB 450-11-1-3-P41-HB

53

Effect of N on Yield - WAB 450-11-1-1-P41-HB (V1) and WAB-450-11-1-1-3-P40-HB (V2)



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2006 Long rains trials

Experiments are on going in all the four sub-stations of the project, namely:

- Botanic Garden at Maseno University,
- Alupe field station of Lake Basin Development Authority,
- Kilombero Agricultural Training and Research Institute at Ifakara, Morogoro,
- Kenya Agricultural Research Institute, Kibos.
- Uganda, National Agricultural Research Organization – Ngeta.

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Soya bean and Bambara Groundnut Intercrop with NERICA Rice 21 das

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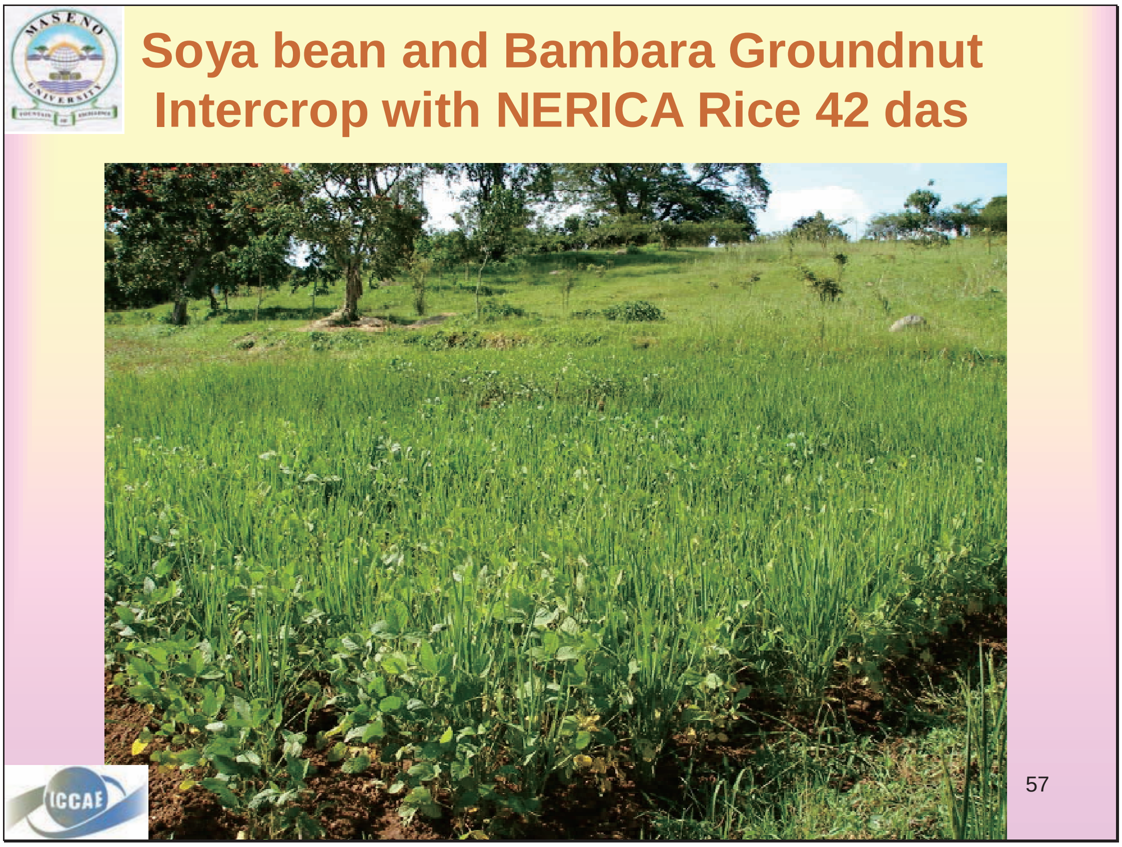
Soya bean and Bambara Groundnut
Intercrop with NERICA Rice 42 das
ICCAE
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NERICA - Alupe Experimental Plots - LBDA
ICCAE
58

NERICA Field Trials at Maseno 2006

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NERICA Technical Review Team Maseno Fields

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NERICA 10 at Grain filling Stage, Maseno

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GRAIN YIELD FOR SOME RAINFED RICE CULTIVARS [WESTERN KENYA]

Variety	Number of Panicles/M^2	Filled Grain Rippening Ratio (%)	1000 Grain Weight (g)	Yield (Kg/ha)
KAISO K23	452.5	77.0	20.3	2323.0
KR – 35	364.5	62.8	24.8	2527.0
KR - 108	379.6	67.8	27.7	2527.5
NERICA 1	235.6	85.7	30.0	3395.1
NERICA 4	259.6	85.7	27.3	2578.5
NERICA 10	205.4	92.8	26.7	3325.3
NERICA 11	296.9	86.5	30.2	4024.5
WAB 450-11-1-3-P41-HB	221.4	87.1	25.8	2898.1
WAB 450-11-2-BL1-DR1	193.8	82.2	31.8	3000.8
PAKISTAN R3	378.7	73.9	27.6	3104.0
PISHORI	459.6	67.8	26.8	2493.6
DOURADO	190.2	86.8	33.6	3035.9
CV	*17.40*	*8.32*	*7.51*	*23.54*
LSD 5%	*89.34*	*11.23*	*3.52*	*1170.43*
LSD 1%	*121.42*	*15.27*	*4.79*	*1590.86*

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NUTRITIONAL QUALITY OF NERICAs

SAMPLE TREATMENT	PROTEIN (%)
NERICAs POLISHED VS PARBOILED	10.2 vs 10.7
NERICAs	10.0 vs 10.9
GUINEAN VARIETY	9.4 vs 10.7
IMPORTED VARIETY*	7.7
STANDARD REF. (USDA)	8.1

TAIWAN & CHINA*

Source, ARI 2006

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Intervention Strategy 1

- NERICA varieties were developed for rainfed or upland conditions; however, there is need to quantify the spectrum of several varieties in cultivation with regard to their water requirements for effective production.
- However, physiological characteristics of NERICA are not fully known and there is an urgent need to conduct research in NERICA agronomic and physiological parameters geared to high productivity under limiting water availability.

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Intervention Strategy 2

- Establishing seed banks requires elaborate information on the ecophysiology of the donor plants, especially with regard to overcoming environmental constraints, since stress is a major limitation to crop production worldwide.
- There is growing interest in identifying and selecting genotypes that will maintain growth and productivity under limited water conditions.

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Intervention Strategy 3

- NERICA may need a shuttle adaptive research approach in order to select varieties which are adaptable to several regions of different agro-ecological structures.
- Through this process varieties which can perform well in the Sub-Saharan Africa can be produced or selected within a short time, thereby reducing the breeding programme period.

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Intervention Strategy 4

- In Sub-Saharan Africa presently, the greatest need is to increase food production above the population growth rate.
- However, this will not be achieved unless fertilizer usage is increased and combined with higher yielding varieties and improved crop management practices.
- The realization of this target also depends on the improvement of the continent's infrastructure network.

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Intervention Strategy 5

- Weed control has been identified as a factor, reducing NERICA production in East Africa, especially the *Striga hermonthica* which causes up to 70% loses in cereals.
- Identification of NERICA varieties that can withstand the weeds' effect will be desirable to promote production.
- Striga is the main parasitic weed devastating NERICA production in Sub-Saharan African.

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Intervention Strategy 6

- In recent Africa Rice Congress (ARC) in Tanzania, it was realized that Sub-Saharan Africa has the lowest number of available scientific expertise which is about 83 scientists per million people, compared to 1100 scientist per million in industrialized countries and 785 per million in Asia.
- At this level of scientific expertise in Africa, it is paramount that capacity-building programme focusing on the development of a multi-disciplinary researchers and extension staff is urgently needed.

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Intervention Strategy 7

Lack of certified seeds is the main draw back to releasing some of the high potential NERICA varieties in Kenya.

- Efforts are now being made to bulk the seeds of selected NERICA lines for release to farmers by 2008 long rains season but there is also a need to bring in private sector stakeholders in certified seed production and marketing.
- Sasakawa-Global 2000 has played the role of seed production successfully in Asia and Uganda, their experience is an asset in NERICA seed dissemination.

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Intervention Strategy 8

- Pest and diseases evaluation in NERICA fields should be carried out and the results used to identify correct remedial measures and development of necessary pesticides and other crop protection chemicals relevant to NERICA rice production.

- Harvesting and post-harvesting techniques need to be surveyed and recommendation made on best practices on processing and storage.

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Intervention Strategy 9

- Value addition and milling requires quick access to good quality mills to enhance profitability of the rice produce by farmers in contrast to the middle traders.
- Market surveys and identification of ready market for the produce will also entice more small-holder farmers to continue with rice production both for food security and cash crop.
- In Uganda farmers have earned up to Ush. 3,740,000 (about US$ 2,000) for NERICA production per hectare.
- This earning has enables NERICA farmers to meet several of their family obligations.

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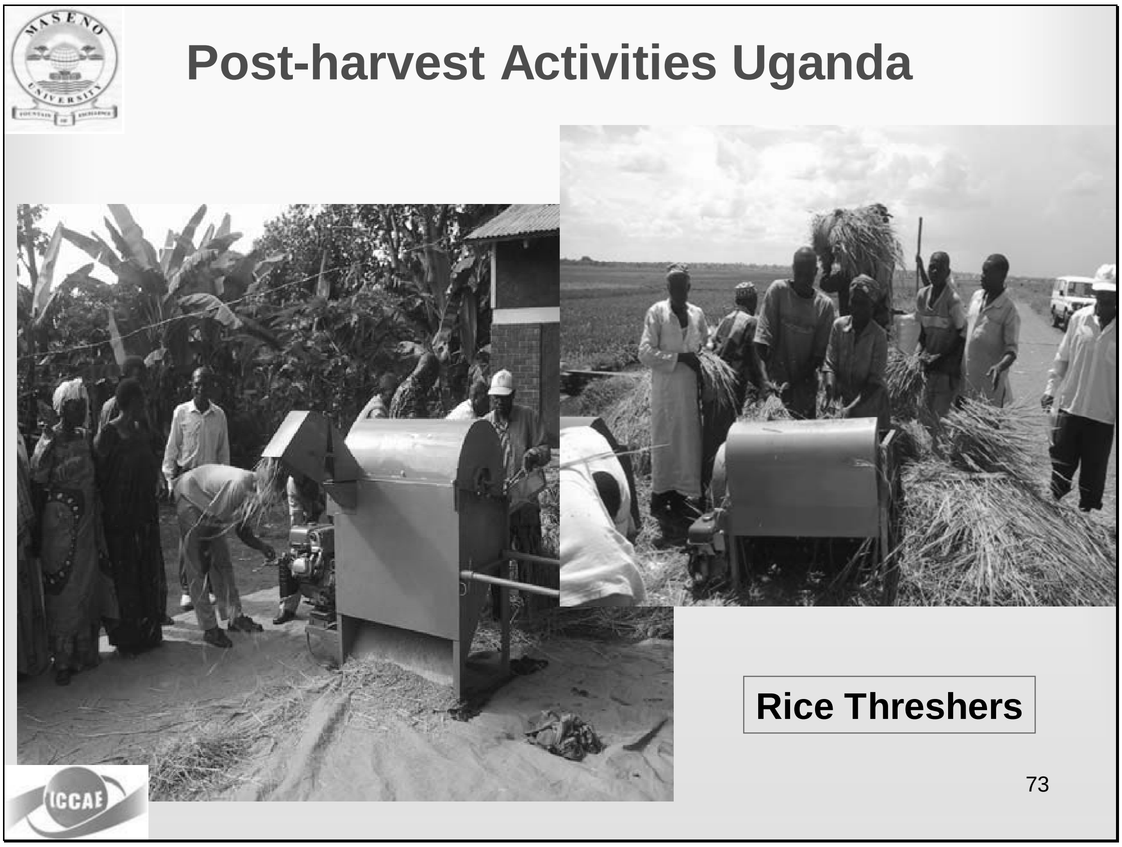
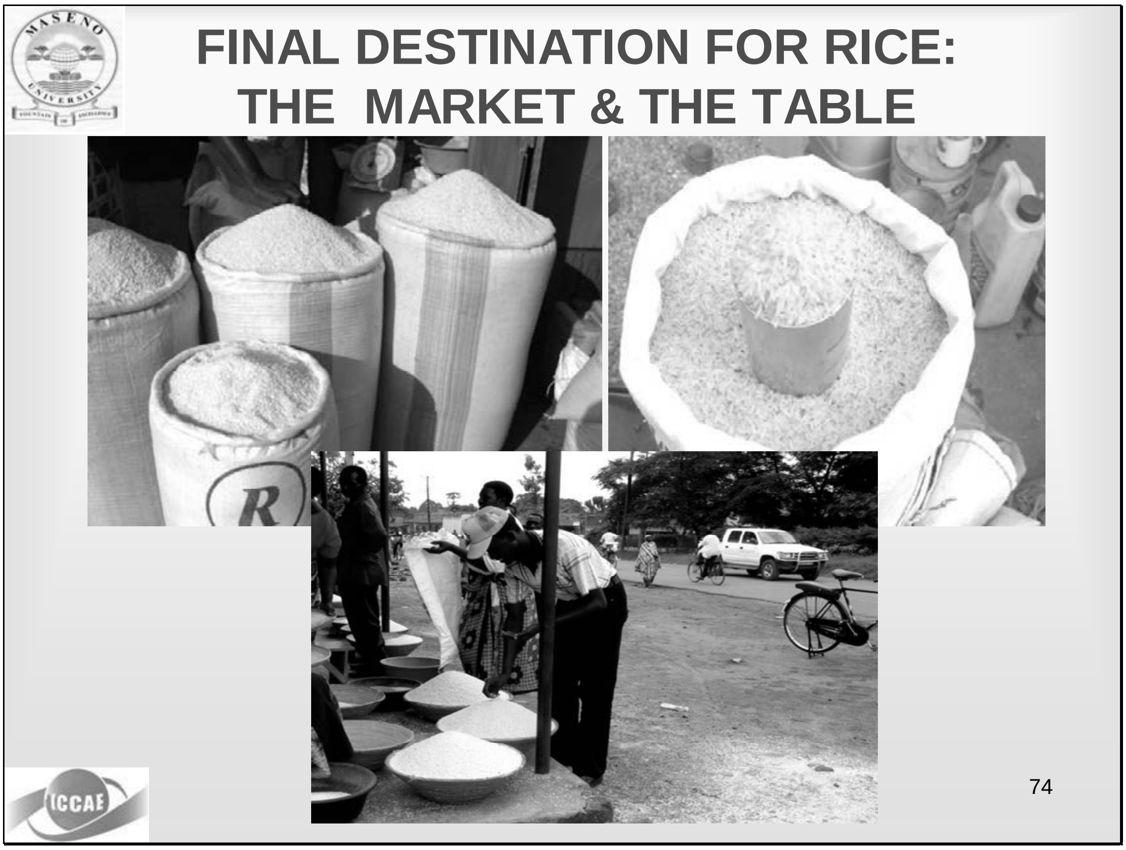

Post-harvest Activities Uganda
Rice Threshers
73


FINAL DESTINATION FOR RICE:
THE MARKET & THE TABLE
74

Benefits to Farmers

- Benefits from rice growing have been proven to be greater for farmers working in groups than those working individually. Such benefits include sharing labour and information and also better marketing.

- On-farm water harvesting after heavy rains have also improved production to the farmers involved.

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Conclusion

- The findings from the research strategies and up-scaling of production technologies will be a resource and attribute to the performance and implementation by various Ministry of Agriculture extension services in different countries in the region.
- This will spirally lead to better natural resource management practices and improved rice production, marketing and availability to rural and urban communities.

- If coordinated well, then this will enhance the role of NERICA in food security and poverty reduction in the Sub-Saharan Africa.

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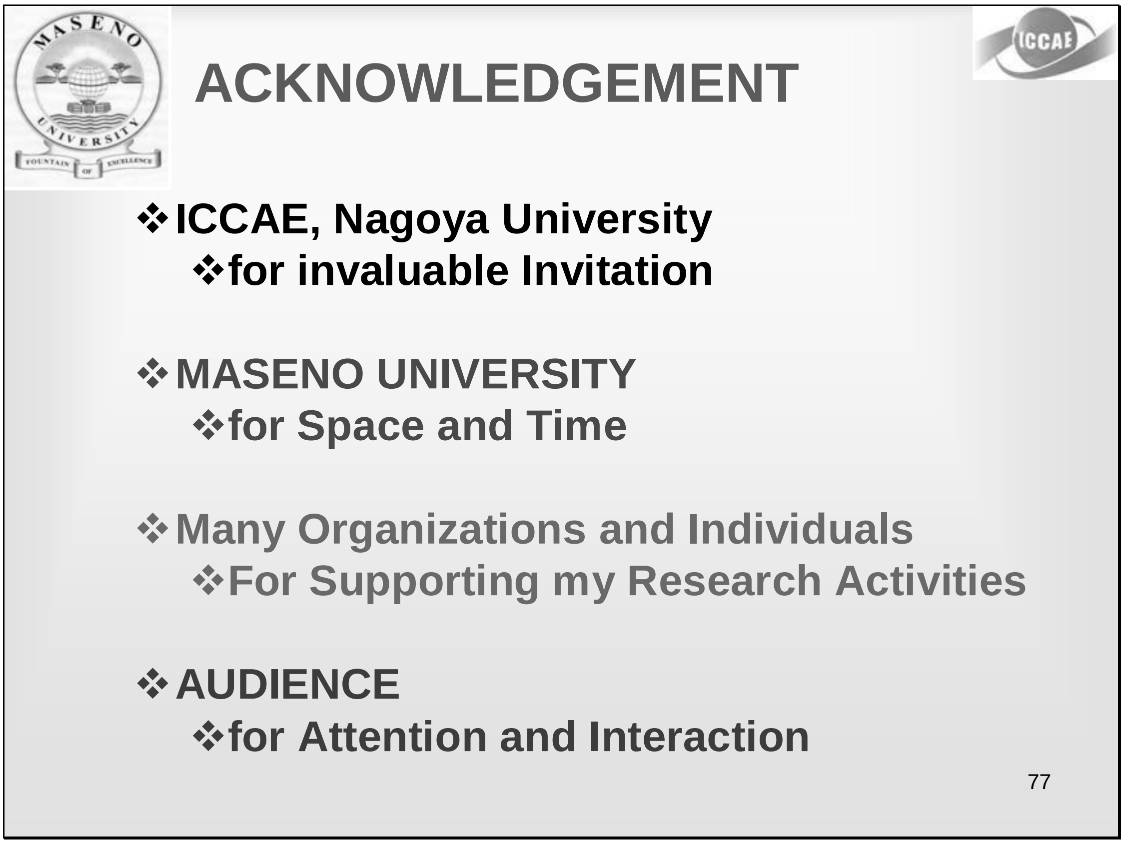
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ACKNOWLEDGEMENT
❖ICCAE, Nagoya University
❖for invaluable Invitation
❖MASENO UNIVERSITY
❖for Space and Time
❖Many Organizations and Individuals
❖For Supporting my Research Activities
❖AUDIENCE
❖for Attention and Interaction
77


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質疑応答
Question and Answer Session

Rice Production in Africa: A Key to Promoting the Sub-Saharan Africa Food Security
アフリカにおける米の生産：サハラ以南アフリカの食料安全保障を強化するためのキー

John C. Onyango
Professor, Maseno University, Kenya
Visiting Professor, ICCAE, Nagoya University (at the time of presentation, October 2006)

司会：浅沼　修一
名古屋大学農学国際教育協力研究センター
Chair person: Shuichi Asanuma, Professor, ICCAE, Nagoya University

Asanuma, Chair:

Thank you very much for your general introduction of NERICA; on its production, problems, and dissemination in Africa. I'm surprised to hear that NERICA has such a potential to grow its yield up to 3 tones/ha with the farmers skill. As you said in the conclusion, coordinating them well would make it possible to improve the food security. I think this is important.

We are behind the schedule. Do you have any questions for Dr. Onyango?

Wakatsuki:

My name is Wakatsuki from Kinki University. Thank you very much for your nice presentation. I am also extremely impressed by your presentation and recognized, for realizing the green revolution in Africa, the basic infrastructure is necessary.

May I ask you about your target of NERICA dissemination? Do you think fertilizer is the key? If the yield of NERICA or of any other rice is less than 4 tons/ha in the farmers' fields, the use of fertilizer may not be productive. Normally at that level, fertilizer use cannot be sustained due to its high cost. The yield should be higher than 4 tons/ha. So, in that case, do you think what strategy should be adopted to increase the yield at the farmers' fields? I think that the green revolution would be possible when 4 tons or higher is realized in the farmers' yield, otherwise any fertilizer use can not be economic. This is my opinion. Could I have your comment about that?

Onyango:

Thank you very much for that question Dr. Wakatsuki. I think the fertilizer use has been in high debate for a very long time. That kind of thinking is not new. Actually, even when we are talking about the Green Revolution in Asia that is, India and Pakistan, the fertilizer was a problem and so was the crop production.

But I think the scientists who were dealing with the crop at that particular time made the governments realize that if the aim was to increase production then fertilizer had to be involved. If that (increased use of fertilizer) is going to be the case, even though the farmers are poor, they are ready to offer labor on their farms, so the government should come up with subsidy to bale them out to increase NERICA production.

The problem with the fertilizer is still there as at now we also have environmentalists who are concerned with pollution factors caused by fertilizer run-off from farm lands. However, this can be mitigated by having buffer crops to take up run-off nutrient load before discharge into water bodies.

Since the subsidy worked for Green Revolution it is possible to employ the same method to increase production. The countries affected with low rice production spends about US$ 1.5 billion to import rice, it follows that, if they spend a fraction of that money to access fertilizer for farmers then they can assist small holder producer increase production. The agricultural extension staff will also help with safe environmental management of fertilizer usage.

Asanuma, Chair:

I will take one more question. No question? I have a question. You showed us in your slides regarding intercropping of NERICA with Soya beans and Bambara groundnuts. What is the purpose of the experiment in terms of farm management?

Onyango:

Thank you. The purpose of the experiment is to help with the replenishment of the soil nitrogen, because the two crops are legumes, hence good in nitrogen fixation at scientific level. But at community level, most farmers we are dealing with are already intercropping Soya beans and Bambara groundnuts with maize. Our experiments are therefore aimed at developing a package for technology transfer. We want to have enough information for this transfer so that we can win farmers’ confidence in using rice instead of maize thereby increasing the production.

Asanuma, Chair:

If there is no other question, thank you very much, Professor Onyango.

Profile

ジョン・C・オニャンゴ John C. Onyango

マセノ大学理学部長・教授

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1986年ケニア・ナイロビ大学理学部植物学修士課程修了(植物生理学)、1989年英国サセックス大学博士課程修了(作物・植物生理学)。1986年から1991年までナイロビ大学教員、1992年から2001年までマセノ大学植物学科長。その後、同大学理学部植物生理学教授に就任し、現在に至る。2004 年から2008年までマセノ大学理学部長を務め、2006年8月から12月まで名古屋大学農学国際教育協力研究センター客員教授を務め、名古屋大学山内章教授、浅沼修一教授とともに共同研究を実施。

1993 年、1996 年、2000 年、2003 年にはドイツ・バイロイト大学アーウィン・ベック教授、1995 年にはロンドン大学デニス・ベイカー教授のもとで研究を行う。フルブライト・アフリカ上級研究者プログラムで米国ルイジアナ州の稲作研究試験場、リチャード・デュナン教授の下で9か月間にわたり研究を行う。

これまでドイツ・アフリカ学術交流(DAAD)、ドイツ国際技術協力(GTZ)、ドイツ研究財団(DFG)、アフリカ高地イニシアチブ(AHI)、ドイツ連邦教育研究省、ビクトリア湖研究イニシアチブ(Vic Res)(SIDA IUCEA)、日本の国際協力機構(JICA)、また、アフリカ人造り拠点(AICAD)などからも研究ファンドを得ている。

オニャンゴ教授が行った重要な研究の一つとして、ドイツ連邦教育研究省から研究費を受け BIOTA の下で実施した、コミュニティの資源有効活用に関する高価値植物の保全に関するプロジェクト『東アフリカ E12 プロジェクト:東アフリカ山林の植生、再生、民族植物学』が挙げられる。

現在は、AICAD と JICA とが行っている NERICA のケニア国内地域適応性試験において、特に、天水稲作、植物生理学、生物多様性に関する研究を意欲的に行っている。現在の研究は、ケニアにおける NERICA の適応試験、およびビクトリア湖地域におけるケニアの伝統的天水稲作法の普及研究。

Academic career

Professor Onyango obtained his Bachelor of Science and Master of Science in Botany (Plant Physiology) from the University of Nairobi, Kenya in 1982 and 1986 respectively. He later obtained his Ph.D. in Crop/Plant Physiology from the University of Sussex, United Kingdom in 1989.

Professional career

Professor Onyango has had an illustrious career in University teaching, research and administration since 1986 to date. He first taught at the University of Nairobi from 1986 to 1991. He then joined Maseno University in 1992 to become Chairman of Department of Botany up to 2001. He rose through the academic ranks to become a Professor of Plant Physiology in the Faculty of Science a position he serves until to date. Professor Onyango was also Dean of the Faculty of Science from 2004 to 2008 at the same university. He was a Visiting Professor from August to December 2006 at the International Center for Cooperation in Agricultural Education (ICCAE), Nagoya University conducting research with Professor S. Asanuma in Professor Akira Yamauchi's Laboratory.

Research Interests and Achievements

Professor Onyango in the past has been awarded several three-months research fellowship awards that enabled him to carry-out distinguished research in Professor Erwin Beck's Laboratory at the University of Bayreuth, Germany in 1993, 1996, 2000 and 2003; Professor Denis Baker's Laboratory at University of London 1995; Nine-months sabbatical leave research in Professor Richard Dunand's Laboratory at Rice Research Station, Crowley, at Louisiana State University, USA. Sponsored by Fulbright Senior African Scholars' Program.

Professor Onyango's outstanding research work is evidenced by his numerous publications in refereed journals and the many research grants he has been awarded by distinguished organizations, among the German Academic Exchange for Africa (DAAD), German International Technical Cooperation (GTZ), German Research Foundation (DFG) African Highland Initiative (AHI), German Federal Ministry of Education and Research, Lake Victoria Research Initiative – (Vic Res) (SIDA IUCEA), Japanese International Cooperation Agency, (JICA) and AICAD.

One important research initiatives he has undertaken is that of the conservation of high value plants for efficient community utilization of resources a project that was sponsored by the German Federal Ministry of Education and Research, under the BIOTA – East Africa, E12 project on Vegetation, Regeneration and Ethno-Botany of East African Mountain Forests.

Professor Onyango is currently an active researcher in the NERICA-rice research initiative promoted by Japanese International Cooperation Agency (JICA), and AICAD and his research work has focused on rain-fed rice and plant physiology and biodiversity in general. His current research is on Adaptability trials of NERICA in Kenya and Agronomic development of Kenya's traditional rain-fed rice in Lake Victoria region.

第2章　研究

Chapter 2　Research

根からみた作物の水ストレス耐性
Roles of Roots in Relation to Water Stress Tolerance of Crop

山内　章[1*]・犬飼義明[1]・狩野麻奈[1]・Roel Suralta[2]・小川敦史[3]
名古屋大学大学院生命農学研究科[1]; フィリピンイネ研究所[2]; 秋田県立大学[3]
(*ayama@agr.nagoya-u.ac.jp)

要　約

作物の生産性を規定する主要因の一つは、水である。作物が栽培されている圃場においては、土壌環境は一定であることはむしろまれで、常に変動している。さらに空間的にも不均一である。このことは研究者の間ではっきりと認識されているとは言えず、水ストレス耐性と作物根系の発達と機能との関係を考える上では、たいへん重要な視点である。

作物が栽培されている圃場においては、栽培期間中、長期にわたって乾燥あるいは過湿ストレスが続く場合より、むしろ乾燥と過湿の間で土壌水分条件が変動することの方が実態に近いと考えられる。このような変動は、乾燥や過湿の単独のストレスに比べ、根の発育と機能にとってより厳しいストレス要因として働く可能性がある。

この問題をイネについて考えてみる。世界的にみるとイネ栽培地域の約半分が天水田（rainfed lowland rice field）で、灌漑設備が整っていない。この天水田における最大の収量制限要因は、水ストレスである。天水田には、深さ 20cm あたりに硬盤層という不透水層が存在し、そのため一時的に湛水状態となる場合がある。すなわち、硬盤層より下の心土は通常、湿潤状態であるが、硬盤層より上の作土は不定期な降雨によって嫌気的と好気的条件を繰り返し、その際に起こる水ストレスが生産性の低下を招く。このように、天水田における水ストレスは、畑状態で起こる単純な乾燥ストレスとは質的に異なるものである。さらには、世界的な水不足に対応して、潅漑設備が整っている水田においても、節水栽培技術の開発が急がれているが、ここでも共通の問題が存在する。

このような、時間的・空間的に不均一な土壌条件下で、イネ根系はどのような形質を具備すべきか？

環境条件に対して反応し、形態を変化させる能力を可塑性と呼ぶ。そこで、茎葉部より分配された光合成産物を効率よく利用して、変動する土壌環境、とくにストレス環境に応答して、個体の成長を安定させるような能力を有する、すなわち可塑性の大きい根系が、機能的に高いと考えることができる。しかし一方、この可塑性という形質は、遺伝学的にはたいへん扱いにくく、これをまともに取り上げるような育種プログラムもこれまでにはなかった。しかしこの形質は、作物のストレス耐性と密接に関連している可能性が高く、注目する必要がある。

本論文では、主として筆者らがこれまでに行ってきた研究成果をもとに、土壌環境の中で、とくに水ストレス耐性を中心に、作物根の発育や機能が果たす役割を、可塑性をキーワードに考えてみたい。

Roles of Roots in Relation to Water Stress Tolerance of Crop

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Abstract

Among the various soil conditions, the soil moisture effect is probably most commonly recognized. Soil environment is rarely constant but continues to change and is heterogeneous in space as well. These facts are quite important when the root development and function are analyzed in relation to their roles in water stress. During cropping period, it may be rather common that soil moisture conditions fluctuate between drought and excess in moisture than that the conditions continue to be either of them. It is important to note that such fluctuation can be more stressful as compared with singly consistent stress of either drought and excess in moisture on crop root development and function. In case of rice, more than a half of areas planted with rice is rainfed lowland field without irrigation. The most severe constraints to production there is water stress. Under rainfed lowland conditions, a hardpan that is water impermeable tends to be formed approximately 20 cm below soil surface, and thus waterlogged conditions can temporally appear. In other words, subsoil below the hardpan is usually wet while the topsoil above the hardpan is often exposed to frequent wet and dry cycles that are caused by irregular rainfall, and such water stress can cause substantial reduction in growth and yield of rice plants. As such, the water stress under rainfed lowland conditions is essentially different from the simple drought stress under upland conditions. Furthermore, global trend of water scarcity badly demands the development of water-saving rice production technology in irrigated rice fields, which however inherently contains the similar problem of water stress as rainfed lowlands. Then what kinds of root traits should rice plants possess under such heterogeneous soil environment in time and space? A root system of a crop plant is an integration of component roots with dissimilar morphology, anatomy and possibly physiological functions. They are different also in developmental responses to various environments. The ability of the plant to change its morphology as environmental conditions change is known as phenotypic plasticity. The root system that is high in function may be defined as that developmentally responds to environmental changes in a way that it stabilizes the whole plant growth, i.e., plastic root system. Such trait is difficult to be dealt with genetically and thus has been rarely incorporated in any breeding program. This paper aims to briefly review our research outputs with related areas on root system development and function in relation to the stress tolerance, especially that of water stress, of crop plants.

Key Words:
Aerobic rice, heterogeneity, irrigated lowland, plasticity, rainfed lowland, water saving production

Water stresses in rice fields and the roles of roots for plant adaptation

It is believed that roots play important roles in crop adaptation to various environments (Wang et al., 2006; Wang and Yamauchi, 2006; Yamauchi et al., 1996), but no practical rice variety has been developed based on root trait. It may be partially because the root traits responsible for the rice plant adaptation vary with the nature of the growing environment. For example, under upland conditions where soil moisture is available mainly in deep layer, the desirable traits may be simple and clear; deep and thick roots at least for vegetative growth. On the other hand, generally under field conditions, soil environment is rarely constant but continues to change and is heterogeneous in space. For example, the topsoil of rainfed lowlands is often exposed to frequent wet and dry cycles that are caused by irregular rainfall (Wade et al., 1999).

Irrigated rice fields with water-saving technology such as aerobic rice and alternate wetting and drying system (Bouman et al., 2005) also inherently contain the same nature of soil moisture environment as found in rainfed lowlands, that is, the fluctuating soil moisture but with less intensity and possibly more frequency. Although we need careful examination as to whether such fluctuations cause any ‘drought’ stress, we assume that moisture fluctuation alone can be stressful for root development and function. These may be understood if we address simple questions as follows; What would happen to the deep roots that developed in response to drought when the soil is suddenly waterlogged by rain or irrigation? What would happen to plants when droughted if the root system is shallow after being grown in waterlogged and O2 deficient soil? Then what kinds of root traits should rice plants possess under such heterogeneous soil environment in time and space?

Desirable root traits under water stress conditions

Root plasticity

A root system of a crop plant is an integration of component roots with dissimilar morphology, anatomy and possibly physiological functions. They are different also in developmental responses to various environments. The ability of the plant to change its morphology as environmental conditions change is known as phenotypic plasticity (O’Toole and Bland, 1987). The root system that is high in function may be defined as the one that developmentally responds to environmental changes in a way that it stabilizes the whole plant growth, which may be called as plastic root system.

Fig. 1 shows the root systems of Job’s tears (adapted to excess moisture conditions), Japanese barnyard millet (adapted to both excess moisture and dry conditions), and Pearl millet (known to be drought resistant) grown under waterlogged, well-watered and droughted conditions. The root systems showed very sharp plasticity according to their adaptation ability to soil moisture conditions. For example, Job’s tears showed promoted root system development under waterlogging and inhibited development under drought and pearl millet’s root system was severely inhibited under waterlogging but especially fine branching was apparently promoted under drought, while the root system of Japanese barnyard millet relatively maintained the development under both extreme conditions (Galamay et al., 1992).

In this aspect, we have accumulated experimental evidences by comparing different crop species and varieties, which show that the response of root system to a certain soil environmental condition largely determines the plant’s ability to adapt to the condition. Other examples include sorghum grown under high root-zone temperature (Pardales et al., 1991; 1992), waterlogging (Pardales et al., 1991), allelopatic influence (Pardales 1992), cassava under fluctuating soil moistures (Pardales et al., 1999; Pardale and Yamauchi, 2003; Subere et al., 2009), sweetpotato under high root-zone temperature (Pardales et al., 1999) and soil moisture fluctuations (Pardales et al., 2000), various food legumes under different soil moistures and temperature (Mia et al., 1996), maize under heterogenous N distribution (Tanaka et al., 2000) and rice under water stress (Bañoc et al., 2000a; b; Wang et al., 2009).

Fig. 2 shows the growth of rice varieties, Nipponbare and KDML 105 (rainfed lowland variety in North East Thailand) grown under soil moisture gradients from wet to dry. We identified KDML 105 as a variety that shows very sharp root developmental plasticity in response to changing soil moisture conditions (Bañoc et al., 2000a; b). This figure therefore strongly suggests that the root plasticity may play quite important roles in the plant growth in the wide range of soil moisture.

As such, the phenotypic plasticity, the ability of root traits to change developmentally and functionally in response to the changing conditions was suggested to be one of the most important traits for adaptation (Yamauchi et al. 1996). Such trait is difficult to be dealt with genetically and thus has been rarely incorporated in any breeding program.

We showed that in rice root system, the development of different component roots and their plastic responses to drought are under different QTL control. Such QTL were found also to differ with the intensities of water stress (Wang et al., 2005). We further showed that root osmotic adjustment is one of the physiological bases for the plasticity (Ogawa and Yamauchi, 2006). Especially, the sugar accumulation on root axes induced by water stress was found to be closely associated with plastic lateral root branching under the condition suggesting that such responses may be one of the physiological bases of the plasticity exhibited by the root system (Ogawa et al., 2005).

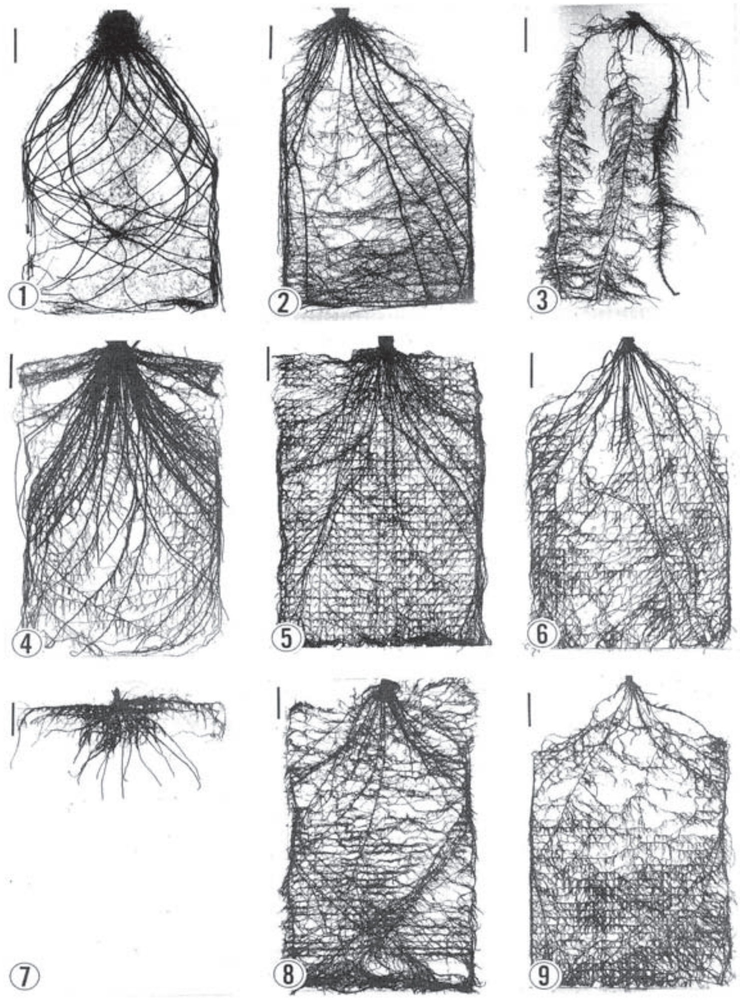

Fig. 1 Root system development of Job's tears (*Coix lacrima-jobi* L.) (upper, 1, 2, 3), Japanese barnyard millet (*Echinochloa utilis*) (middle, 4, 5, 6), Pearl millet (*Pennisetum typhoideum* L.) (bottom, 7, 8. 9) grown under waterlogged (left, 1, 4, 7), well-watered (center, 2, 5, 8) and droughted (right, 3, 6, 9) conditions. (Galamay et al., 1992)

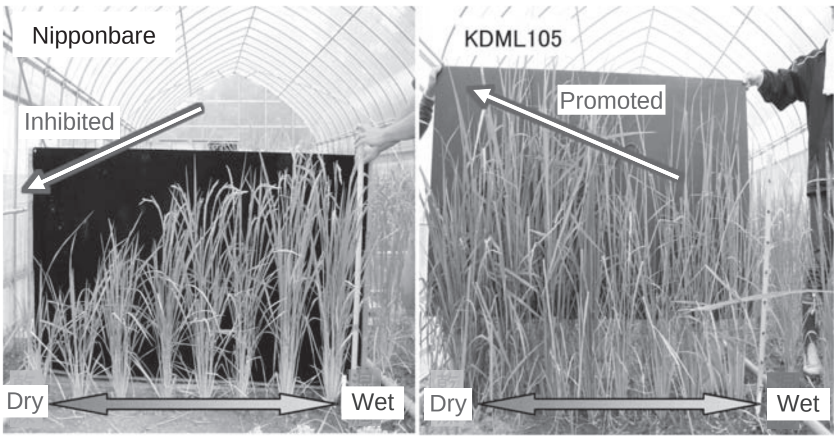

Fig. 2 Growth of rice varieties, Nipponbare (left) and KDML 105 (rainfed lowland variety in North East Thailand) (right) grown under soil moisture gradients from wet to dry.

With this paper, therefore, we propose that the plasticity is one of the key root traits that are required for rice plants to adapt to various environments with soil moisture fluctuation including rainfed lowlands and irrigated lowlands with water-saving production systems.

Identification of key root traits in rice

Our recent studies have been aiming at evaluating the genetic variations in responses in dry matter production, shoot growth and root system development to constant drought stress and transient moisture stress conditions (drought and O_2 deficiency) to identify key root traits that contribute to plant adaptation to various intensities of drought stress and fluctuating soil moisture stresses.

Constant drought stress

Fifty-four chromosome segment substitution lines (CSSLs) derived from Nipponbare and Kasalath parents provided by the Rice Genome Research Center of the National Institute of Agrobiological Sciences, Japan were used in the field experiments for three years. We used a watertight experimental bed installed with line source sprinkler system, which creates and maintained various intensities of soil moisture stresses as shown in Fig. 3. Results showed that these CSSLs generally showed reduced plant height, tillering and dry matter productions as the drought intensified in both years, which were associated with reduced photosynthesis and transpiration, and stomatal conductance. However, compared with Nipponbare, CSSL45 and 50 relatively maintained dry matter production with increasing drought stress due to their ability to maintain or promote root elongation and branching under the conditions. Specifically, their growth in shoot and roots were not different from Nipponbare at 40% and above in soil moisture content (SMC), while the dry matter production and total root length in those CSSLs peaked around 30-35 % of SMC. Under severe drought at 10 % of SMC or below, the extent of shoot and root growth reductions were similar to those of Nipponbare (Kanou et al., 2007; Yamauchi et al., 2008). These results strongly suggest that plastic root responses of rice genotypes may be one of the key traits that contribute to plant adaptation to various intensities of water stress.

Fig. 3 Watertight experimental bed installed with line source sprinkler system, which creates and maintained various intensities of soil moisture stresses.

Transient moisture stress

Two aerobic genotypes (UPLRi7 and NSICRc9), one irrigated lowland (PSBRc82), Kasalath (*indica*) and Nipponbare (*japonica*) CSSLs parents were grown under transient moisture stress in a growth chamber for 2 weeks (one week under each moisture stress) (Suralta and Yamauchi, 2008). The transient moisture stress treatments were drought to O_2 deficient (stagnant) and stagnant to drought conditions. Then, the 54 CSSLs were also evaluated in similar manners.

Consistent genotypic differences were found between aerobic and irrigated lowland genotypes in lateral root production responses to transient moisture stresses (Suralta et al., 2008b). Under transient stagnant to drought condition, the root trait that mainly determined the genotypic differences was the ability to maintain seminal root elongation and branching of lateral roots along seminal root axis, nodal root production and elongation. Under transient drought to stagnant condition, the differences were mainly determined by greater ability in maintaining seminal root elongation and nodal root production, which were exhibited by aerobic genotype. The seminal roots of aerobic genotypes had the ability to enhance root aerenchyma formation when subjected to stagnant condition while the irrigated lowland genotype completely lost such ability once droughted. Kasalath showed much greater ability in lateral root production under both transient moisture stresses than Nipponbare. This indicates the potential utilization of their CSSLs for precise identification of desirable root traits with reduced effects of genetic confounding (Suralta et al., 2008b).

Among the 54 CSSLs, Line 47 was identified to show no significant differences in shoot and root growth with the recurrent parent Nipponbare under non-stressed conditions but consistently exhibit greater lateral root production under both transient conditions. Using this line in comparison with Nipponbare, the key root traits observed with genetically diverse rice cultivars and the CSSL as shown above were confirmed to contribute to better adaptation through enhanced water uptake, stomatal conductance, photosynthesis and dry matter production when grown in soil with fluctuating moistures (Suralta et al., In press). Some of the traits were found to be common with those identified for aerobic and irrigated lowland genotypes grown under constant drought and waterlogged conditions (Suralta and Yamauchi, 2008).

The selected CSSLs under constant drought and transient moisture stresses are being used for further production of near isogenic lines on the QTLs to examine quantitatively the physiological function of the root plasticity for plant adaptation under constant drought and transient moisture stresses as well as its genetic regulation.

Conclusion

Roots undoubtedly play one of the key roles for crop plants to grow and adapt to environments with abiotic stresses such as water stress. It is primarily important to characterize to understand the environment and the nature of the stresses of the target area so that desirable traits required for the growth and adaptation can be specifically identified. One typical example is the difference between simple drought and soil moisture fluctuations under various rice production ecosystem. One of the key traits we have so far identified is the developmental plasticity of root system. We still need to accumulate direct evidence on roles of root plasticity in whole plant growth by producing near isogenic line, chromosome segment substitution line, which can also be useful for QTL analysis. For developing varieties that can be practically grown in the field, evaluation on genotypes (QTL) x environmental interaction is essential in the target ecosystems.

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Roles of roots in relation to water stress tolerance of crop

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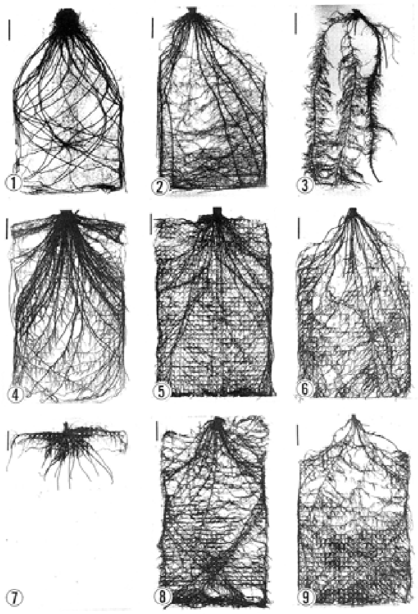
Characteristics of crop-grown fields

Heterogeneity

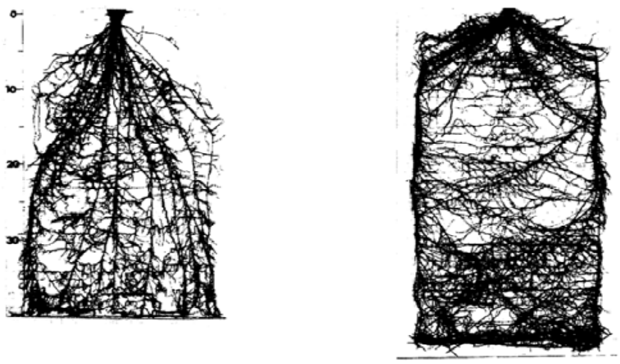
- in space
  - resource distribution
- in time
  - moisture fluctuation

Soil moisture and root system development



Source:
Galamay et al. 1992.
Jpn. J. Crop Sci. 61:494-502.

Root system structure of rice and maize



	Rice	Maize
NRNo.	29	17
TRNo.	42423	11645
TRL	177.8	130.1
TRSA	0.058	0.122

Fig. 3. Root system of 30-day-old rice (concentrated-type) and maize (scattered-type). The root systems were sampled and photographed using the root-box pin-board method. Scale is in centimeter. Here, NRNo. is nodal roots number; TRNo., total root number (including lateral roots of different orders); TRL, total root length (m); TRSA, total root surface area (m^2) (Yamauchi et al. 1987a and b).

Source:
Yamauchi et al. 1987.
Jpn. J. Crop Sci. 56:608-617;
Yamauchi et al. 1987.
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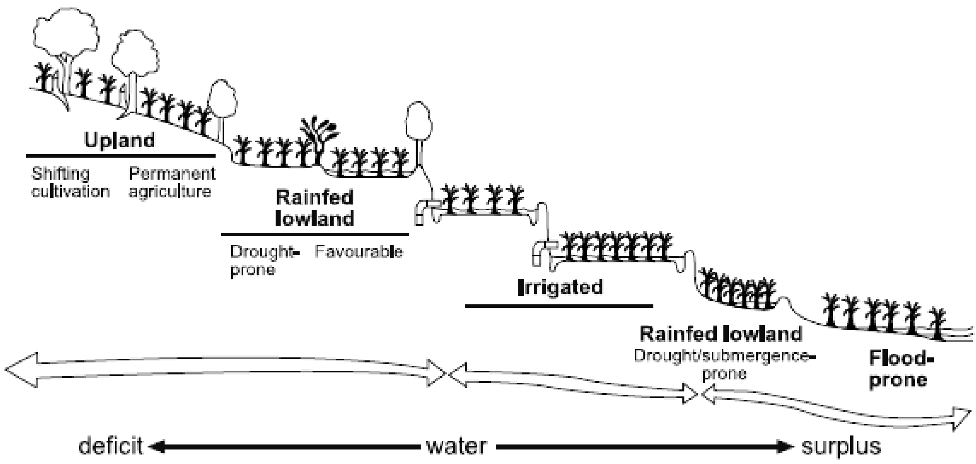
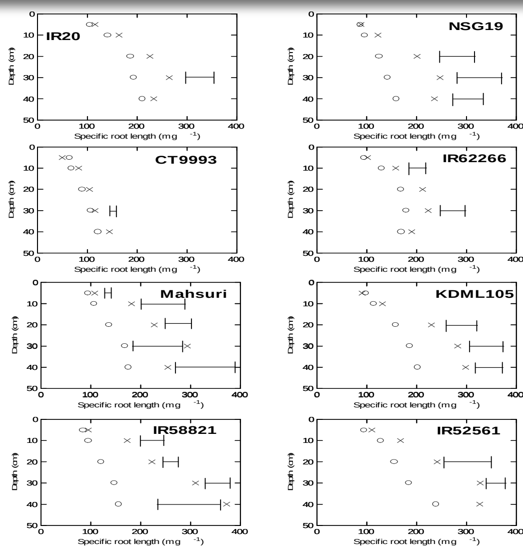
Characteristics of rice ecosystem



Rice roots response to soil moisture fluctuation



Source: Azhiri-Sigari et al. 2000. Plant Prod. Sci. 3, 180-188.

Soil moisture fluctuations and root elongation

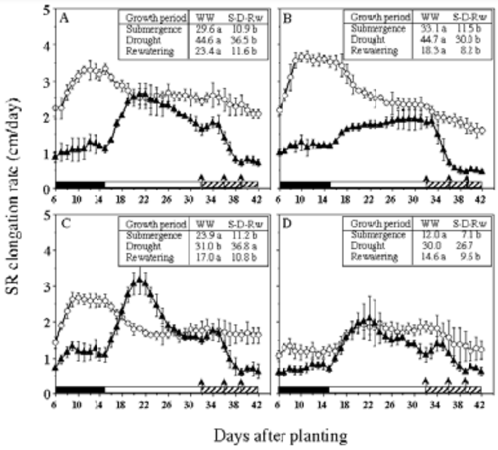


Fig. 2. Daily seminal root elongation rate of four rice cultivars, IRAT109 (A), Dular (B), KDML105 (C), and Honenwase (D) under well-watered (WW) and soil submerged-droughted-rewatered (S-D-Rw) conditions in Exp. 2.

Numbers inside the graph indicate the SR length (cm) in each growth period; drought and rewatering periods under WW and D-Rw conditions. Arrows indicate the time of rewatering was administered. Columns denote mean and standard deviation of three replicates. SR length values with different letters are not significantly different at 5% level of significance based on Duncan Multiple Range Test.

Symbols : (—○—) well-watered conditions, (—▲—) submerged-droughted-rewatered conditions, (■) soil submergence period, (□) drought period and (▨) rewatering period.

Source:
Bañoc et al. 2000.
Plant Prod. Sci. 3 (2): 197-207.

Soil moisture fluctuation and lateral root development

Table 4. Branching density of lateral roots in four rice cultivars grown under well-watered and soil submerged-droughted-rewatered conditions (Exp. 2).

Cultivars/	Growth Period								
Growing	Soil Submergence			Drought			Rewatering		
Conditions/	Branching Density of 1OLRs			Branching Density of 1OLRs			Branching Density of 1OLRs		
% of Control	Total (cm-1)	L-type (cm-1)	S-type (cm-1)	Total (cm-1)	L-type (cm-1)	S-type (cm-1)	Total (cm-1)	L-type (cm-1)	S-type (cm-1)
IRAT109:									
WW	13.1	3.6	9.5	12.4	3.4	9	12.9	3.5 a	9.4 b
S-D-Rw	14.3	3.2	11.1	13.5	2.9	10.6	14.7	1.4 b	13.3 a
% of Control	109.2 ns	88.9 ns	116.8 ns	108.9 ns	85.3 ns	117.8 ns	114.0 ns	40.0*	141.5*
Dular:									
WW	16	4	12	13.2	2.2	11	8.3 b	0.64 b	7.7 b
S-D-Rw	17.2	3.2	14	14.7	1.8	12.9	19.7 a	1.6 a	18.1 a
% of Control	107.5 ns	80.0 ns	116.7 ns	111.4 ns	81.8 ns	117.3 ns	237.3*	250.0**	235.1**
KDML105:									
WW	13.8 b	2.6	11.2 b	10.3	1.1 b	9.2	9.8	0.33 b	9.5
S-D-Rw	18.5 a	2.7	15.8 a	10.3	2.5 a	7.8	10.7	1.3 a	9.4
% of Control	134.0*	103.8 ns	141.1*	100.0 ns	227.3**	84.8 ns	109.2 ns	393.9**	98.9 ns
Honenwase:									
WW	15.6	3.0 b	12.6	14.5	2.6 a	11.9	8.9 b	0.62 b	8.3 b
S-D-Rw	17.2	4.4 a	12.8	11.2	1.6 b	9.6	14.0 a	1.7 a	12.3 a
% of Control	110.2 ns	146.7*	101.6 ns	77.2 ns	61.5*	80.7 ns	157.3*	274.2**	148.2*

For abbreviations, legend and statistical significance, see Tables 1 and 3 for details.

Source:Bañoc et al. 2000. Plant Prod. Sci. 3(3): 335-343.

Phenotypic Plasticity; dynamic aspects of root system sturucture

Ability of a genotype to alter phenotype in response to environment

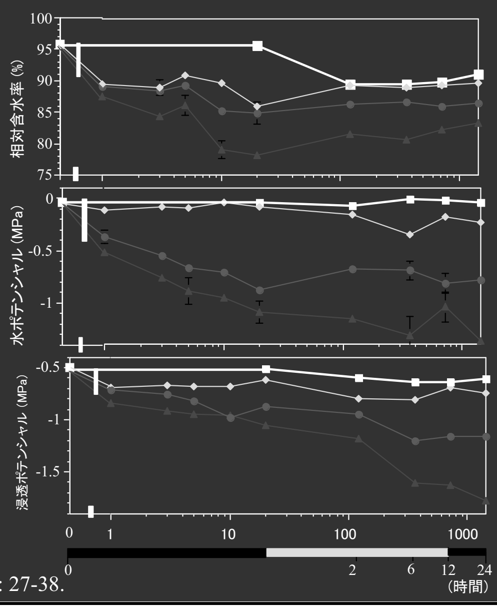
- Soil moisture → lack, excess, fluctuate
- Soil temperature
- Chemical substances
- Nutrient distribution
- Microorganism

Root osmotic adjustment 1

Water relation of elongation portions of seminal root (maize)

Water potential of medium

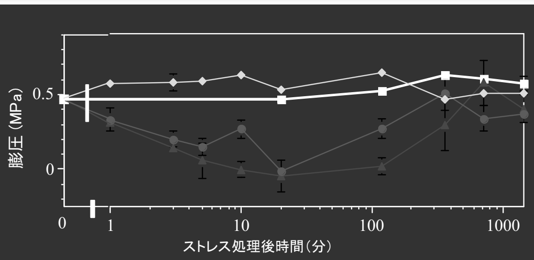
- -0.08MPa
- -0.13MPa
- -0.41MPa
- -0.89MPa



Source: Ogawa and Yamauchi 2006 Plant Prod. Sci. 9 (1): 27-38.

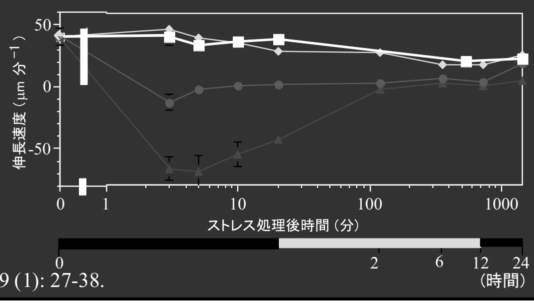
Root osmotic adjustment 2

Change in turgor in relation to root elongation



Water potential of medium

- -0.08MPa
- -0.13MPa
- -0.41MPa
- -0.89MPa



Source: Ogawa and Yamauchi 2006 Plant Prod. Sci. 9 (1): 27-38.

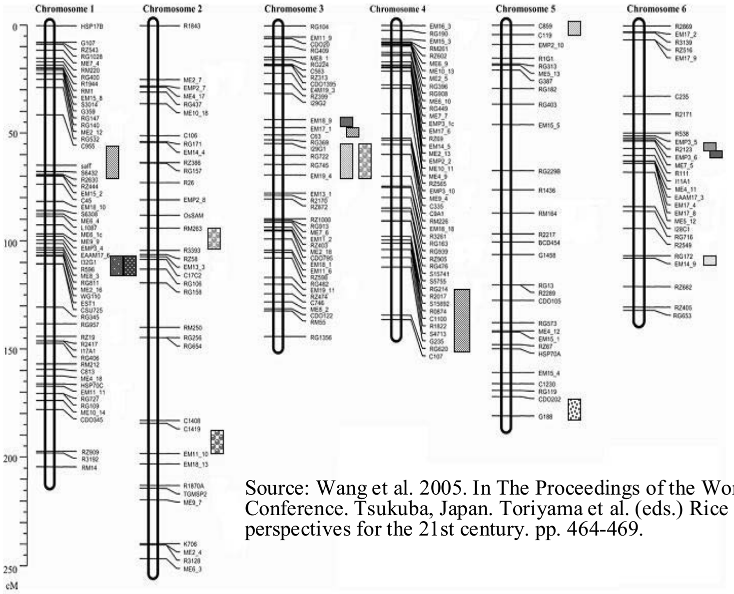
CT9993 vs IR62266

CT9993:
- Japonica, early maturity
- Avoidance strategy/responsive
- Relies on extraction of more water
- Capacity to penetrate the hardpan
- Capacity to elongate roots at depth
- Weak root signal in stress
- QTLs for deep thick roots
- Leaf proteins increase in abundance under stress
- Specific adaptation to some drought conditions

IR62266:
- Indica, early maturity
- Tolerance strategy/stable
- Relies on regulation of water loss
- Osmotic adjustment ability
- Stomatal conductance regulation
- Strong root signal in stress
- QTLs for osmotic adjustment
- Leaf proteins decrease in abundance under stress
- General adaptation over environments with stable yields

Source: Siopongco et al. 2006. Plant Prod. Sci. 9 (2): 141-151.

Genetic background for plasticity *(QTL)*



Source: Wang et al. 2005. In The Proceedings of the World Rice Research Conference. Tsukuba, Japan. Toriyama et al. (eds.) Rice is life: scientific perspectives for the 21st century. pp. 464-469.

QTL identified for root plasticity traits

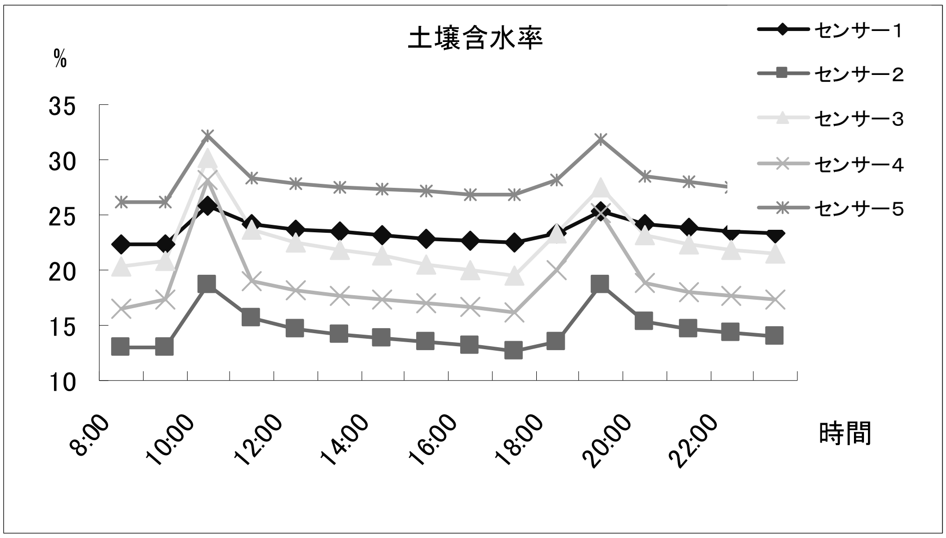
- **ALLL: Average L type lateral root length under well-watered condition**
- **TLLL: Total L type lateral root length under well-watered condition**
- **LLLL: The longest L type lateral root length under well-watered condition**
- **TLLL: The longest L type lateral root length under water stress condition**
- **AMLL: Average M type lateral root length under well-watered condition**
- **AMLL: Average M type lateral root length under water stress condition**
- **TMLL: Total M type lateral root length under well-watered condition**
- **TMLL: Total M type lateral root length under water stress condition**
- **LMLL: The longest M type lateral root length under well- watered condition**
- **SMLL: The shortest M type lateral root length under water stress condition**

- **LN: The lateral root number per cm seminal root axis under well-watered condition**
- **LN: The lateral root number per cm seminal root axis under water stress condition**
- **LLN: The L type lateral root number per cm seminal root axis under well-watered condition**
- **MLN: The M type lateral root number per cm seminal root axis under well-watered condition**
- **SLN: The S type lateral root number per cm seminal root axis under water stress condition**

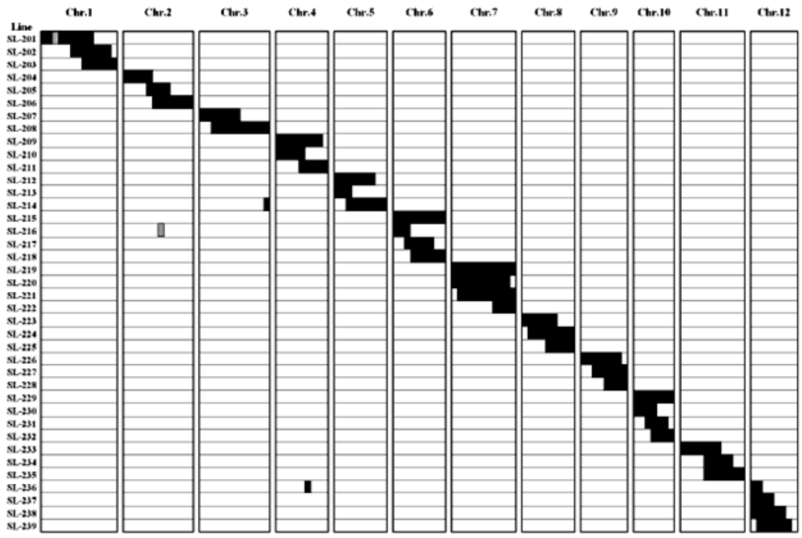
Soil moisture graduation

- Functional significance of plasticity
- Control and stress?

Soil moisture fluctuation



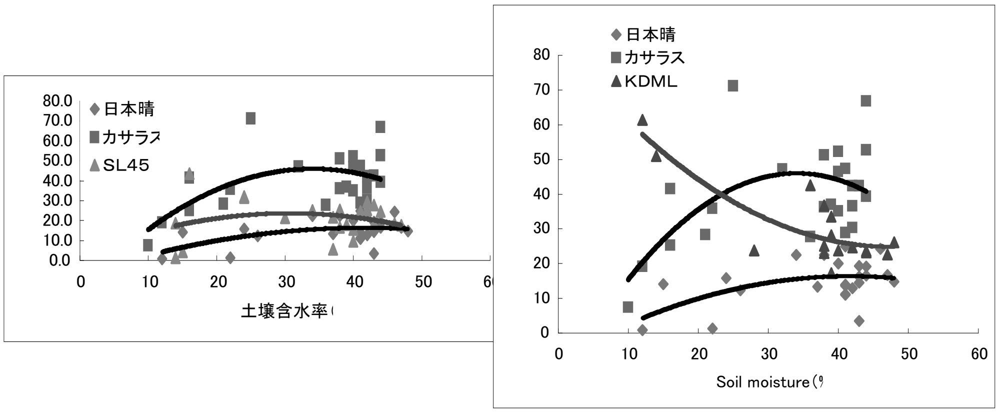
Chromosome segment substitution lines for rice



Source: Rice Genome Resource Center, National Institute of Bioagricultural Science

Kasalath and KDML 105

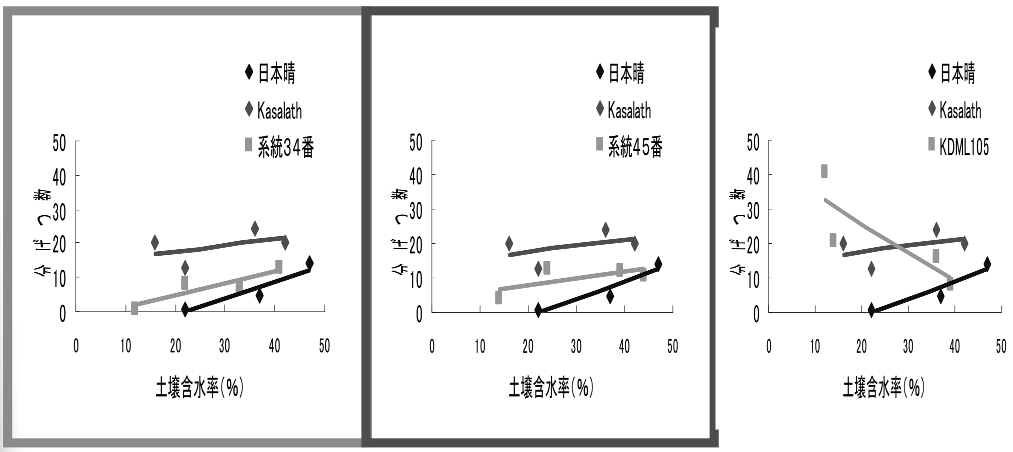
Dry matter production under soil moisture gradient



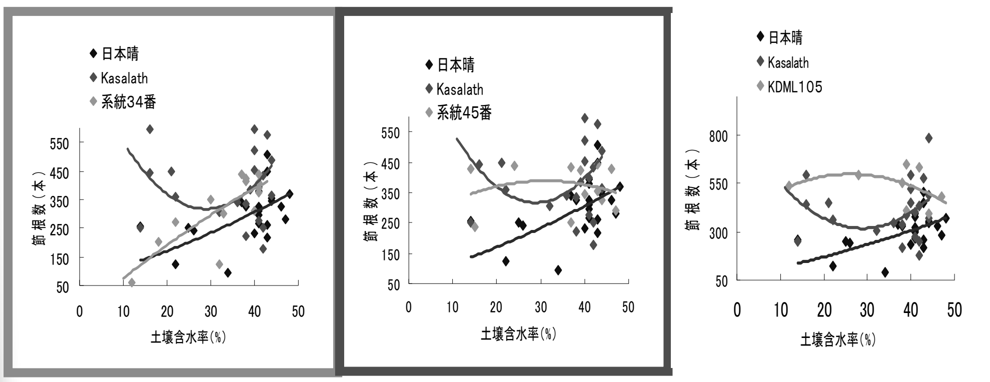
Screening the lines that clearly differ from Nipponbaqre

Source: Kanou et al. 2007. In the Proceedings of The 2nd International Conference on Rice for the Future, 5-9 November 2007, Bangkok, Thailand. pp. 216-220.

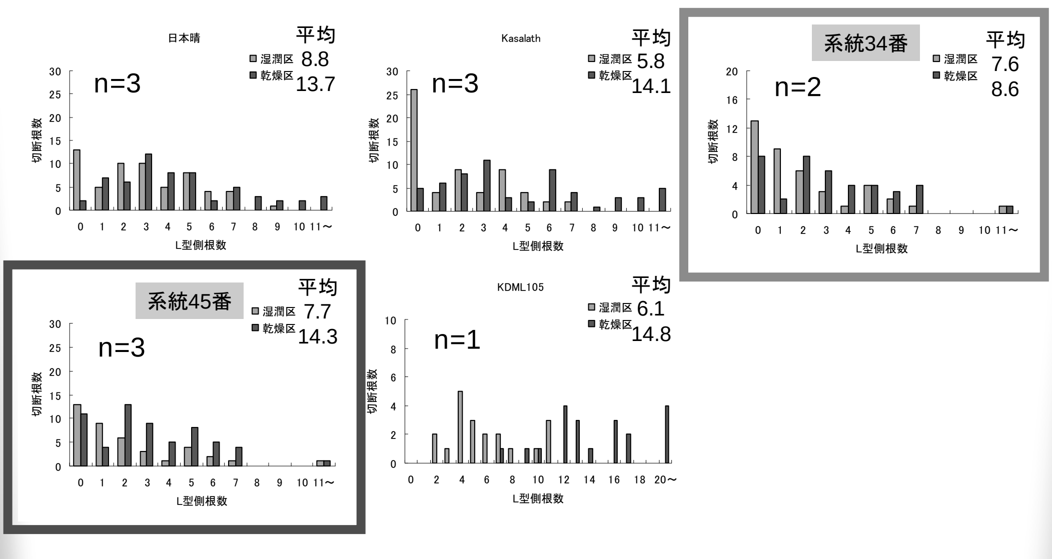
Tillering under soil moisture gradient



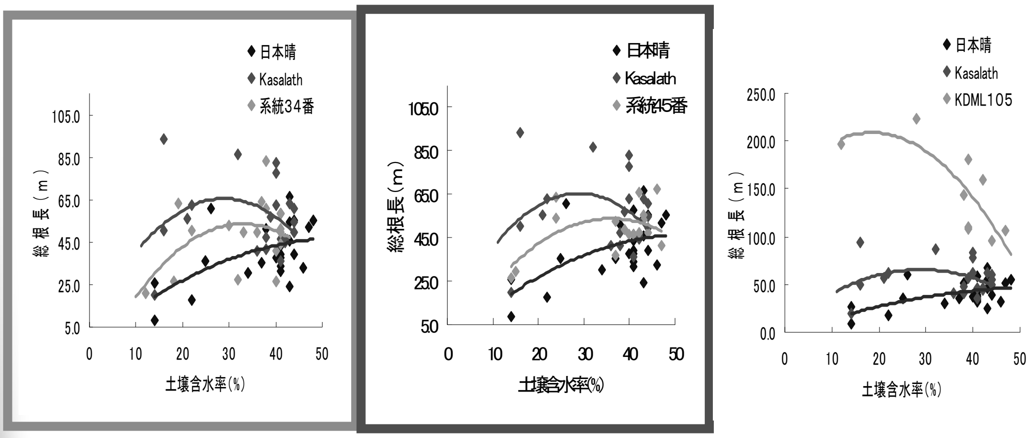
Rooting under soil moisture gradient



Branching under soil moisture gradient



Root system development under soil moisture gradient



Water requirement by rice production

- 3,000 to 5,000 liters of water to produce 1 kg of rice grains
- 2 to 3 times more water than to produce 1 kg of wheat or maize grains.

Water saving rice production

- **Saturated soil culture (SSC)**

  Soil is kept as close to saturation as possible by shallow irrigation to obtain about 1-cm floodwater depth a day after the disappearance of standing water

- **Alternate wetting and drying (AWD) system**

  Irrigation water is applied to obtain 2-5 cm floodwater depth after a certain number of days (ranging 2-7 days)

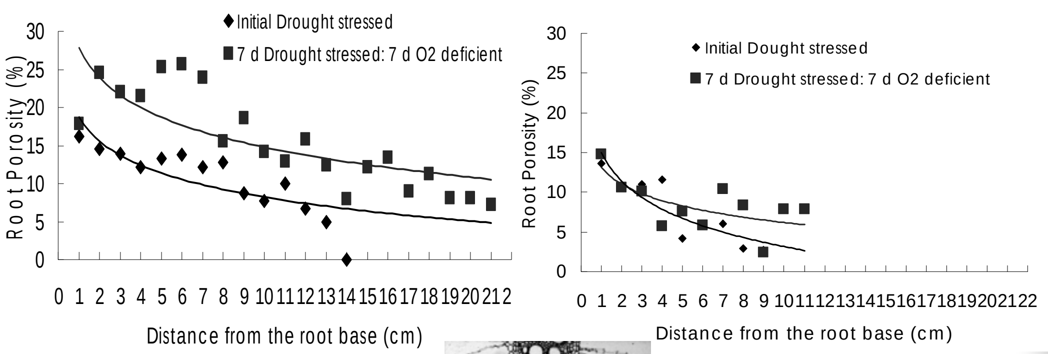
- **Thin-water-layer irrigation and draining depending on the development of rice**

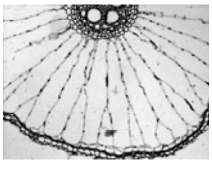
  A thin standing water layer exists throughout the growing season, except for transplanting, end of effective tillering, and at heading (flowering) stage

- **Aerobic rice**

  To grow rice like an **irrigated upland crop** such as wheat or maize , that is on non-puddled, aerobic soil without standing water

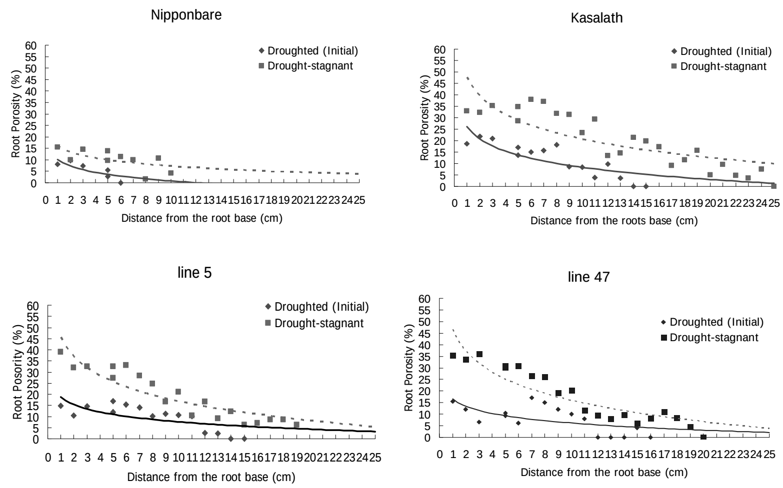
Aerenchyma development under soil moisture fluctuations





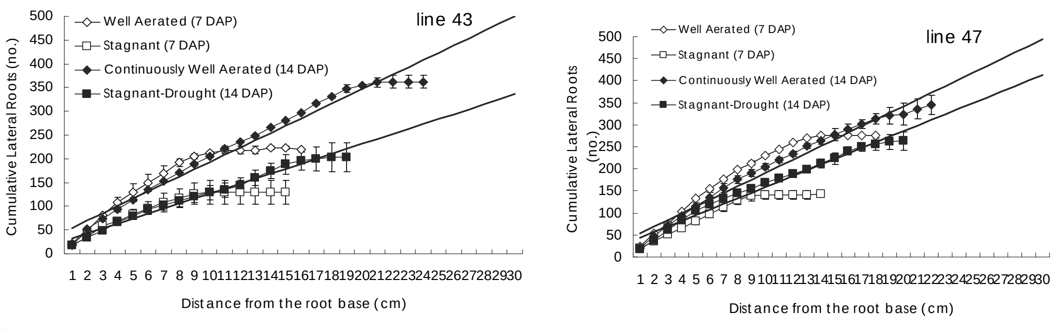
Source:
Suralta and Yamauchi 2008.
Environ Exp Bot 64:75–82.

Aerenchyma development: genotypic difference



Root porosity along seminal root axis selected lines and parents under transient drought stressed-stagnant conditions.

Lateral root development

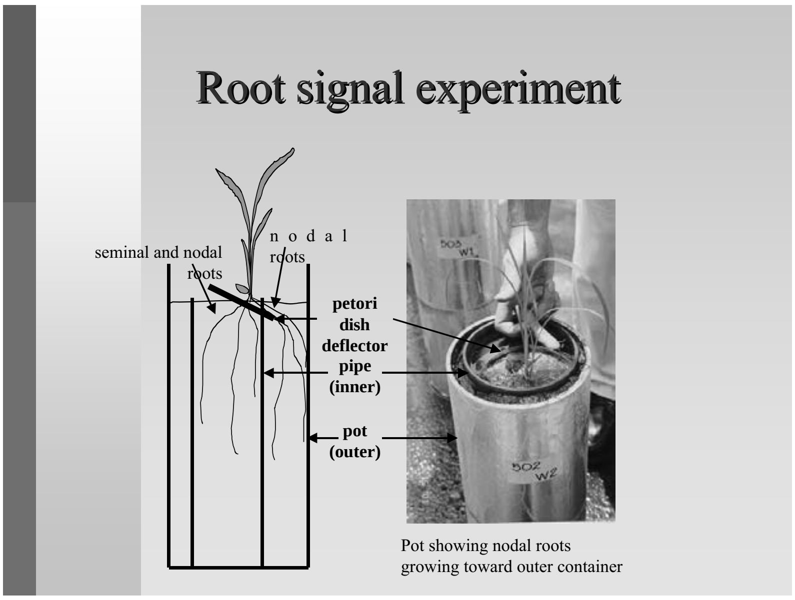


Lateral root development along seminal root axis of selected lines and parents under transient stagnant-drought stressed conditions.

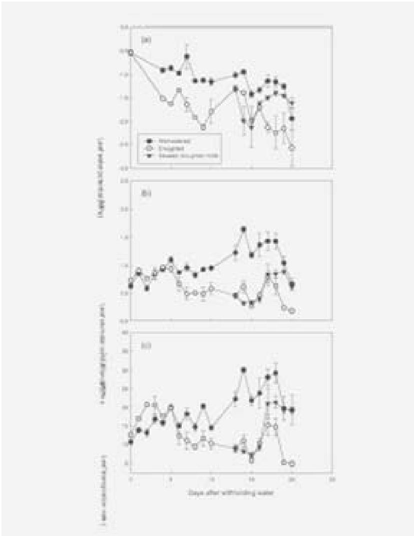
Source: Suralta et al. 2008. Plant Prod. Sci. 11: 457-465.

Experiment on drought responses at IRRI

Soil heterogeneity-root signal



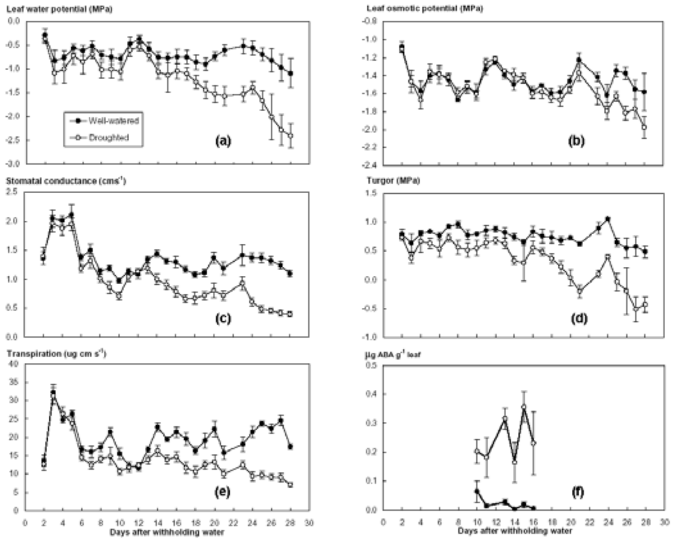
Stomatal response to soil drought



Source:
Siopongco et al. 2008.
Plant Prod. Sci. 11: 28-41.

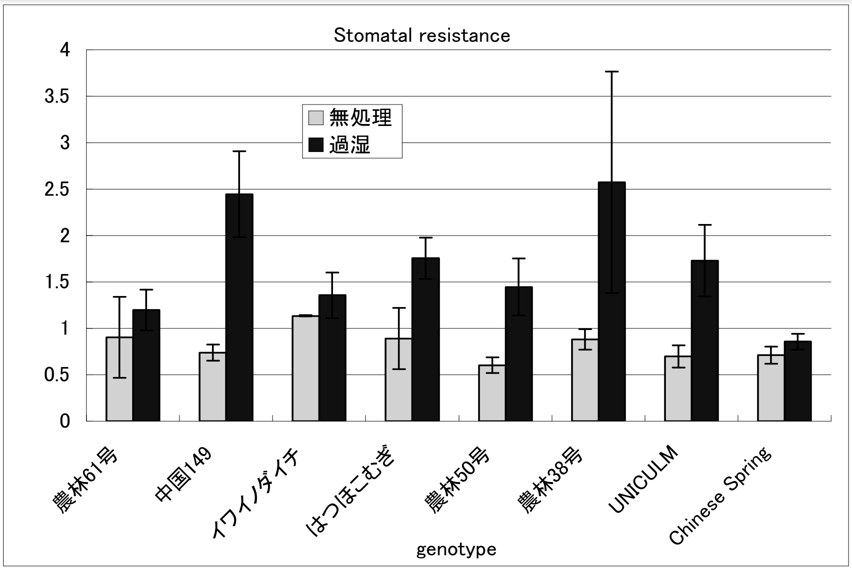
Confirmation by field experiment

Root signal



Source: Siopongco et al. 2009. Plant Prod. Sci. 12 (1): 17-28.

Stomatal response to waterlogging in wheat



Source: Okada et al. 2007 Root Research 16(4):191

Further research 1

- Direct evidence on roles of root plasticity in whole plant growth
  →Near isogenic line, chromosome substitution lines
- QTL analysis on root plasticity
- Gene identification

Further research 2

- Understanding of ecosystem and environment of target area
  →production and environment What is the real issue?
- Strengthening of stress tolerance
  →Traits directly involved?
  →Production and survival
- Towards production technology and genetic improvement
  → ecophysiology to molecular breeding

質疑応答
Question and Answer Session

根からみた作物の水ストレス耐性
Role of Roots in Relation to Water Stress Tolerance of Crop

山内　章　Akira Yamauchi
名古屋大学農学国際教育協力研究センター
Professor, Graduate School of Bioagricultural Sciences, Nagoya University

司会：浅沼　修一　Chair person: Shuichi Asanuma
名古屋大学農学国際教育協力研究センター
Professor, ICCAE, Nagoya University

Asanuma, Chair:

Thank you very much Professor Yamauchi.　It is very fresh idea to me that not only continuous drought is important but further important is fluctuation of soil moisture condition between drought and water stress, and response of plant roots to the fluctuated moisture conditions.

Do you have any questions?

Koyama:

My name is Koyama from JIRCAS.　You showed us about the water requirements.　That of rice is higher, two or three times higher, than maize.　I think it's O.K., but does that mean rice is not suitable for dry areas?　If it's not really suitable, we should not promote it in those areas.　What is the base of this calculation?　Is this based on the normal practice, or?

Yamauchi:

This value was cited from the work of the International Rice Research Institute. This one, the water requirement of rice includes the evaporation from the paddy rice field and the seepage of water to the deeper soil.　This calculation is based on the irrigated rice production with continuously flooded conditions that we normally know especially in this country, Japan.　We also have the data for maize that of course are grown under upland conditions with sufficient irrigation for comparison. Several years ago, I also tried to compare the water requirement and water use efficiency that is the dry matter production ability per unit amount of water used. And the rice was among all the cereal crops examined weakest to water shortage. It requires water most among the major cereal species examined.

There is a very serious conflict of water usage for rice in industrial sectors and agriculture, and it is now happening especially in China and other developing countries.　So, we really have to try to reduce the water use.　So, instead of continuous flooding conditions, alternative technologies that can reduce water use are being produced as we may not need continuous flooded conditions for rice production.　Results of long-time experiment show that we can not avoid yield penalty under wet-and-dry cycle conditions, which most of the water-saving technologies so far proposed contain.　So, we're trying to find mechanisms as to why the rice suffers from the yield penalty under the alternative wet-and-dry irrigation system.

Asanuma, Chair:

Any other questions? Professor Yamauchi, do you have any data or idea about the difference in water requirements between upland rice and maize? We are now talking about continuous flooded conditions that water requirement of rice may be four or five times higher than maize. But when water requirements are compared between upland rice and maize, which requires more?

Yamauchi:

Though I do not have data available for the comparison at the moment, I do not think they are much different if grown under the same upland field conditions. Dr. Onyango, do you have any idea which produces more dry matter and requires more water?

Asanuma, Chair:

We ICCAE invited a researcher from KARI Kibos of Kenya early this year who told us that during the drought conditions of the last year, the upland rice NERICA grew better than the maize. She said, "I would think maybe the NERICA rice is more tolerant to the fluctuation of soil moisture conditions, and of course it depends on the rainfall time of the regions".

Onyango:

I think from Professor Asanuma's statement, some information was not provided for the KARI Kibos statement on NERICA water requirement. The trial was during the short rain season and the rainfall was erratic. However, there was heavy rainfall for about one week which flooded the fields. During the floods, maize was affected more than rice and as a result the production of maize was reduced more than rice. Genotypically even upland rice will recover faster than maize from the anoxia conditions imposed by short duration of flooding. Generally rice is relatively heavy feeder in terms of water requirements.

Asanuma, Chair:

Thank you very much for your correction. If there is no other question, let me close this session. Thank you very much, Professor Yamauchi.

Profile

山内 章 **Akira Yamauchi**

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1987年名古屋大学大学院農学研究科博士課程満期退学。1988年名古屋大学より農学博士学位。1988年9月からテキサス工科大学農学部、続いてテキサス農工大学ブラックランド研究所にてポストドクトラルフェローとして、作物根の水吸収メカニズム、可塑性の研究に従事。1990年から名古屋大学農学部で作物学の助手、1992年から助教授、1999年から循環資源学教授、2007年から名古屋大学農学国際教育協力研究センター長に就任し、現在に至る。

この間一貫して、ストレス生理学、ならびに作物根の発育や機能を生理生態学的、さらには遺伝学的側面から明らかにする研究に従事してきた。また、レイテ州立大学（フィリピン）、国際イネ研究所などと共同研究を展開してきた。専門分野は作物生理生態学。

Academic career

Professor Yamauchi received Ph.D. in 1988 from Graduate School of Agricultural Sciences, Nagoya University.

Professional career

Professor Akira Yamauchi joined Texas Tech University as a post-doctoral research scientist, and Blackland Research Center of Texas A & M University, where he studied water uptake mechanism of plant root.

Professor Yamauchi started to work for School of Agricultural Sciences, Nagoya University as an assistant professor in 1990 and an associate professor in 1994 for crop science. His research work has been mainly on crop stress physiology and root system development and functions from physiological, ecological and genetic aspects in collaboration with other institutes such as Leyte State University (Philippines) and International Rice Research Institute. Since 1999, he has been working as Professor, the Division of Biosphere Resources Cycling, Nagoya University, and Director of International Cooperation Center for Agricultural Education, Nagoya University since 2007.

わが国のこれまで 77 年にわたる陸稲育種研究の成果
Achievements of Upland Rice Breeding in Japan in the Past 77 Years

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独立行政法人　農業・食品産業技術総合研究機構　作物研究所
National Institute of Crop Science
National Agriculture and Food Research Organization (NARO), Japan

要　約

わが国における陸稲育種研究は，食糧自給率の向上を目的として 1929 年に農林省が全国の 5 ヵ所（秋田，茨城，三重，鳥取，鹿児島）に陸稲育種指定試験地を設置したことに始まる。戦後の組織再編以降は，茨城県農業総合センターが唯一の指定試験地として品種育成を担ってきたが，作付面積の減少等の理由から 2005 年度で終了した。この 77 年の間に 61 品種が育成されている。

この間の研究内容および成果は時代背景ごとに大きく分けると以下のとおりである。

1929-1950

食糧の増産が強く求められた時期である。とくに開拓地では，陸稲は経営が安定するまでの欠かせない食糧として重視された。品種育成は，耐干性の向上と多収性を目標として推進され，この結果，短強稈で栽培しやすく，当時としては良食味の「農林 12 号」や多収品種「農林糯 26 号」等が育成された。また，播種期や栽植密度，敷わら効果等の陸稲栽培に関する基本的な研究やカリ欠乏土壌やリン酸欠乏土壌等の開拓地で栽培するための品種比較試験が行われた。

1951-1970

引き続き食糧の増産が求められる中で，畑地かんがい設備が整備され始めた。水稲品種ではいもち病の多発等のため，畑かん栽培への転用が困難なことから，畑地かんがいを前提とした専用品種の育成が目標とされ，主に水稲と陸稲との交配により品種育成が進められた。この結果，強稈・多収品種「オカミノリ」（農林 24 号×水稲農林 29 号），良質・多収品種「ミズハタモチ」（越路早生×ハタコガネモチ）等が育成された。また，かん水栽培法や陸稲の麦間栽培法に関する研究が多くなされた。

1971-1988

米の生産調整が開始される中で，陸稲は野菜の連作障害を緩和する効果があることから，クリーニングクロップとして野菜作の輪作体系に取り入れられ始めた。このため，野菜作との組合せが容易で干ばつ回避効果も期待される早生品種の育成が主目標とされ，早生熟期「トヨハタモチ」や「キヨハタモチ」が育成された。また，陸稲により連作障害が緩和される仕組みに関する研究や外国陸稲の耐干性（深根性）の評価と交配母本としての利用，ハウスを利用した独自の耐干性検定方法の開発が進められた。

1989-2005

野菜作を中心とする畑作経営が一段と集約化する中で，野菜作との組合せがより容易な極早生熟期で，安定生産が可能となる高度耐干性品種の育成を目標として品種育成が推進された。この結果，まず，外国陸稲「JC81」に由来する深根性を導入した中生・高度耐干性品種「ゆめのはたもち」が育成され，次に「ゆめのはたもち」の耐干性と「関東糯 166 号」の早生・耐冷性を集積することに成功した早生・安定多収品種「ひたちはたもち」が育成された。また，陸稲需要の拡大を図るための加工特性に関する研究やイネゲノム研究の進展にあわせて陸稲を遺伝資源として利用し，陸稲の有する新規いもち病圃場抵抗性遺伝子を水稲へ導入する研究が進められた。

本発表では、主として演者らがこれまでに行ってきた研究成果をたどりながら、土壌環境の中で、とくに、土壌水分を中心にその作物根の発育や機能に及ぼす影響を、可塑性をキーワードに考えてみたい。

Achievements of Upland Rice Breeding in Japan in the Past 77 Years

Takuro Ishii
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National Agriculture and Food Research Organization (NARO), Japan

Abstract

In 1929, the government breeding program began upland rice breeding research at five breeding stations (Akita, Ibaraki, Mie, Tottori and Kagoshima). Though only Ibaraki Agricultural Center continued upland rice breeding after the post war reorganization, upland rice breeding ended in March 2006 because of a sharp decrease in cultivation area. Sixty-one varieties were bred from 1929 to 2006. Many studies had been carried out on drought resistance and other similar conditions.

The achievements of upland rice breeding in each time period are as follows:

1929-1950

The increase of crop production was strongly requested. Upland rice played an important role until farming managements stabilized particularly at reclaimed field. The breeding objectives in this period were mainly high yielding and drought resistance. As a result “Norin 12” which is a high yielding variety with relative short culm and “Norinmochi 26” which is a high yielding glutinous variety and others were released. There were also discussions on basic cultivation studies such as sowing time, sowing quantity and straw mulch effect as well as a variety of screening tests for reclaimed fields suffering from potassium and/or phosphorus deficiency.

1951-1970

The field irrigation systems began to be equipped in upland field, while the increase of crop production was still requested. As the paddy rice was not suitable for upland cultivation due to damage from blast disease, the specific varieties were requested for the cultivation at upland fields with irrigation systems. Therefore breeding was mainly promoted by a cross between paddy rice and upland rice. As a result high yielding varieties such as “Okaminori”, “Mizuhatamochi” and others were released. Additionally many studies on the cultivation methods using field irrigation and cropping systems with wheat or barley cultivation were carried out.

1971-1988

When the overproduction of paddy rice became a serious issue, upland rice began to be used as a rotation crop because it had an effect on the decrease in continuous cropping injury of vegetables. Thus, the breeding of early maturing varieties which made the rotation with vegetable cultivation efficient and were expected to have the effect on drought escape was promoted. As a result early maturing varieties such as “Toyohatamochi” and “Kiyohatamochi” were released and evaluations of deep rooting of foreign upland rice cultivars as well as their utilization as breeding materials were conducted. The greenhouse method for evaluation of drought resistance was also originally exploited.

1989-2005

As vegetable cultivation became more intensive, the very early maturing varieties with high drought resistance were requested for the stable management of crop rotation. As a result, first medium maturing variety “Yumenohatamochi” with deep rooting which was derived from foreign upland cultivar “JC81” was released. Then a very early maturing and stably high yielding variety “Hitachihatamochi” which had the drought resistance acquired from “Yumenohatamochi” and very early maturation and cold tolerance acquired from “Kantomochi 166” was released. Additionally, studies on the processing suitability for the promotion of upland rice consumption were discussed.

Based on the idea of using upland rice as a genetic resource, the introgression of blast resistance genes from upland rice into several types of paddy rice by using DNA markers was also promoted.

In 1929, the governmental breeding program began upland rice breeding research at five breeding stations (Akita, Ibaraki, Mie, Tottori and Kagoshima). Though only the Ibaraki Agricultural Center continued upland rice breeding after the post-war reorganization, upland rice breeding ended in March 2006 because of a sharp decrease in cultivation area. Sixty-one varieties were bred from 1929 to 2006.

In this article, first, I outline the achievements of upland rice breeding on the basis of historical background, then, I focus on the drought resistant breeding which had been carried out consistently during this period mainly based on the results of Ibaraki Agr. Center.

1. Transition of acreage and yield of upland rice

Fig. 1 shows the transition of cultivation area and yield per hectare of upland rice in Japan after 1900. Upland rice was an important crop for staple food until 1960's. The cultivation of upland rice was encouraged for a production increase of rice after World War II. The largest cultivation area of upland rice was 180,000 hectares in 1960. However its cultivation was dramatically decreased under the overproduction of paddy rice. At present, the yield is about 2.4 t/ha that is about half of paddy rice in Japan.

2. The achievements of upland rice breeding in each time period

1) I period (1929-1950)

The increase of crop production was strongly requested. Upland rice played an important role especially at reclaimed fields until farming managements stabilized. The breeding objectives in this period were mainly high yielding and drought resistance. As a result, "Norin No. 12" (1936) which is a high yielding variety with relative short culm and "Norinmochi No.26" (1947) which is a high yielding glutinous variety and others were released. There were also discussions on basic cultivation studies such as sowing time, sowing quantity and straw mulch effect as well as a variety of screening tests for reclaimed fields suffering from potassium and/or phosphorus deficiency.

2) II period (1951-1970)

The field irrigation systems began to be equipped in upland field, while the increase of crop production was still requested. As the paddy rice was not suitable for upland cultivation due to damage from blast disease, the specific varieties were requested for the cultivation at upland fields with irrigation systems. Therefore, breeding was mainly promoted by a cross between paddy rice and upland rice. as a result high-yielding variety

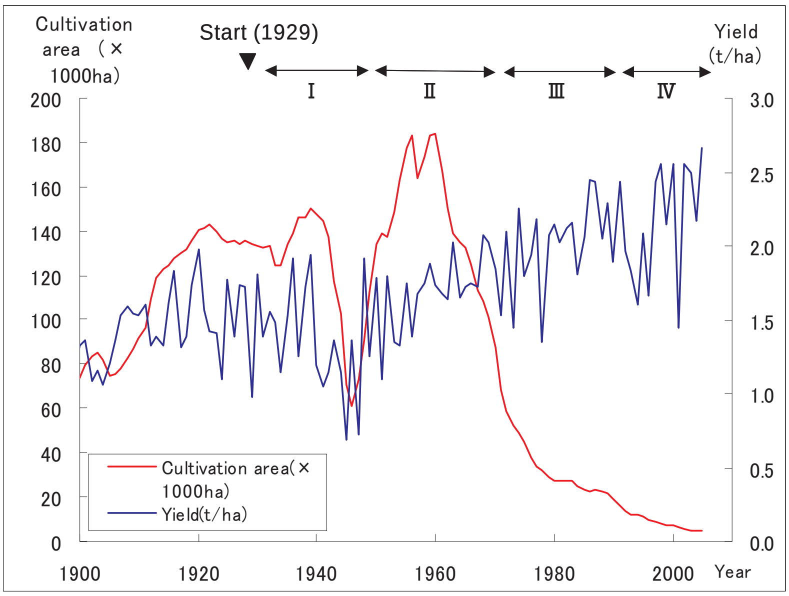


Fig. 1　Transition of cultivation area and yield per hectare of upland rice in Japan

"Okaminori" (1966), and high-yielding with good quality "Mizuhatamochi" (1969), *etc*. were released. “Okaminori” was bred from the cross between “Norin No.24” and paddy rice “Norin No.29”, and “Mizuhatamochi” was bred from the cross between paddy rice “Kosijiwase” and “Hatakoganemochi”. Additionally many studies on the cultivation methods using field irrigation and cropping systems with wheat or barley cultivation were carried out.

3) III period (1971-1988)

When the overproduction of paddy rice became a serious issue, upland rice began to be used as a rotation crop because it had an effect on the decrease in continuous cropping injury of vegetables (Fig. 2). Thus, the breeding of early maturing varieties which made the rotation with vegetable cultivation efficient and were expected to have the effect on drought escape was promoted. As a result early maturing varieties such as “Toyohatamochi” (1985) and “Kiyohatamochi” (1988) were released (explained later). Evaluations of deep rooting of foreign upland rice cultivars and their utilization as breeding materials were conducted. The greenhouse method for evaluation of drought resistance was also originally exploited (explained later).

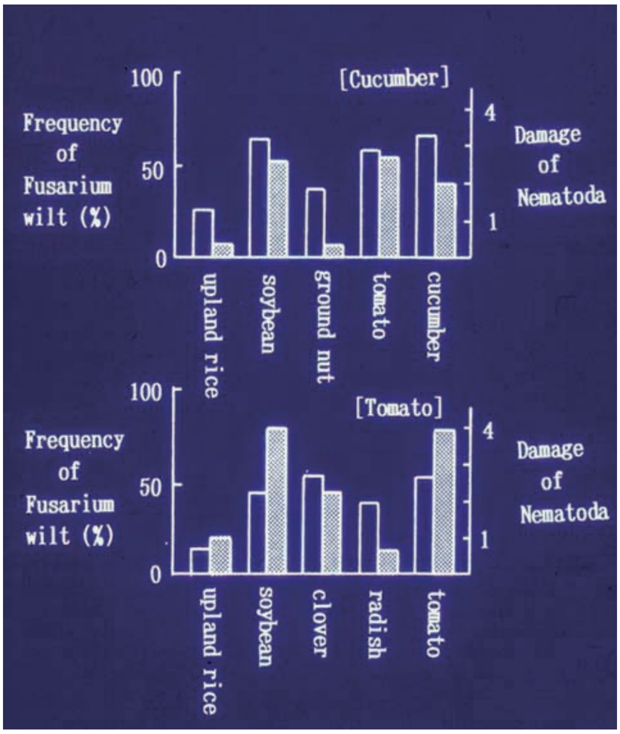


Fig. 2 Effectiveness of upland rice to control injuries of vegetables under continuous cropping (Matsuda 1974)

4) IV period (1989-2006)

As vegetable cultivation became more intensive, the very early maturing varieties with high drought resistance were requested for the stable management of crop rotation. As a result, medium maturing variety “Yumenohatamochi” (1996) with deep rooting which was derived from foreign upland cultivar “JC81” was released (explained later). Then a very early maturing and stably high yielding variety “Hitachihatamochi” (2005) which had the drought resistance acquired from “Yumenohatamochi” and very early maturation and cold tolerance acquired from “Kantomochi No.166” was released (explained later). Additionally, studies on the processing suitability for the promotion of upland rice consumption were discussed. Based on the idea of using upland rice as genetic resources, the introgression of blast resistance genes from upland rice into several types of paddy rice by using DNA markers was also promoted.

Breeding strategy to improve drought resistance in Japan

Two breeding strategies can be considered as the drought-resistance mechanisms of upland rice, "drought escape" and "physiological resistance" in Japan. We had been working to improve drought resistance by the following three steps; 1) breed early maturing varieties to avoid drought damage, 2) breed deep rooting varieties to develop physiological resistance, and 3) combine early maturation and deep rooting.

1) Early maturation

In Japan, rainy season is from early June to late July. After this period, season enters summer and drought damage becomes serious. The reproductive stage is the most susceptible for drought. Thus it is possible to avoid drought damage if this stage can be shifted away from the period when the possibility of drought is high.

We bred an early maturing variety, “Toyohatamochi” in 1985. Its heading date is about two weeks earlier than that of “Tsukubahatamochi”, a medium maturing variety.

Photo 1 shows the upland rice field in August 1994 when there was a serious drought. “Tsukubahatamochi” (Photo 1, right), which heading date is in middle August, suffered serious damage. However, “Toyohatamochi”(Photo 1, left), which had already passed its heading stage in late July showed the growth condition that would bring a certain level of yield and this variety can be described as succeeding in avoiding the drought. As “Toyohatamochi” shows drought resistance, its cultivation area represents about 70% of the total acreage of upland rice now.

Photo 1　Upland rice after rainy season August.
Left half of photo is very early maturing variety “Toyohatamochi”, right is medium maturing “Tsukubahatamochi”.

Photo 2　Observation of root by the trench method

2) Deep rooting

The root distribution at lower soil is related to drought tolerance because deep rooting varieties can absorb much water from deep soil layer even in a year of drought and can thus minimize drought damage.

We used the trench method to evaluate root depth of local varieties including foreign varieties from South and Southeast Asia, China, Taiwan, Africa, USA, Europe, etc (Photo 2). In this method, a power shovel was used to dig a 60cm groove along the plant rows after harvesting, then distribution and quantity of roots at each soil depth were investigated directly.

As a result, we found some African, Indian and Chinese varieties having deeper roots than Japanese upland rice varieties. In particular, Jaypole collection No.81 (abbreviated as JC81), IR3646, IRAT10, IRAT109, IRAT110, and Nam Sugai 19 were among those with highly developed root systems (Nemoto *et al.* 1998) and these were crossed with Japanese upland rice varieties to obtain superior deep rooting varieties.

Backcrossing of “Norinmochi No.4”, a Japanese upland rice variety with “JC81”, a deep-rooting Indian variety was promoted. After continuous strain selection of the progenies of the cross by the trench method, we succeeded in breeding "Yumenohatamochi", a medium maturing variety with deep rooting in 1996 (Photo 3). The trench method is the reliable method as evaluation of drought resistance, but it needs much labor. Therefore, we developed a simple evaluation method of using test beds installed in a greenhouse (Photo 4). The process of evaluation of drought resistance is as follows (Suga *et al*.)

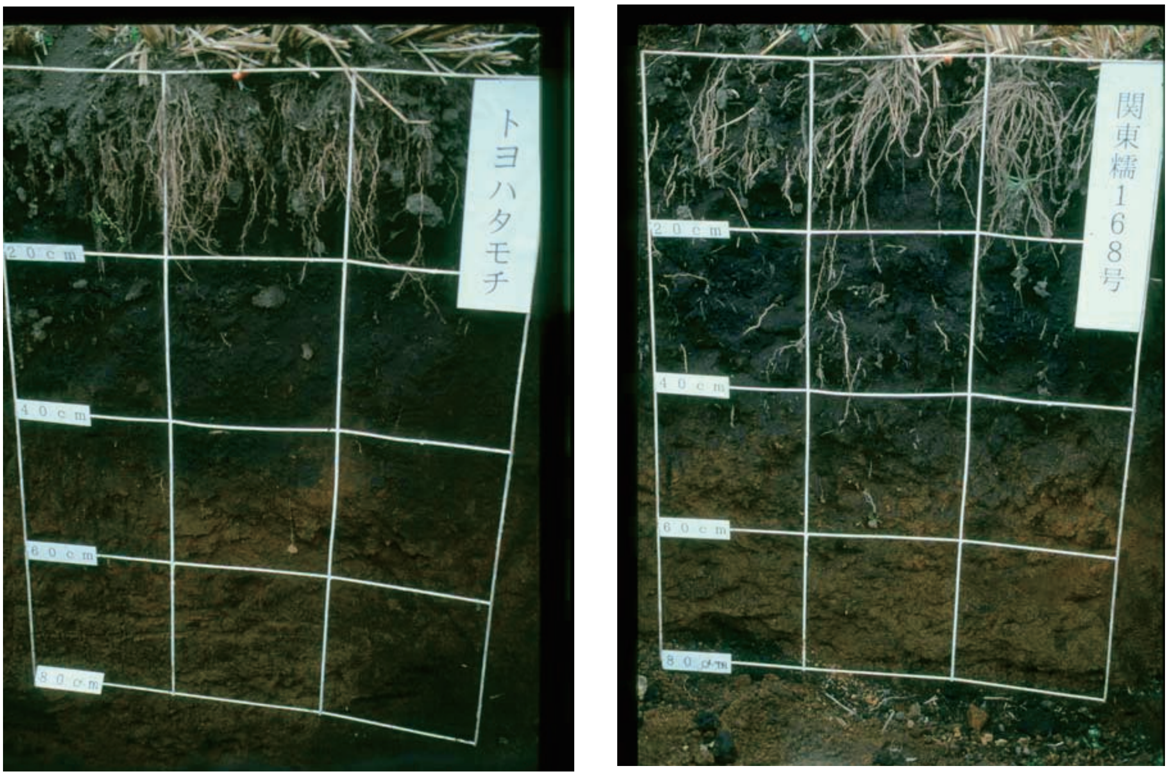


Photo 3 Comparison of root distribution of “Toyohatamochi” (left) and Yumenohatamochi (right)

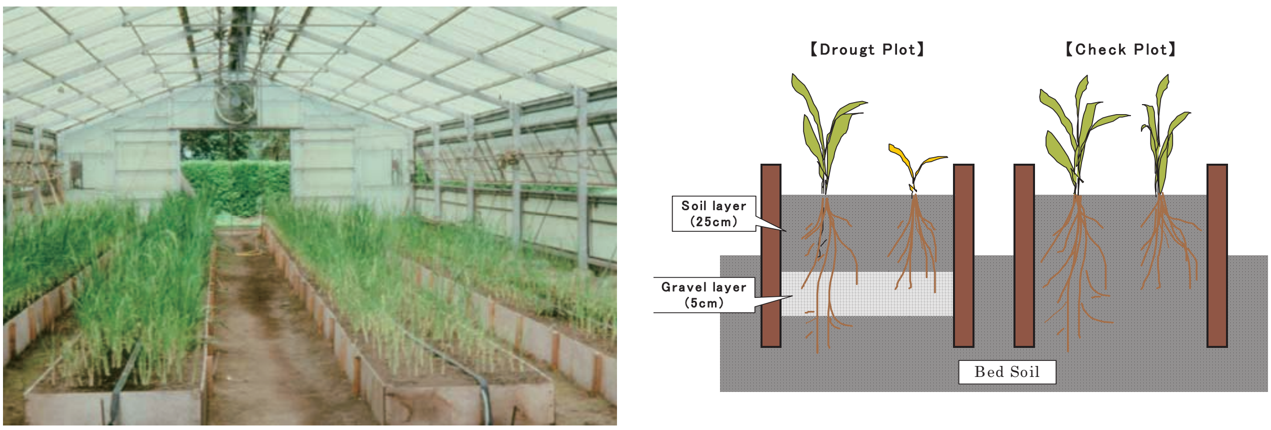


Photo 4 Screening house of deep rooting upland rice (left) and structure of bed (right)

The upland rice sown in the test beds are grown by sprinkling water over the soil surface and the irrigation is stopped at the reproductive stage when the plant is sensitive to water shortage.　The bed of drought plot has a gravel layer 30 cm below the surface. Because the gravel layer serves as a water shutting-off layer, it prevents the moisture in the bed soil layer from rising up to the upper plowed soil layer. Thus after sprinkling over the soil surface is stopped, the moisture of the plowed soil layer decreases greatly.　Deep rooting upland rice can continue growing because their root extend through the gravel layer and can absorb moisture from the bed soil, but shallow rooting one suffers serious drought damage since its roots are distributed only up to the plowed soil layer.　The degree of reduction in yield in the plot where drought treatment is made is affected greatly by the length of roots and so the method is very effective in evaluating the deep rooting character of bred strains.

3) Combination of early maturing and deep rooting character

We succeeded in breeding “Hitachihatamochi” by combining the very early maturing character and the deep rooting character in 2005. This new variety was selected from the cross between early maturing variety "Kantomochi No.166" and the hybrid of "Kantomochi No.166" and "Yumenohatamochi". "Hitachihatamochi" is an early maturing variety with slightly short culm length.　Its yielding ability is higher than that of standard variety "Kiyohatamochi" by 20% almost every year.　It also shows high cold tolerance as well as drought resistance.

Photo 5 shows that drought resistance of “Hitachihatamochi” is stronger than that of early maturing varieties such as “Toyohatamochi” and “Kiyohatamochi” (Photo 5). The leaves of “Hitachihatamochi” did not wither, whereas those of “Toyohatamochi” and “Kiyohatamochi” withered up.

“Hitachihatamochi” was adopted as a recommended variety in Ibaraki Pref., which holds about 70 % of total Japanese upland rice area, in 2005. The release of this variety is expected to stabilize upland rice cultivation in Ibaraki Pref. and also in Japan.

4. Future directions

Upland rice has not been used so much as breeding materials of paddy rice, because it was difficult to remove bad characters linked with upland rice. But upland rice varieties are expected to become handy genetic resources to improve paddy rice because selection technologies using DNA markers have being developing rapidly nowadays.

When seeing worldwide, upland rice is one of the most important crops in the developing countries such as Western Africa and Latin America. Moreover, the water resources has being deteriorated globally, various characters of upland rice by which water-saving cultivation becomes possible, will get more attention in the near future.

Photo 5　Drought resistance of “Hitachihatamochi”, “Toyohatamochi”, “Kiyohatamochi” and “Yumenohatamochi”　(from left to right)

References

1) 60th anniversary journal of Ibaraki Agricultural experimental station

2) 70th anniversary journal of Ibaraki Agricultural experimental station

3) 80th anniversary journal of Ibaraki Agricultural experimental station

4) 90th anniversary journal of Ibaraki Agricultural experimental station

5) 100th anniversary journal of Ibaraki Agricultural research institute

6) 50th anniversary journal of governmental breeding program

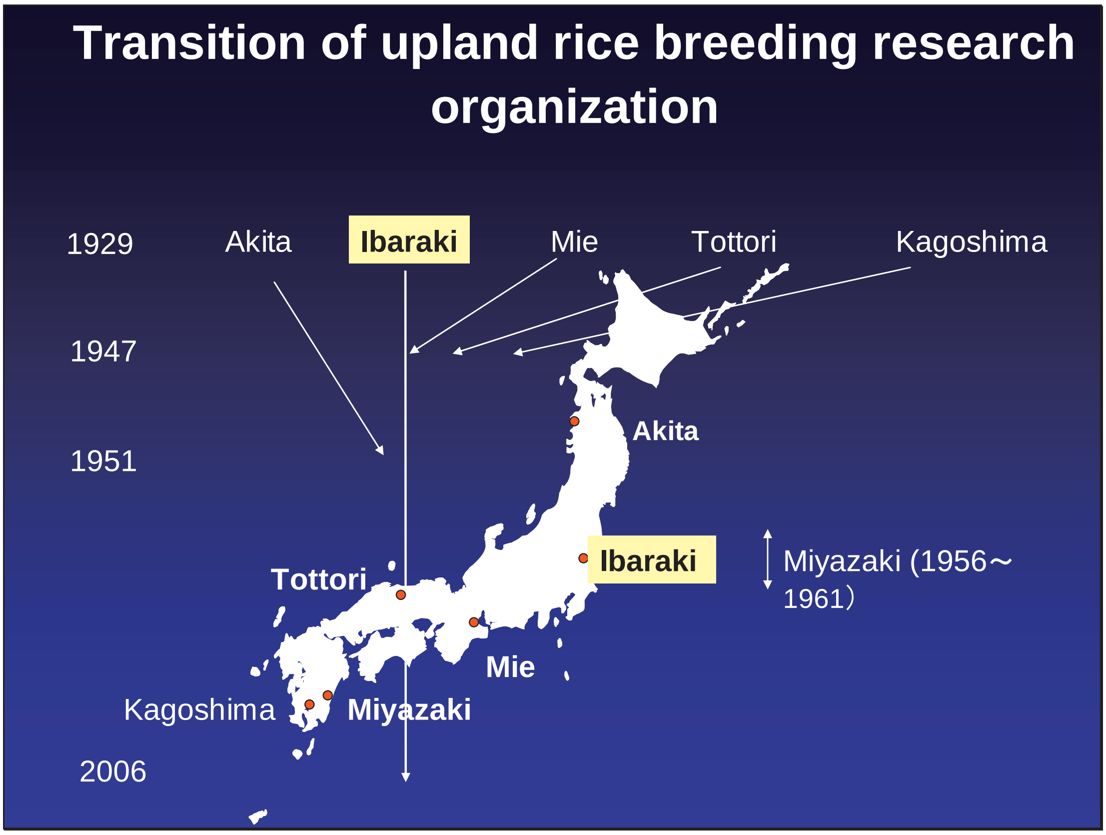
7) 70th anniversary journal of governmental breeding program

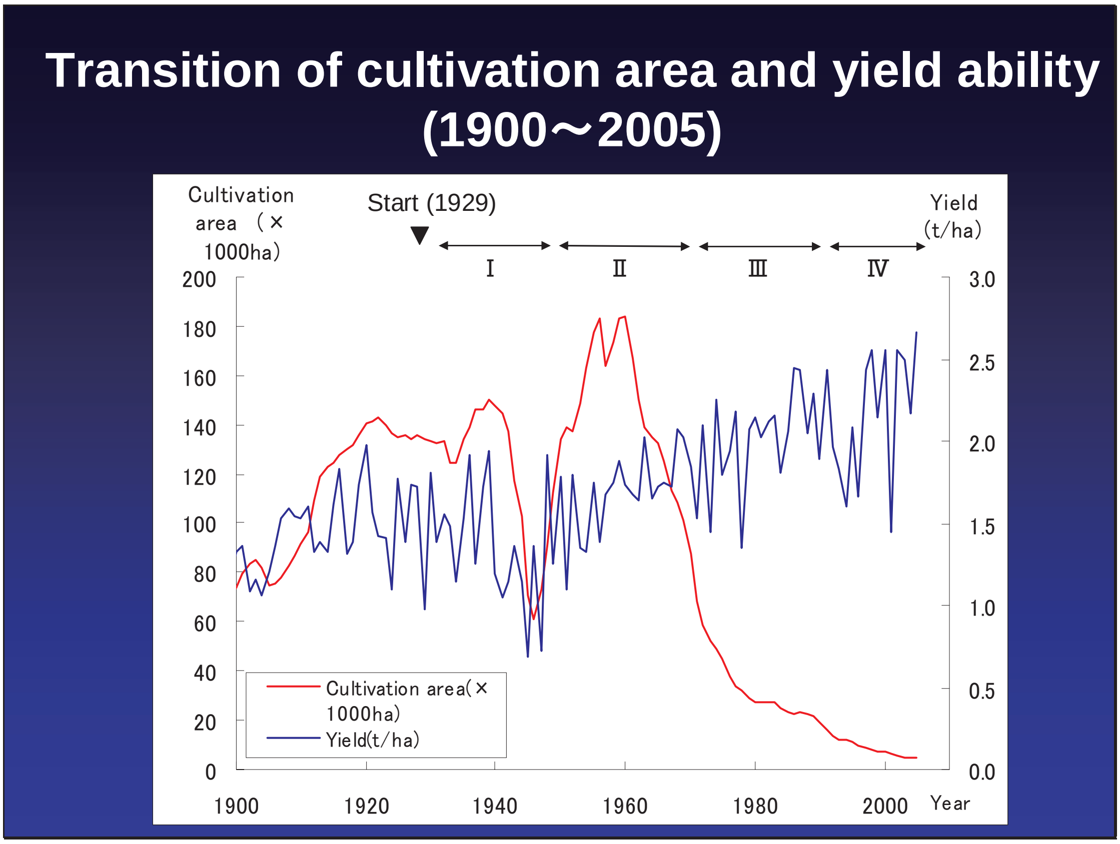
8) Matsuda A (1974) Nogyo Ibaraki 20 –22.

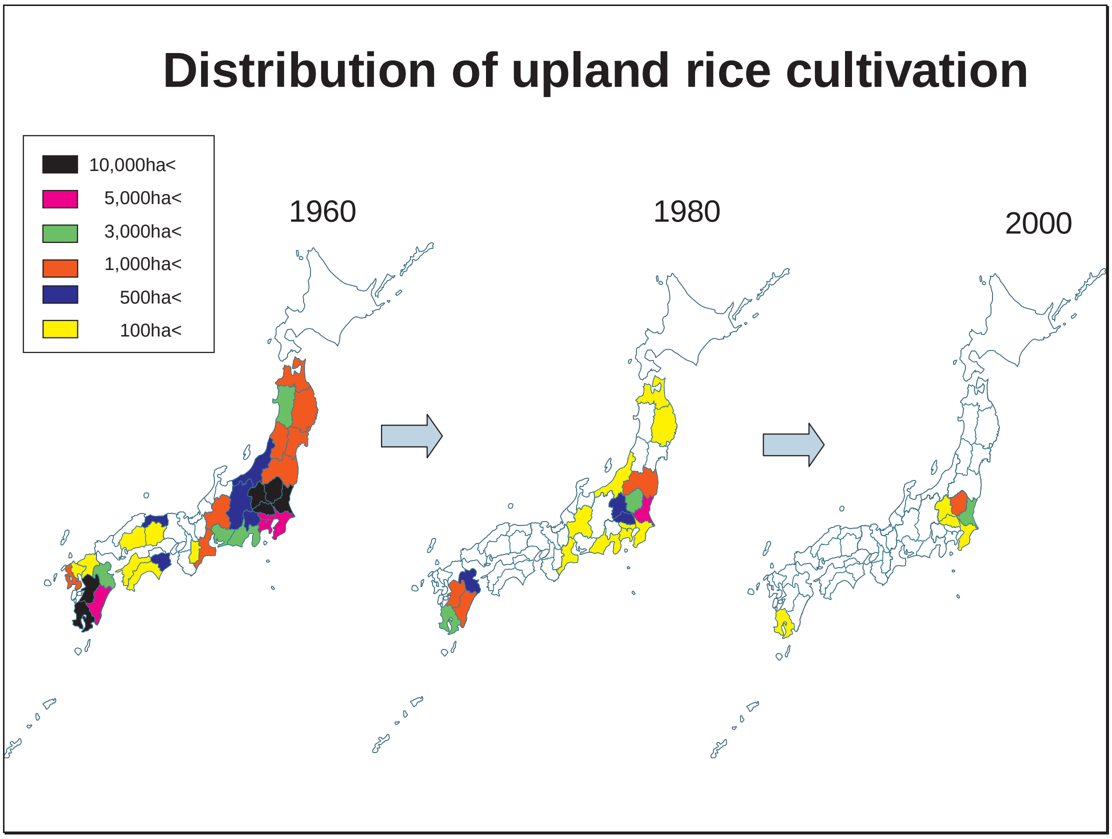
9) Nemoto *et al*. (1998)


Achievements of upland rice breeding in Japan in the past 77 years (1929-2006)
Takuro Ishii
National Institute of Crop Science,
National Agriculture and Food Research Organization
(NARO)


1. Outline of achievements in each time period
2. Breeding strategy to improve drought resistance

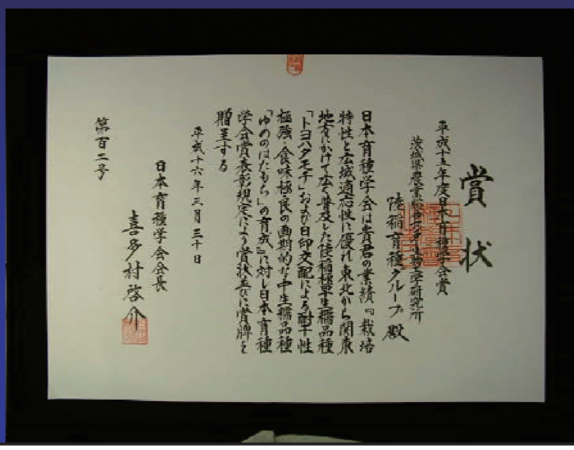

Transition of upland rice breeding research organization
1929
Akita
Ibaraki
Mie
Tottori
Kagoshima
1947
1951
Akita
Ibaraki
Miyazaki (1956～1961)
Tottori
Mie
Kagoshima
Miyazaki
2006


Transition of cultivation area and yield ability (1900～2005)
Cultivation area (×1000ha)
Start (1929)
Yield (t/ha)
Ⅰ
Ⅱ
Ⅲ
Ⅳ
200
180
160
140
120
100
80
60
40
20
0
3.0
2.5
2.0
1.5
1.0
0.5
0.0
1900
1920
1940
1960
1980
2000
Year
Cultivation area(×1000ha)
Yield(t/ha)

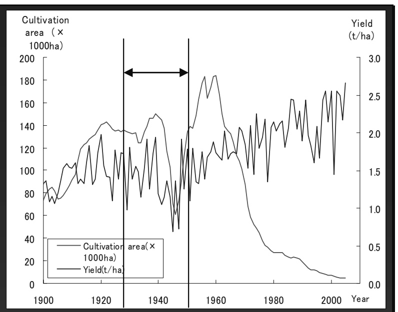


Main achievements

- ○ Sixty-one varieties were released; Toyohatamochi, Yumenohatamochi, Hitachihatamochi, *etc*.
- ○ Prize of Japanese society of breeding（Ibaraki Agr. Center, 2004)



Period Ⅰ（1929～1950）



○ Background
request for increase of crop production, promotion of reclamation

○ Breeding objectives
high yielding, drought resistance

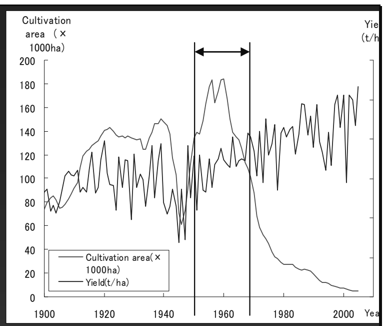
○ Varieties released (27 varieties)
Norin 12 (1940): high yielding, good eating quality
Norinmochi 26（1947) : high yielding, drought resistance

Period Ⅰ（1929～1950）

○ Related studies

- Cultivation methods: desirable pattern of sowing; time, quantity, density,row width, *etc.*
- Variety screening：for reclaimed fields suffering from K or P deficiency
- Drought resistance：effects of planting density, transplanting, straw mulch, cut-off leaves, *etc.*

Period Ⅱ（1951～1970）



○ Background

request for increase of crop production,
promotion of field irrigation system

○ Breeding objectives

specific varieties for cultivation under irrigation system,
high yielding, good quality

○ Varieties released (23 varieties)

Okaminori（1966): high yielding,（Norin24× Norin 29(paddy rice))
Mizuhatamochi（1969): high yielding, good quality,
（Koshijiwase (paddy rice) ×Hatakoganemochi）

Period Ⅱ（1951～1970）

○ Related studies

➢Cultivation methods：

◆Sowing or transplanting time, influence of shading, *etc*. under cropping system with wheat or barley

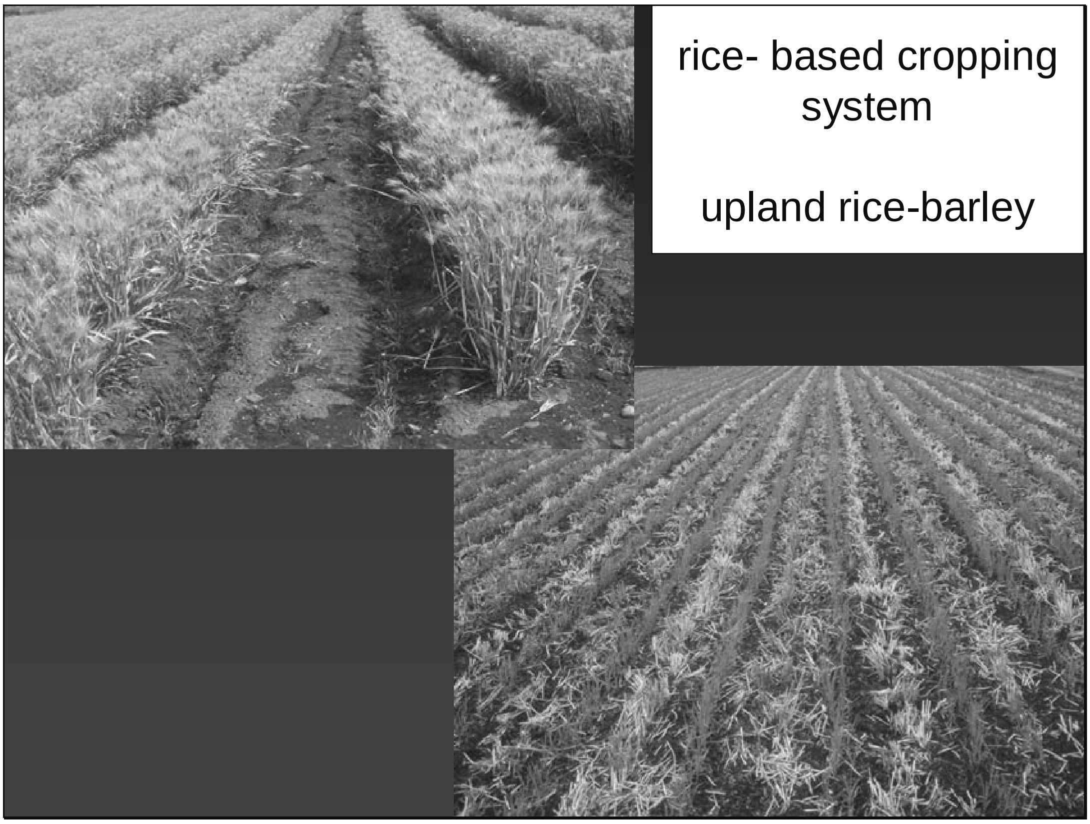
◆Yield test, grain quality, relationship between sowing time and heading date, *etc*. under irrigation system

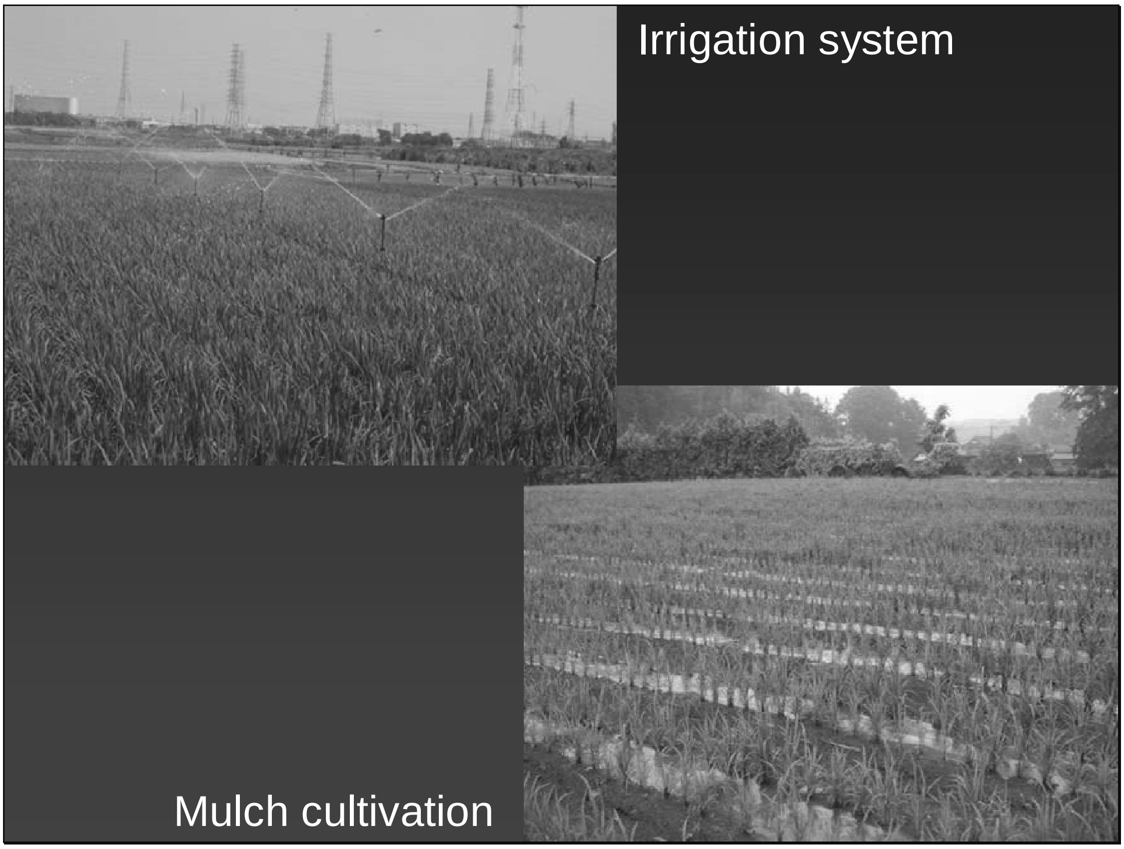
◆Mulch cultivation

➢Drought resistance：

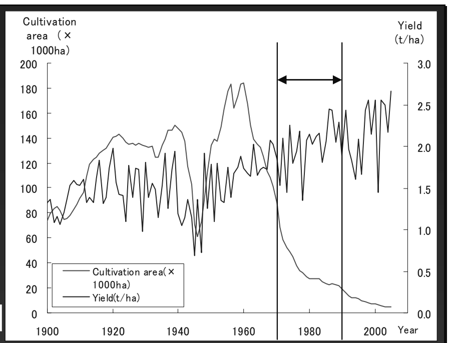
◆Difference in T / R’ ratio (weight of top / weight of roots) among varieties

◆ Relationship between T/R’ ratio and planting density, top dressing, types at seedling stage,*etc*.


rice- based cropping system
upland rice-barley


Irrigation system
Mulch cultivation

Period Ⅲ（1971～1988）



- ○ Background

  overproduction of paddy rice,

  increase of high value crop production (vegetables) in upland field

- ○ Breeding objectives

  early maturing, high yielding, drought resistance

- ○ Varieties released（8 varieties）

  early maturing : Fukuhatamochi (1978) ,
  Toyohatamochi (1985) ,
  Kiyohatamochi（1988)

Period Ⅲ（1971～1988）

- ○ Related studies

  - ➢Cropping system: effectiveness to control continuous cropping injury of vegetables,

    mechanisms of decreasing continuous cropping injury

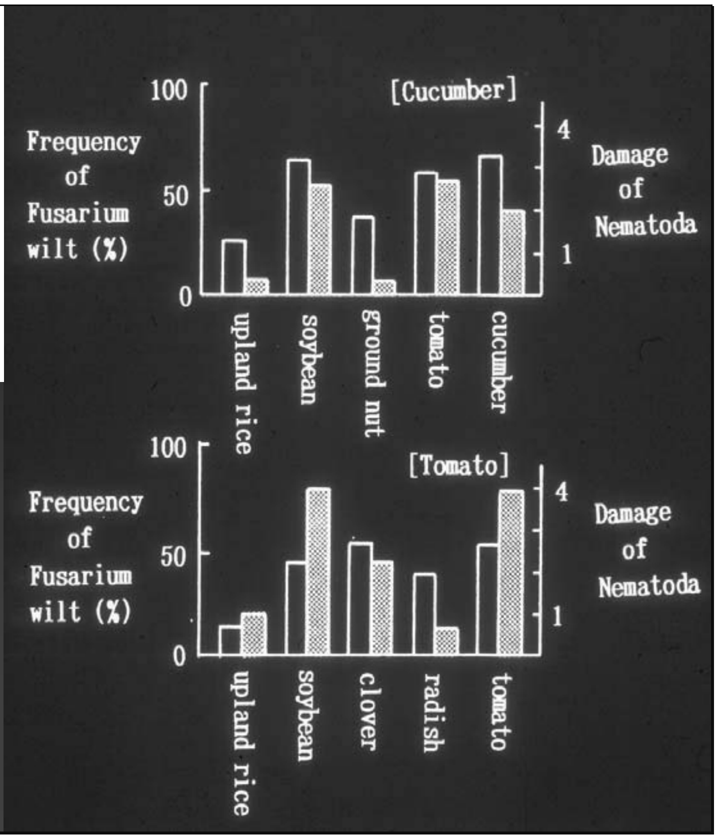
  - ➢Drought resistance: screening of foreign varieties with deep rooting

    green house method for evaluation

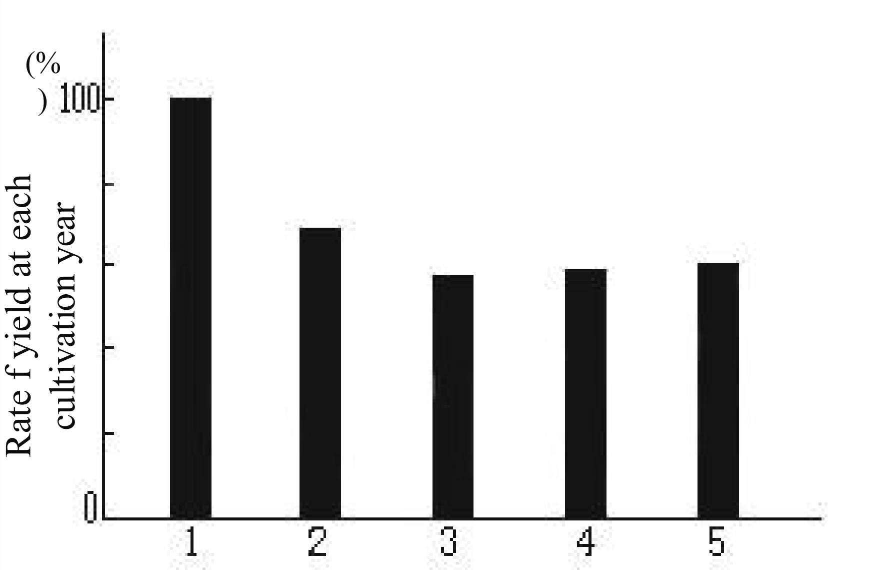
  - ➢Disease resistance: inoculation method for evaluation of "Bakanae disease"

Cropping system with vegetables

Effectiveness of upland rice to control injury disease of vegetable under continuous cropping
(Matsuda 1974)

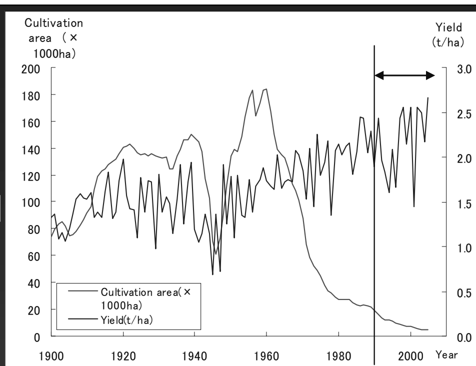


Yield of upland rice under continuous cropping



(Hasegawa *et al.* 1964)

Period Ⅳ（1989～2006）



○ Background

acceleration of intensive upland field management

○ Breeding objectives

very early maturing, stably high yielding, processing suitability

○ Varieties released（3 varieties）

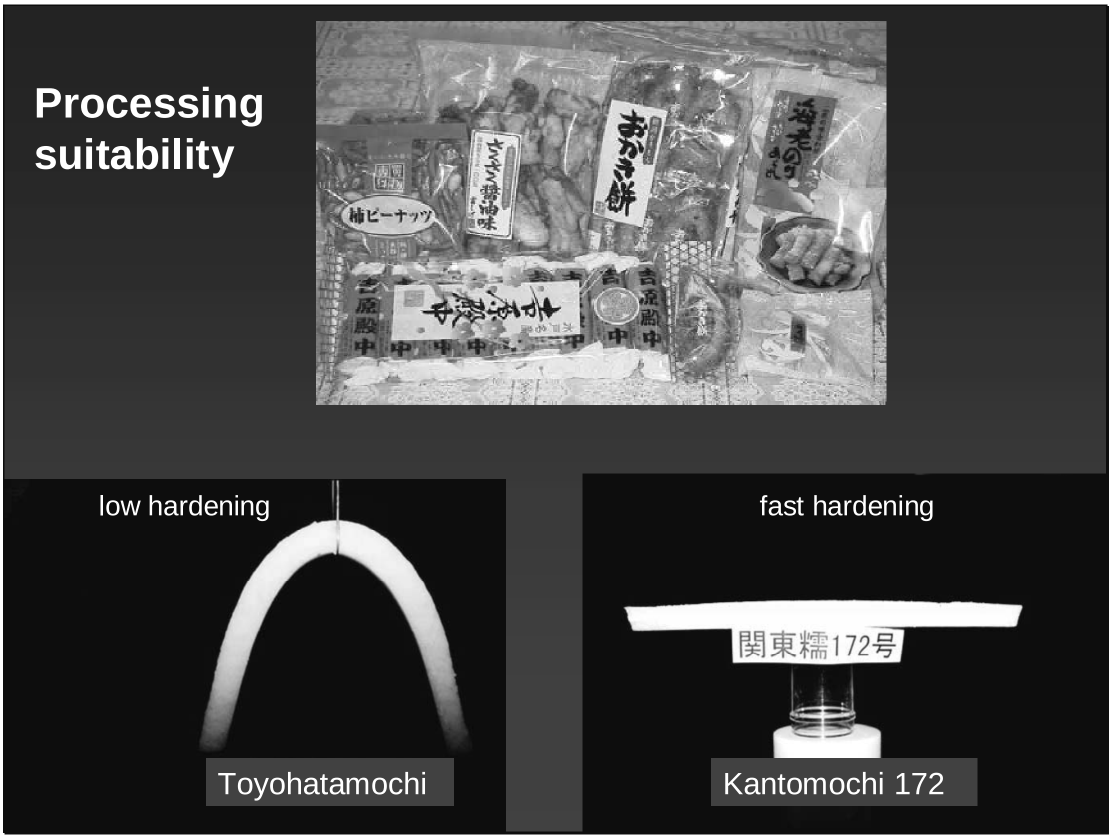
Yumenohatamochi(1996) : medium maturity, deep rooting, good eating quality

Hitachihatamochi（2005) : early maturity, stably high yielding

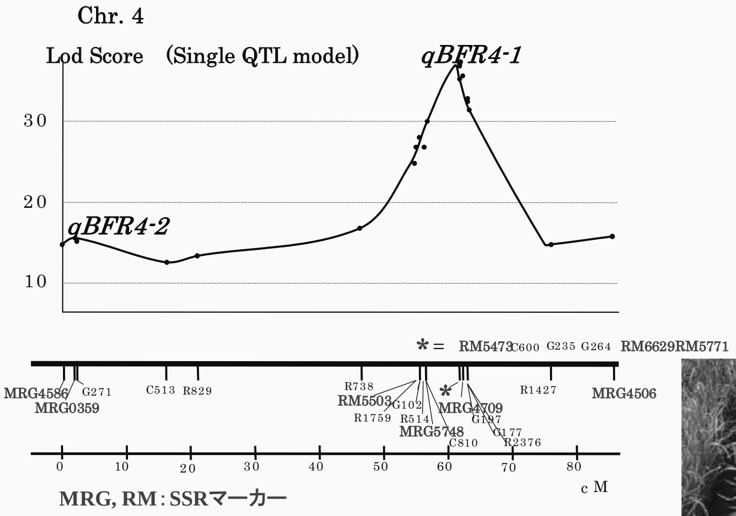
Period Ⅳ（1989～2006）

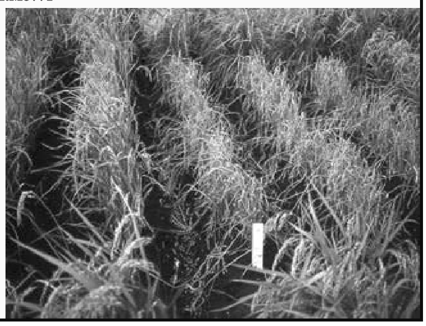
○ Related studies

- Processing suitability：fast hardening lines
- Drought resistance：detection of QTLs
- Utilization as genetic resources：
  Introgression of blast resistant genes to paddy rice,
  Core collection from local upland rice varieties



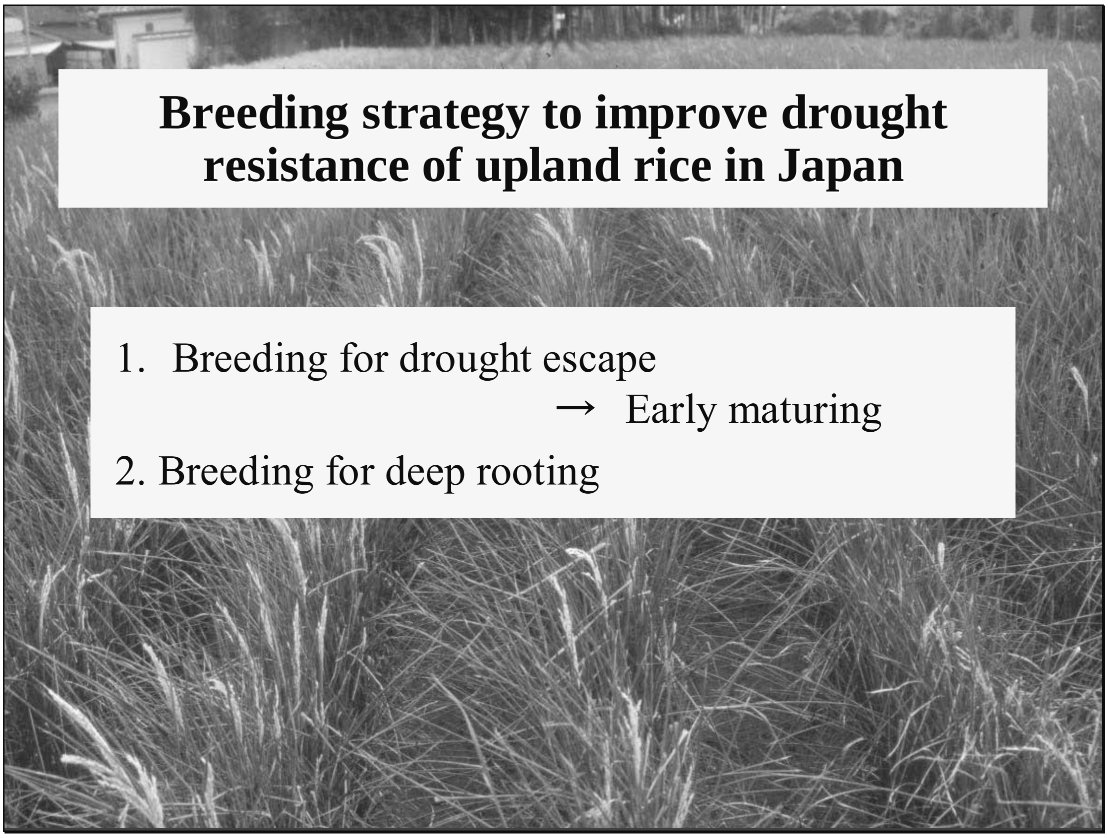
New QTLs of blast field resistance from upland rice "Kahei"





Occurrence of drought injury at each growth stage in Japan

Germination period	Vegetative period	Reproductive period
⇩	⇩	⇩
Low temperature	Rainy season	Mid summer
		⇩
		Drought injury

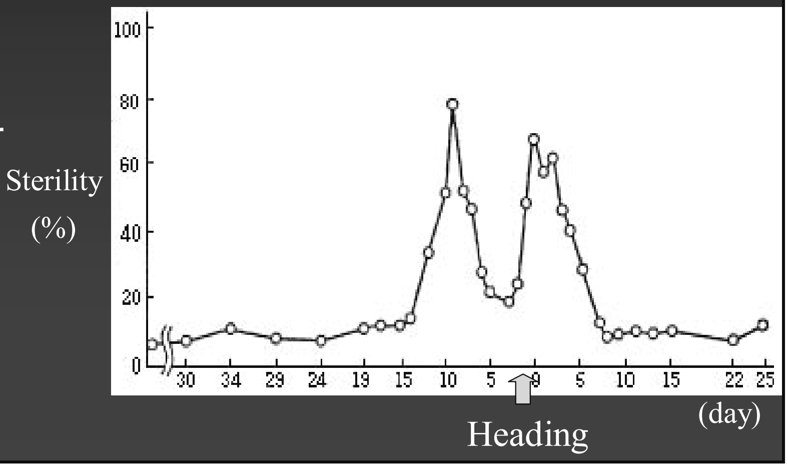


Drought escape ➡ Early maturing variety **"Toyohatamochi"**

The most sensitive period of crop to drought: period from panicle formation to heading

The hottest period: August

Effect of cut off water supply for grain sterility



Breeding of deep rooting in Ibaraki Agriculture Center

1. Enlargement of genetic resource;

   Varietal screening of foreign varieties with deep rooting by using “*Trench method*”

2. Establishment of selection method

   Utilization of evaluation system of progeny lines by using “*Specific nursery bed* ” (green house method)

Varietal screening of deep rooting by the trench method

Observed characters

Root volume, Thickness

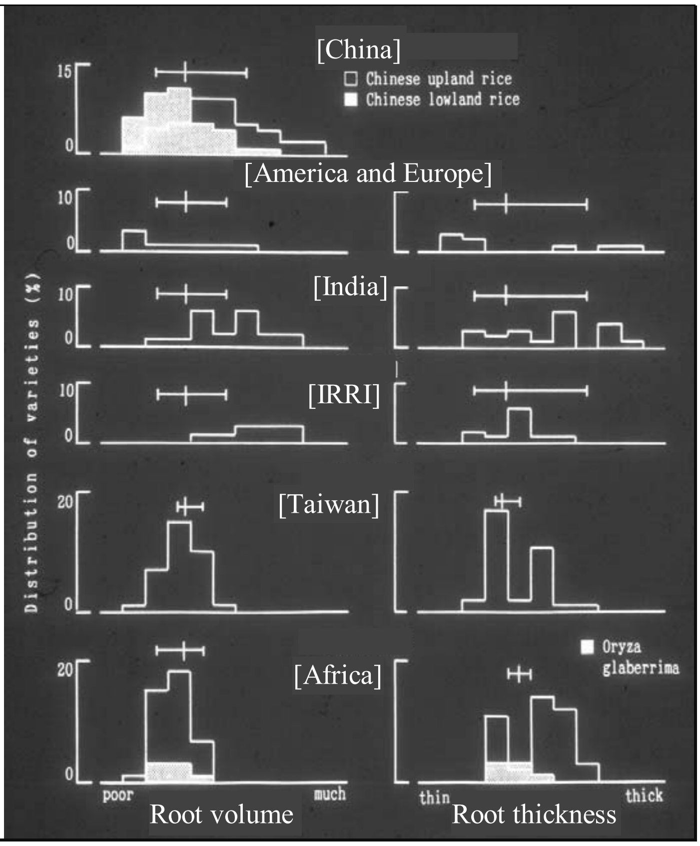
Depth of root tip

Varietal screening of rooting under trench method

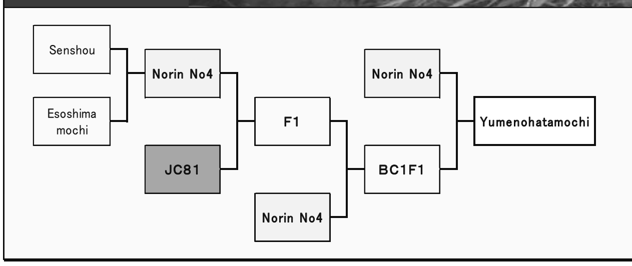
Detected foreign varieties with deep rooting

- **JC81**, B5416 (India)
- IRAT10, 109 (Liberia)
- Nam Sugai (China)
- IR3646(IRRI), etc.

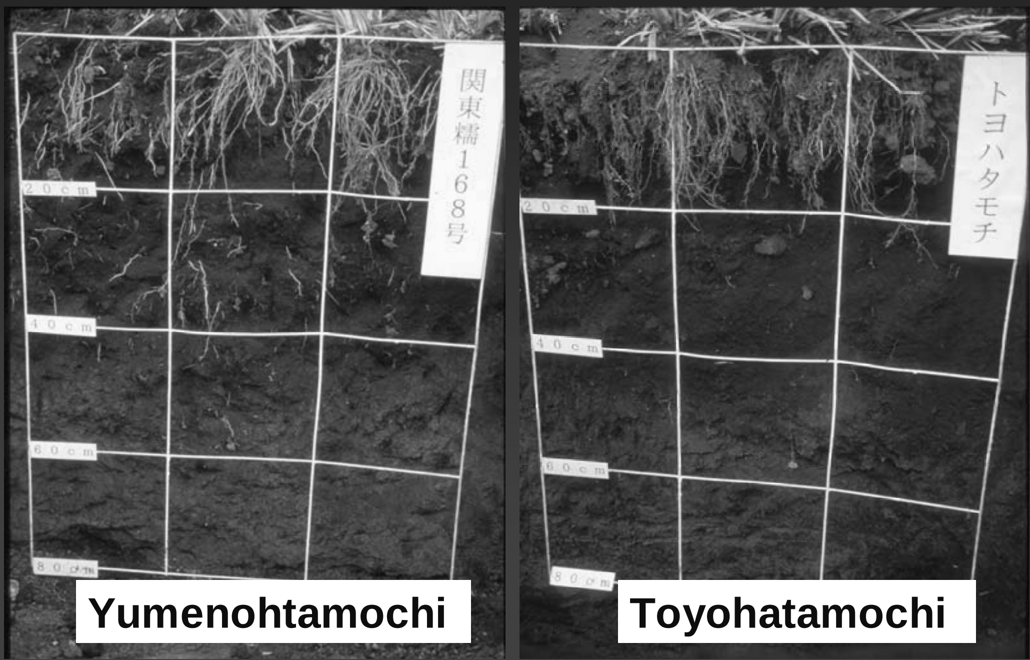
(Ibaraki Agri. Center 1979 to 1983)



Establishment of deep rooting variety "Yumenohatamochi" (1996)

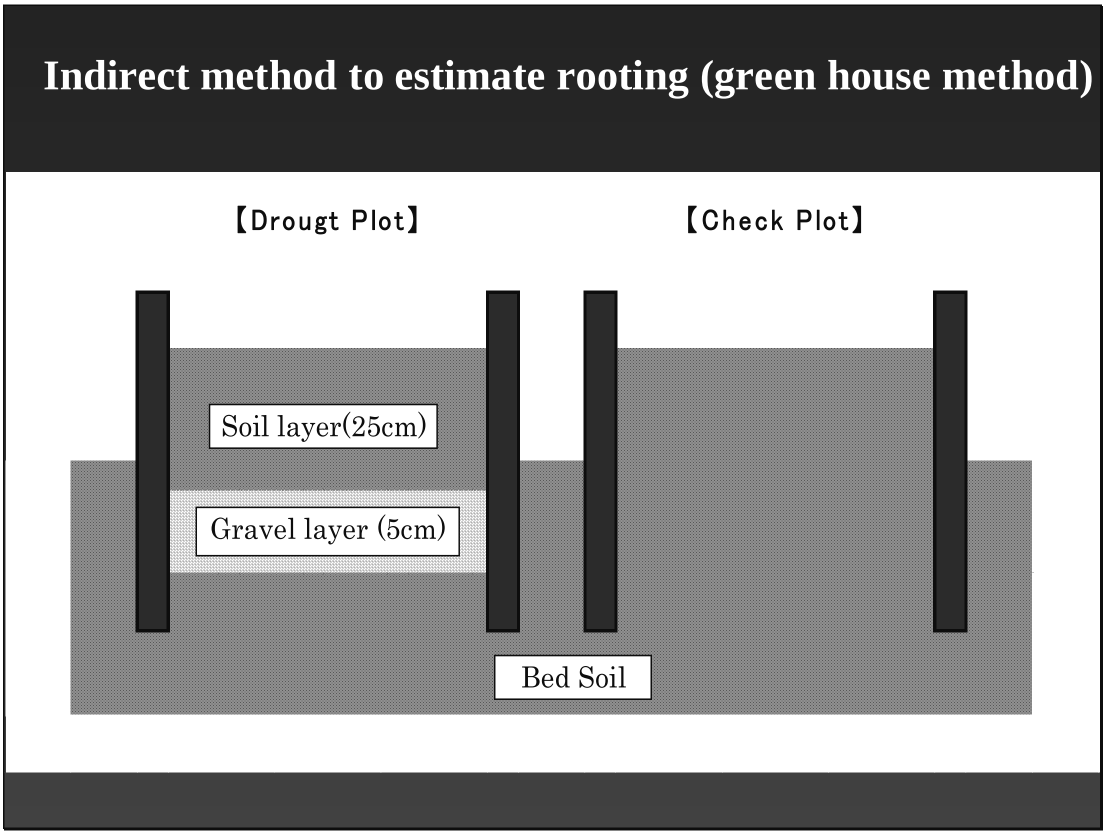


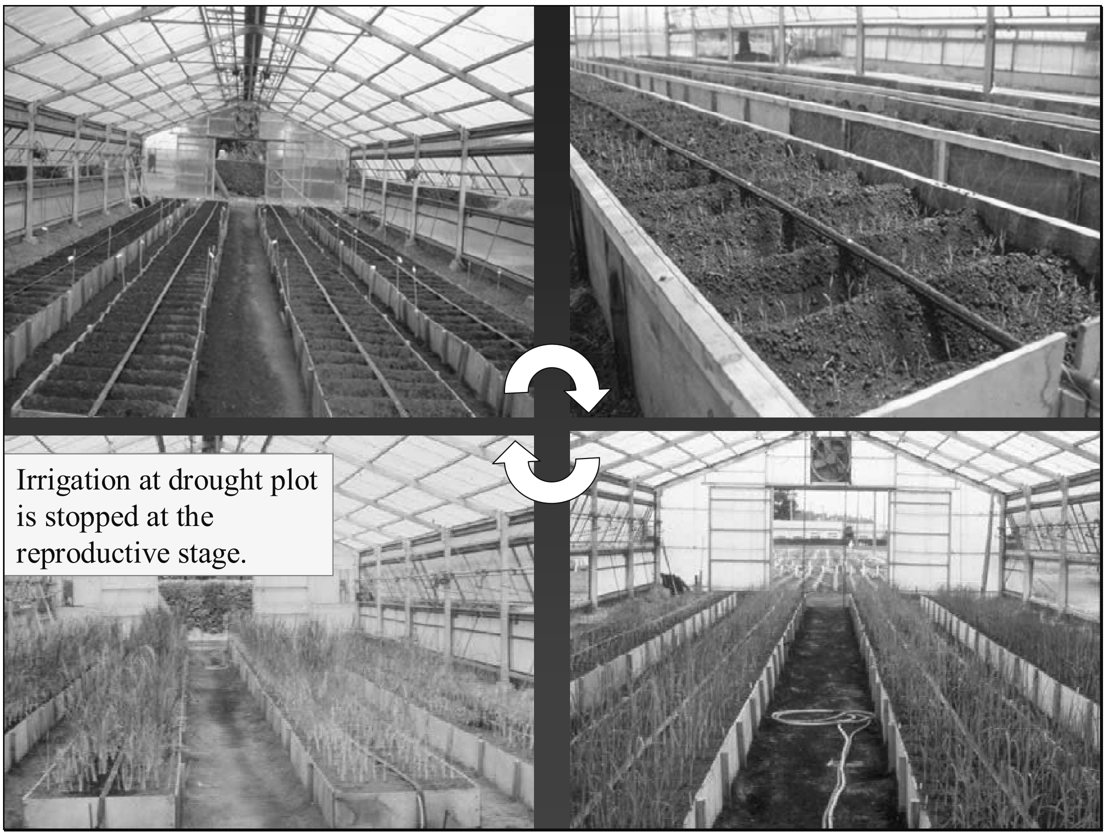
Deep rooting variety "Yumenohatamochi"

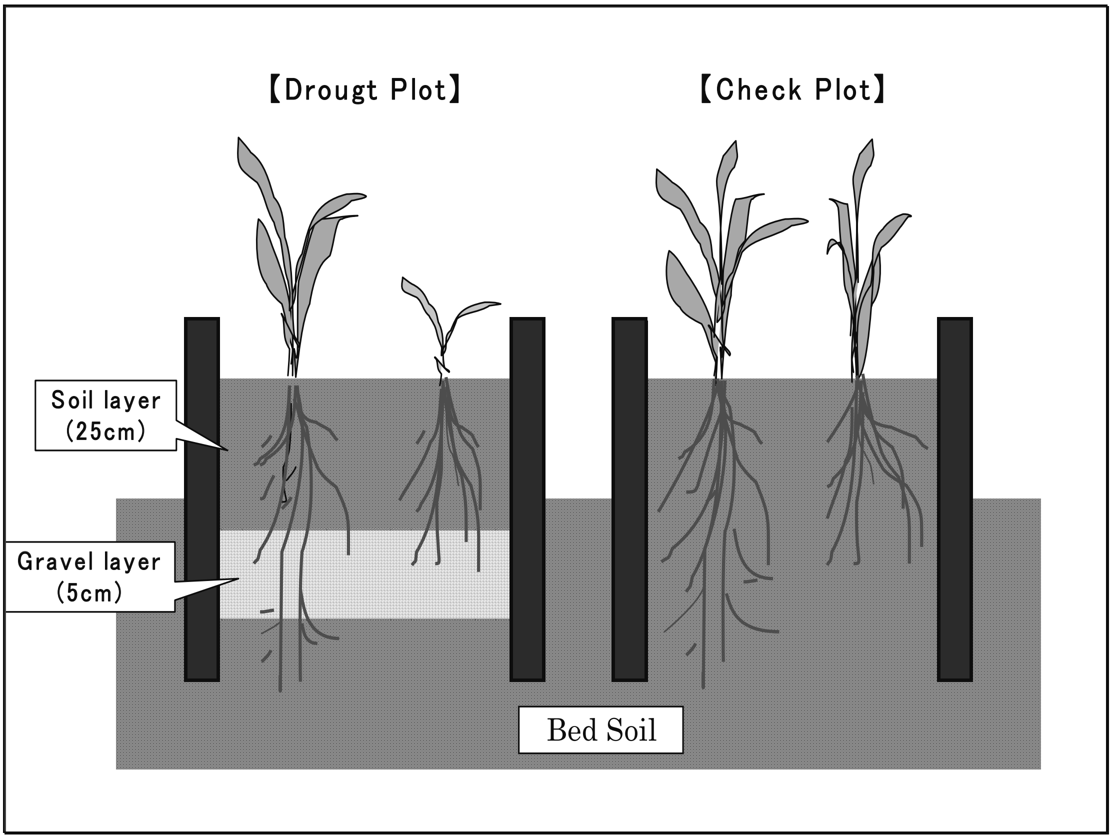


Yield of "Yumenohatamochi" in drought year

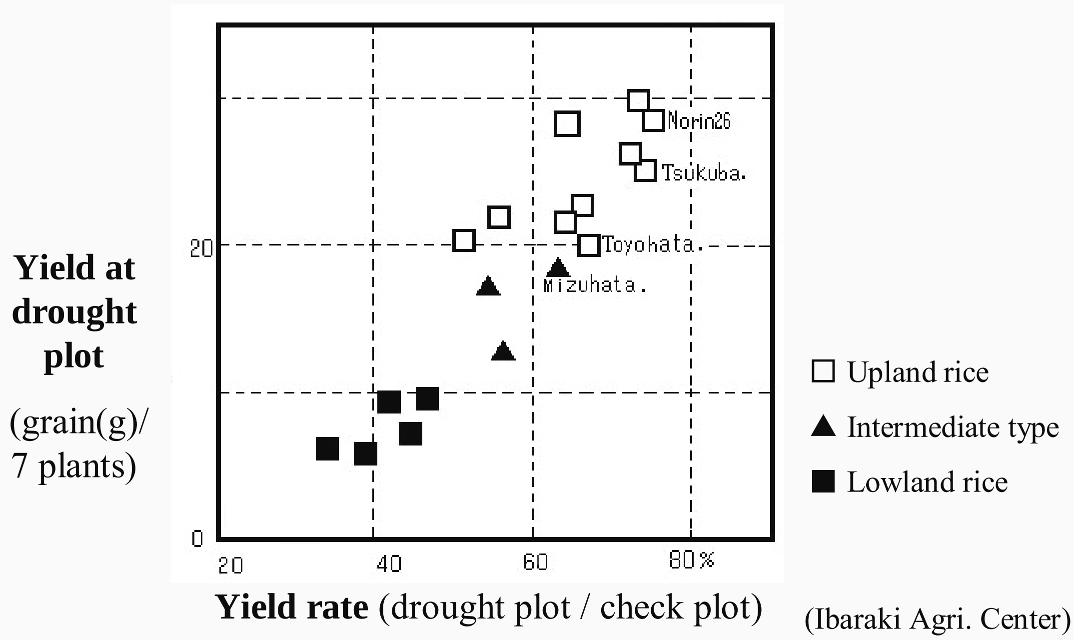
Varieties	Average yield from 1989 to 1995		Average yield in drought years 1992 and 1994	
	Yield (t/ha)	Rate (%)	Yield (t/ha)	Rate (%)
Yumenohatamochi	3.42	111	1.64	148
Tsukubahatamochi	3.09	100	1.11	100
Norinmochi26	2.74	89	0.58	52


Indirect method to estimate rooting (green house method)
【Drougt Plot】
【Check Plot】
Soil layer(25cm)
Gravel layer (5cm)
Bed Soil


Irrigation at drought plot is stopped at the reproductive stage.



Distribution of grain yield of rice varieties in specific nursery bed method



(Ibaraki Agri. Center)

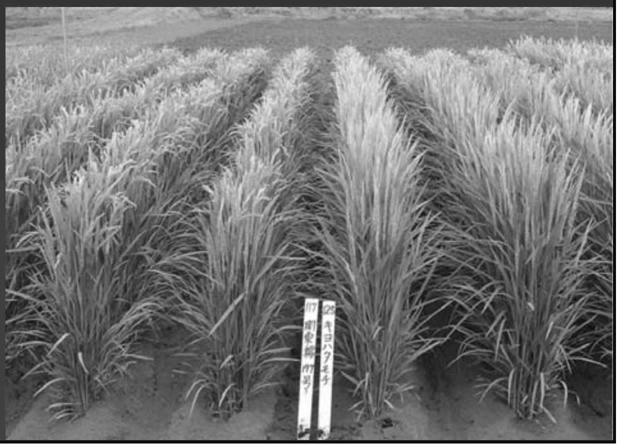
Combination of drought escape and deep rooting

↓

New variety “Hitachihatamochi” (2005)

Early maturing, stably high yielding variety “Hitachihatamochi” (left)

(right: Kiyohatamochi)



Drought resistance of early maturing and high yielding variety “Hitachihatamochi”

Hitachihatamochi Toyohatamochi Kiyohatamochi

Characteristics of "Hitachihatamochi"

Variety name	Heading date	Culm length (cm)	Pancle length (cm)	Panicle number (/m^2)	Whole weight (t/ha)	Brown rice weight (t/ha)	Yield ratio (%)
Hitachihatamochi	7.29	69	19.3	297	9.3	3.6	120
Kiyohatamochi	8. 2	73	20.2	289	9.6	3.1	100
Toyohatamochi	7.28	71	19.7	265	8.2	2.7	85

(1999-2004)

Acknowledgement

Agriculture, Forestry and Fisheries Research Council of Ministry of Agriculture, Forestry and Fisheries (MAFF) for financial aid,

Ibaraki local government for assistance for promotion of breeding

質疑応答
Question and Answer Session

わが国のこれまで77年にわたる陸稲育種研究の成果
Achievements of Upland Rice Breeding in Japan in the Past 77 Years

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杉本（司会）:

Thank you very much for your presentation.　Mr. Ishii has briefly explained Japanese government's experience of Japanese government for seventy-seven years over upland rice varieties, and drought resistance, as well as deep-root varieties.
Are there any questions?

二口：　先ほど若月さんからもNERICAの問題に関連して質問させていただいたのですが、4トンほど取るためには、窒素などの肥料を入れないといけないだろうということでした。実は私は「アフリカ人造りプロジェクト」にまだ関係していますので参考までに伺いたいのですが、例えば nitrogen response という言い方をしますが、paddy の場合は還元層というのがあり、有機物が非常に緩行的にゆるくリリースされると聞いています。しかも多分硫安などが多いものですから、陸稲の場合とか NERICA の場合だとウレア(尿素)とかそういうものを使うことになるのかというのが一点と、その施肥の方法が、還元層があるためにリリースされるのが割にゆっくりだと我々作物屋は聞いていたので、そういう点からすると、NERICA などに対する upland の実験をなさってきた経験からNERICAのようなuplandの場合の肥料のやり方、もしくはnitrogen response、かつてIR-8の場合、非常に問題になったわけですが、栽植密度やrainy seasonとの関係もありますし、簡単にいいますと、窒素反応の lowland rice とupland riceにおける違いについてひとつお話しを伺いたいと思います。

石井：　私どもでは、施肥量は窒素レベルでだいたい 12 キロぐらい与えていまして、それがごく一般的な栽培方法だと思います。窒素を与えれば与えるほど取れますが、ただ、全重が重くなると今度干ばつに弱くなるわけですし、蒸散量も増えることになりますので、あまりやりすぎるのは良くないと思います。10キロぐらいが最適な量ということで落ち着いているのだと思います。ただ、品種によってかなり窒素反応の差があります。

日本の在来品種と比べてみましても、すぐに茎数、穂数が増えて反応するものとなかなか反応しないものもあります。あまり穂数が増えない場合はどんどんやればいいのでしょうが、すぐに増える品種だとなかなかやれないというところで、当時の施肥試験などもいろいろやられているわけですが、品種ごとにこの品種にはこういうふうにやる、という結果になっていまして、NERICA の場合もそれぞれに応じて最適な施肥量を見つけていかなくてはならないだろうと思っております。

二口：　施肥には普通はやはりウレアを使うのですか？

石井：　私どもでは硫安で普通の追肥です。

二口：　私達の場合は硫安の割合が優勢なのですけれども、upland の場合は農家もウレアを畑作物的な考えかたで使うのですか？　日本の場合についてはどうでしょうか。

石井：　日本の場合は水稲に準じたような形で与えています。

二口：　はい、どうもありがとうございました。

神代：　JIRCAS の神代ですが、耐乾性の品種についておたずねします。深根性ということで「ゆめのはたもち」とか、「ひたちはたもち」といった2つの乾燥耐性のものについて述べておられたのですが、これはいわゆる乾燥耐性を構成している形質、例えば、蒸散量、気孔開度というのは深根性と何かリンクして関わっているのでしょうか。

石井：　ちょっとそこまでは見ていないのですが、「ゆめのはたもち」の場合は葉の温度がやや低いというような話は聞いたことがあります、蒸散が激しいですから。「ひたちはたもち」の場合はちょっとそこまで確認しておりません。ただおそらく蒸散は激しく出ているような気がします。

神代：　私たちも乾燥耐性のことをやっていますが非常に複雑な形質で何をメルクマールに選抜していいのか、ちょっといろいろ難しいところがあります。例えば深根性のものは乾燥耐性の何％ぐらいを説明できると見積もっていますか？

石井：　それは、何％と答えるのは難しいですね。ただ、今日本で育種する場合にいろいろ幼苗期で検定したりしていろいろやってきたわけですが、結局は成熟期の根の重さを量るのが一番正しいだろうということとでやってまいりました。深根性の根量というのが一番大きな形質になると思います。それ以外の形質はちょっとわかりません。深根性のものが葉面の温度が低いという報告を聞いたこともありますが、葉っぱの温度を

測るというのも、葉の温度は一日の間でもかなり変わるので、実際は根を測るのが一番早いと思います。

若月：　近畿大学の若月です。アフリカと日本では土の固さがかなり違いますね。日本だと山中式の硬度計で 20 でかなり高いですけれど、むこうは 30 ぐらい軽く出ますよね。強さ、硬さ、深さ、そして先ほどの施肥でも相違が出ましたが、それを突破できるような性質、その深根性プラス何か強さみたいな、確か坂上さんが何かされていたようですが、そのあたりは何かやっておられたことありますでしょうか？

石井：　それは私はやっていませんが、昔は表土の深さということで、何センチぐらいまで耕すのが陸稲にとって一番よいかという試験をしたと読んだことがあります。そうしますと、要は深く耕せば耕すほど根が下まで入るので良いというような昭和 15～16 年の試験結果ですが、そういうのはあります。ただ、根の入る強さ、貫通力については日本というか、私たちの研究室では実験をやったことがないです。ただひたすら掘るのみです。

杉本（司会）：

他に質問はありますか？　なければ終わらせていただきます。
ありがとうございました。

Profile

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1989 年京都大学大学院農学研究科修士課程修了。愛知県農業総合試験場で野菜の栽培生理研究に従事した後、1991 年から中国農業試験場で水稲の育種研究に従事。1999 年から農水省農産園芸局および農林水産技術会議事務局で、土地利用型農業の経営展望の立案業務や水田作を中心とした研究プロジェクトの調査･企画業務に従事。2001 年から農業生物資源研究所で遺伝資源の多様性保全の研究に従事した後、2003 年から茨城県生物工学研究所（農水省陸稲育種指定試験地）で陸稲育種に従事。2006 年 4 月から農研機構作物研究所稲マーカー育種研究チームで上席研究員として再び水稲育種に従事し、現在に至る。専門分野は、育種学、統計遺伝学。

Academic career

Mr. Takuro Ishii graduated from Graduate School of Agriculture, Kyoto University, in 1989.

Professional career

After the graduation, Mr. Takuro Ishii worked for the Aichi Agricultural Experiment Station in Japan for two years on vegetable physiology. From 1991 to 1999, Mr. Ishii served as a rice breeder for the Chugoku National Agricultural Experiment Station. For the following two years, he worked as a research coordinator for the Bureau of Crop Production and Agriculture, Forestry and Fisheries Research Council of the Ministry of Agriculture, Forestry and Fisheries of Japan (MAFF). In 2001, he moved to the National Institute of Agrobiological Sciences (NIAS) to study genetic diversity conservation. In 2003, he moved to the Ibaraki Plant Biotechnology Institute and served as an upland rice breeder. In April 2006, Mr. Ishii joined the National Institute of Crop Science as a chief researcher and is currently working on improvement of rice varieties by using the method of marker-assisted selection.

ケニヤにおけるネリカ米普及に具備すべき社会経済的要素
Socioeconomic Factors Needed for NERICA Dissemination in Kenya

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要　約

ケニヤでは人口増加と都市化によりコメがここ数年、多くの世帯で急速に主食の一部を占めるようになってきている（Kennedy and Readon, 1994）。2002 年から 2003 年の間にコメの消費量は 35.2％の増加を示し、2005 年には生産が 8 万 5 千トン、消費が 31 万 1 千トンに達し、生産量と消費量の差は約 1 億 7 千万ドル分の輸入で補填しているとみられる（CBIK, 2005）。

コメの生産量が低い原因として、一方では耕作面積 0.5～2 エーカーの小規模農業経営、適切な作物栽培方法に関する知識不足、マーケティングの不足、低収量品種の利用、コメ以外の作物との競合、コスト的に効率を高める機材の不足が考えられる。他方では、陸稲として 40 万ヘクタール、低地・灌漑地として 65 万ヘクタールが栽培可能面積として賦存している一方、ケニヤ西部では天水で栽培される在来品種 Dourado Prococe（1.5 ton/ha）、および水稲栽培の IR2793-80-1（3.5 ton/ha）の低収量性、沿岸地域では、Kaiso K25 や Parkisan、KR22、KR25 などの在来品種の栽培も、低位な生産量の原因となっている（Atera 2006）。ケニヤ国立農業研究所（KARI）は協力機関と共同して、収量と旱魃耐性に関する NERICA の適応性試験を 11 か所で実施した。その結果、NERICA11 と NERICA4 が普及品種として選抜された。この 2 品種は旱魃耐性が高く、高収量を得られ、調理特性も優れている。収量は 2～3 ton/ha である。

今後の課題として、普及品種を農家に広く導入してもらうためにどんな条件を揃える必要があるのか分析することが必要となっている。技術普及段階に移行する時期は非常に重要である。この段階では社会経済的条件の影響を理解する必要がある。ブンゴマ地域で行われた戸別予備調査の結果は、NERICA 普及を促進する条件、あるいは妨げる条件が数多くあることを示唆している（Okech J N, Takeya H and Asanuma S, April 2006）。また、収量や、様々なストレスに対する耐性の高さ、味の良さといった NERICA の特性に関する情報が不足している場合に NERICA に対する関心が低くなるという結果も見られた。この他にも、生産コストの高さ、経験不足、適切な機材の不足（精米機）、ケニヤ国内市場における輸入米に劣る国産米の競争力、リスク嫌悪、といったことが要素として挙げられる。さらに、栽培面積の１位を占めるトウモロコシに対し、コメの場合は栽培面積で９位、収入額では３位である。予備調査ではこのほか、農家はコメの種子を主に近隣の農家から分けてもらう場合が多く、このことから組織的な種子生産システムが存在しないことも明らかになった。キスムとブシアで行われた戸別調査では、NERICA 普及に対する肯定的・否定的な考え方が、個人個人の場合と、グループの場合で違いがあることを考慮する必要性が浮かび上がった。また、NERICA と他の穀物との関係性（競合、補合、補完）を考慮する必要性も示唆された。

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Socioeconomic Factors Needed for NERICA Dissemination in Kenya

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Abstract

Rice has over the years rapidly increased to become a main food commodity in many Kenyan households due to increase in population and urbanization (Kennedy and Readon, 1994). A recent report indicates that between 2002 and 2003 rice consumption increased by 35.2%, and by 2005 production and consumption stood at 85,000 and 310,951 mts respectively, suggesting that the difference was imported amounting to about $170 million (CBIK, 2005).

The low rice production can be explained on the one hand by the small farm sizes ranging from 0.5 acres to 2acres that farmers cultivate, attributed to lack of knowledge on appropriate crop husbandry practices, poor marketing, low yielding varieties, competition from other food crops and lack of cost effective equipment. Yet there is a potential area of 400,000 and 650,000 ha for upland and lowland/irrigated ecosystems respectively, and on the other hand by low average yields of conventional varieties, Dourado Precoce (1.5 ton/ha) and IR2793-80-1(3.5tons/ha) under rainfed and irrigated cultures, respectively in West Kenya. In the coastal region the conventional varieties grown include Kaiso K25, Parkisan, KR22 and KR 25 (Atera 2006)

KARI and its partners have carried out NERICA adaptability tests focusing on yield and drought tolerance in 11 sites that resulted in selection of NERICA 11 and 4 that are being considered for release. Results have shown that the cultivars are drought tolerant, high yielding and have good cooking quality. The yields range from 2 to 3 tons per ha. Following the selection of NERICA 11 and 4, it is necessary to carry out analysis of the preconditions of diffusion as a strategy geared towards achieving high adoption rate.

Moving into technology dissemination phase is a crucial stage in which it is important to understand the influence of socio-economic conditions. Preliminary results of the household survey carried out in Bungoma district indicated that there are a number of preconditions that can promote or hinder NERICA diffusion (Okech J N, Takeya H and Asanuma S, April 2006). The results include low interest in NERICA which is attributed to lack of information on its characteristics such as yield, tolerance to various stresses and taste. Other factors identified were perceived high cost of production, lack of experience, lack of appropriate equipment (rice mill), low competitiveness of local rice against imported rice in the domestic market and high-risk aversion. In addition while rice is ranked 9th compared to maize which is ranked 1st in land allocation, it is ranked 3rd in income generation priority scale. The preliminary study further revealed farmers obtain rice seed mainly from neighbor's suggesting that there is no organized seed production system. Other preliminary results of the household survey in Kisumu and Busia indicated that we should consider differences between individual and group perception of constraints (opportunities) for dissemination of NERICA, and also think about the relation among NERICA and other crops.

1. Background Situation

Rice has over the years rapidly increased to become a main food commodity in many Kenyan households. As drawn at Fug.1, consumption of rice in Kenya started an increase since early 1990's and especially jumped up from 2000. The change was taken place by a new trend of consumption custom in urbanized people and young generation.

But the rice production in Kenya has not yet developed in 1990's and early 2000's. The gap of the production and consumption of rice subsequently become expanding very rapidly since 1993. The production and consumption of rice in 2005 in Kenya stood at 85,000 and 310,951mts, respectively. It resulted in import of rice and spending of valuable foreign money for the import. The deficit was imported about $170 million (CBIK, 2005).

The low level of rice production in Kenya can be explained on the one hand severe limitation of cultivated land with rice, especially irrigated farm land and on the other hand low yields of conventional varieties, Dourado Precocev (1.5ton/ha) under rainfed cultures. If farmers in Kenya use irrigated land and a variety of IR2793-80-1 (3.5tons/ha) which is already cultivated in some irrigated areas in Kenya, they can produce much more rice. There is a potential area of 400,000 and 650,000 ha for upland and lowland/irrigated environments, respectively in Kenya.

Most of Kenyan farms range from 0.5 ha to 2 ha under subsistent farming. They tend to have insufficient yield for their subsistence due to unstable climate condition. It is expected to develop rice production with favorite condition and new varieties. The issue must be clarified by research accompanied with field survey.

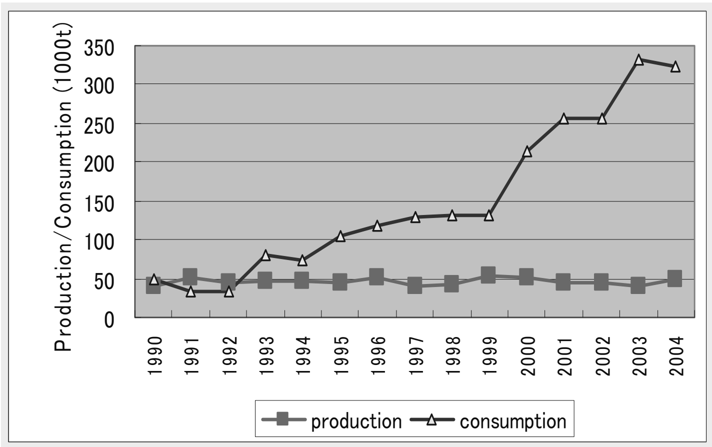


Fig. 1 Production and Consumption of Rice in Kenya

2. Necessary survey to clarify preconditions of NERICA diffusion

2-1. Where has the research of rice in Kenya come up to?

Rice research in Kenya was initiated in 1980's at Kibos and Mwea Tebere. The adaptive rainfed rice research conducted between 1991 and 1995 resulted in the evaluation and selection of 6 upland and 4 lowland rainfed cultivars for rice yield and cooking quality (Kouko *et al* 1995).

In a continued effort to develop high yielding rainfed rice varieties, NERICA was introduced from West Africa Rice Development Association (WARDA). The NERICA cultivars have the potential to increase rainfed rice yield to 3.5 tons/ha and irrigated rice yield to 6.0 tons/ha. KARI and its partners have carried out NERICA adaptability tests focusing on yield and drought tolerance in 11 sites, resulted in selection of NERICA 11 and 4 that were being considered for release in 2006.

2-2. Necessary survey

Following the selection of NERICA 11 and 4, it became necessary to carry out analysis of the preconditions of dissemination as a strategy geared towards achieving high adoption rate.

To get common understanding about the purpose of the survey, there are two points; one is to clarify the socio economic preconditions for NERICA dissemination in Kenya at farm, community, and district levels, another is to find target farmers or groups, and target communities with positive characteristics and thinking. Based on such survey we can make a strategy of NERICA dissemination into target areas.

2-3. Referable information in Uganda

Factors with positive and significant effect on NERICA yield were pointed out by Y. Kijima, et al. (2005). Those are:

1) Experience in growing rice, especially NERICA
2) Farmers learn desirable cultivation practices from their own experience under less extension service
3) Maintenance of soil fertility through proper crop rotations (soil-nutrient responsive)
4) Timing of planting rice under rainwater shortage (large variations depending on the rainfall)
5) Favorable access to market and rice millers
6) Flat areas
7) Community based seed selection and propagation system

Regarding the factor 7th above-mentioned, the African Rice Center already developed a three-year process so that farmers could evaluate the NERICA varieties for themselves under their own climatic conditions. This consisted of establishing a rice garden in a respected farmer's village that compared many varieties of rice including NERICA. At the end of the season, this plot provided seed for farmers to try five varieties on their own acreages.

After the second growing season, farmers were asked to select only three varieties and to pay for the seed. Experiences were compared at harvest time and key learning about agronomic practices shared. By the third year, the superior characteristics of NERICA rice were appreciated and adopted from agronomic and economic perspectives.

In my survey in Aug. 11, 2005, a farmer told me “if somebody takes a good result, he goes to the farm quickly, and leans how to take it from the farming” in Busia near the boarder to Uganda. He was eager to have NERICA varieties.

2-4. Survey of objective conditions

The survey of objective conditions used to be composed of the followings:

1) Natural conditions in each area for possibility of growing NERICA: rainfall (volume and deficit seasons), soil (fertility of low, midst and high land), topography of farmlands (slope, flat), temperature (cultivation times, taste)
2) Technical factors of NERICA: input-output coefficient of each variety on natural conditions
3) Social conditions: extension activities, community based organization, availability to use micro credit
4) Infrastructural conditions: availability to purchase seeds, fertilizer, access to rice millers

2-5. Survey of farmers’ conditions

The survey also has to clarify farmers’ preconditions for NERICA dissemination:

1) Land ownership (paddy, upland, fallow, virgin; size, topography), borrow and lend of land
2) Times of land use per year, kinds of crops, crop rotation, purposes of production (self consumption or cash earning)
3) The number of family members and labors, working members in agriculture and outside jobs
4) Purchase and input production materials (seeds, fertilizer, insecticides, tools, machines), contract of works
5) Technological level (experience of rice and NERICA production, schooling years, yield of main crops)
6) Sales of agricultural products (city, town, rural market; middleman)
7) Business size (sales of products and purchase of materials in money, credits, risk management)
8) Collection of information (from whom, media)
9) Group or corporate activities (training, workshop, cooperative works, cooperative sales, rehabilitation of canals or roads)

2-6. Survey of farmer’s subjective conditions

Furthermore, the survey must to collect information of farmer’s knowledge and attitude concerned to NERICA. For example:

1) Interest: strong, moderate, nothing
2) Need for cash or self-consumption
3) Knowledge: soil-nutrient responsive, yield, cost
4) Technology: drill seeding, timing, water management, crop rotation

5) Crop relations: competitive, complement, supplement
6) Important matters for success: ranking on technology, seeds, fertilizer, water, miller, market should be collected by the survey

In addition, we should also survey on important constrains such as:
1) Less availability to purchase improved varieties
2) Lack of knowledge
3) Lack of technology
4) Lack of water management and conservation systems
5) Lack of low-cost equipment for land preparation, sowing, weeding, harvesting and threshing
6) Lack of extension services
7) Lack of rice miller
8) Lack of credit for farmers, Low price

We use a ranking method among these factors for evaluating constraints.

We need information of the competitiveness to imported rice in price or taste, too. Consumers do not necessarily buy domestic rice, if domestic rice has high price or less favorite taste comparing with imported rice in the market.

3. Results from one survey in Bungoma

3-1. One survey

One survey was done in April, 2006 in Bungoma and Busia to clarify the precondition of farmers for NERICA dissemination. The survey used a method of interview with questionnaire to farmers was implemented; around 6 young interviewers in each area were trained as enumerators through one day course. Then farmers were interviewed individually by the interviews including the authors. The number of farmers selected through random sampling method was both of 26 in Bungoma and Busia. Farmers' meeting was held for giving information of NERICA to them in each area. Here an analysis of those data in Bungoma was described.

3-2. Some features of paddy farmers

When interviewed farmers were divided into two categories in term of paddy farming; paddy farmers and non-paddy farmers, we can make their characteristics clear in Table 1. in this case, paddy means cultivable land for rice. When we observed actual paddy, it sure had small dikes but they have not maintained well as well as canal in that area. Those paddies have not had any water. In that sense, paddy seemed not to promise stable and high productivity of rice production in Bungoma.

Paddy farmers comparing with non-paddy farmers in Bungoma had have relatively small household members and adult family members.

The decision maker of paddy farmers was a little younger than non-paddy farmers and had taken high education. Paddy farmers also have relatively high rate of non-agricultural jobs. In other words, paddy farmers could take high education and consequently get high rate of non-agricultural jobs. Paddy farmers implemented paddy farming and subsequently suppose to obtain better conditions than non paddy farmers.

Table 1 Paddy and non-paddy farmers in Bungoma

	Household members	Adult family members	Age of decision maker	Male (%)	Secondary or higher education (%)	Non-agr. job (%)
Paddy Farmers	7.7	3.5	42.7	76.9	53.8	53.8
Non-Paddy Farmers	11.0	6.1	44.8	84.6	46.2	38.5

Source: Survey in April 2006.
Note: The number of Samples in case of paddy and non-paddy farmers is 13 and 13, respectively.

Paddy farmers have similar working days in one year to non-paddy farmers, as shown in Table 2. They have a little bit small working days in agriculture than non paddy farmers. But they have much more experience in agriculture and rice farming. They have gotten much more training, i.e., on the one hand 46% of paddy farmers had training and 1.4 times of such training, on the other 31% and 0.9 times in case of non paddy farmers. We can also notice that paddy farmers suppose to have better talent for farming and obtaining other jobs.

3-3. Cultivating areas of farmland by paddy farmers

Table 3 shows cultivating areas in 2006 in paddy farmers and non paddy farmers. Comparing those two types of farmers, we can understand size of their farming. Paddy farmers have averagely around twice of paddy comparing to non paddy farmers. Oppositely non paddy farmers have around twice areas of upland with midst and steep slope. Both of two types of farmers have similar size of fallow added with virgin farmland and subsequently paddy farmers have almost similar but a little bit large size of farmland in total with non paddy farmers, as shown in table 3. Depending on these data, we can think about the productivity of their farmland. Paddy farming in Kenya used to have relatively higher productivity and higher income than non-paddy farming in the same unit of farmland. If it is applicable to this analysis, we can estimate that paddy farmers have better production and income in agriculture than non paddy farmers, because paddy farmers have twice areas of paddy under the similar size of total farmland.

Bungoma is not better for rice production due to unstable rainfall even though farmers want to cultivate it. In this area maize is the most main crop and bean is the second main crop in acres. The allocated area for rice was the third position in both types of farmers, but rice did not contribute to cash earning in Bugoma. For cash earning, sugarcane, finger millet and tomatoes added to maize take more important position for paddy farmers, on the other ground nuts and sweet potatoes have significant for non paddy farmers. Total amount of products sales for both types of farmers are almost similar. But total income is higher for paddy farmers than non paddy farmers. That is 75, 615 KShs for paddy farmers, and 53,076 KShs for non paddy farmers.

Table 2 Period of agricultural experience and training in Bungoma

	Working days per year	Working days in agriculture	Agriculture engagement (Years)	Paddy rice (Years)	Upland rice (Years)	Non-agr. Job (%)	
Paddy Farmers	335	270	21.8	6.1	0.6	46.2	1.4
Non-Paddy Farmers	336	284	20.8	2.3	1.5	30.8	0.9

Source: Survey in April 2006

Table 3 Cultivating Areas of Farmland (acres)

Farmland		Paddy Farmer	Non-paddy Farmer
Paddy		1.77	0.85
Upland	Flat	0.31	0.31
	Midst	0.77	1.39
	Steep	0.00	0.10
Fallow		0.62	0.35
Virgin		0.04	0.35
Total		3.51	3.35
Crop rotation		100%	100%

Note: Paddy means cultivable land for rice

3-4. Factors of affecting farmer's decision to accept NERICA

What are factors to affect farmer's decision for accepting NERICA? A regression analysis was done for clarifying the factors, although the number of samples is not enough for statistics. According to table 5, a variable of interest has a positive and higher coefficient with 1% level of significance. Other variable of production cost has negative parameter with 1% level of significance. A factor of experience of rice farming has positive relation and another factor of age has highly negative regression coefficient with both of 5% level of significant respectively. In other words, young farmers having interest in NERICA and experience of rice production should become the target of extension at first when we try to disseminate NERICA to farmers. The factor of production cost needs to economize much more for farmers.

Table 4 Rank of each commodity based on areas and sales in Bungoma

Crop	Paddy Farmers				Non-Paddy Farmers			
	Areas (Acres)	Rank	Sales (KShs)	Rank	Area (Acres)	Rank	Sales (KShs)	Rank
Maize	2.90	1	14274	1	2.10	1	14885	1
Beans	0.71	2	2577	5	1.32	2	4008	2
Sorghum	0		0		0.17	6	2235	5
Sweet potatoes	0.15	6	1031	8	0.24	5	2882	4
Bananas	0.06	9	0		0.32	4	757	10
Soybean	0.15	6	0		0.17	6	1854	7
Finger millet	0.17	5	3585	3	0.13	9	2123	6
Tomatoes	0.21	4	3302	4	0.06	11	1731	2
Rice	0.47	3	1392	9	0.59	3	894	8
Cassava	0.13	8	1754	7	0.06	11	369	11
Groundnuts	0.06	9	1923	6	0.20	8	3396	3
Kales	0.04	12	346	10	0.09	10	885	9
Sugarcane	0.06	9	3842	2	0		0	
Cotton	0.02	13	47	11	0		0	

Source :compiled by authors

Table 5 Factors of affecting farmer's decision to accept NERICA

Variable	Coefficients
Interest	0.586***
Production Costs	−0.255***
Experience	0.260**
Age	−0.790**
Sex	0.420*
Education	0.002*

Note: ***: 1%, **: 5%, *10% with significant level

3-5. Important factors and major constraints for NERICA dissemination

Farmers were questioned what the important factors and major constraints for NERICA dissemination are?

Farmers thought about important factors shown the figures in table 6. The factor of skill was thought as the important factor by 10 informants among 13 ones. Selling price was the second important factor and milling machine maybe the third.

Concerning to the major constraints, knowledge was the most major constraint due to a new technology for the farmers in Bungoma. Farmers also thought skill and market for NERICA introduction were almost insufficient to them. It shows that the information and practice of NERICA have not been provided to farmers here yet so farmers want to know what is NERICA and how to cultivate it. Milling machine was also thought as a major constraint.

In this regard, let give a glance to ownership of equipment and machine here. Table 7 shows that all equipment and machines used to be hired when farmers use them for their farming. In this regard, to reduce of those hired cost must be expected for almost farmers. On the contrary, it should also notice that milling and threshing machine are owned with one quarter. The farmers who owned such machines maybe contact to treat relevant works with farmers who did not own them. Concerning to pumps, 35% of the farmers borrowed them from the neighbors. We should understand that when farmers in Bungoma implement rice production, they have to do under these conditions.

Table 6　Important Factors and Major Constraints for NERICA

Important Factor for NERICA	Number of High Ranking	Major Constraint	Number of High Ranking
Skill	10	Skill	7
Fertilizer	3	Knowledge	9
Water	0	Water Resource	2
Soil	3	Extension Service	2
Crop Rotation	2		
Threshing Mac.	3	Threshing Mach.	2
Milling Machine	4	Milling Machine	6
Credit	3	Credit	1
Selling Price	7	Market	7

Source: Survey in April 2006
Note: The numbers in the table show high ranked responds by interviewees who belong to the paddy farmers group with 13 samples. For example, 10 mean that 10 interviewees pointed the factor as important one.

Table 7　Percentage Response to Equipment Ownership

Ownership	Equipment and Machines (%)			
	Pumps	Milling	Threshing	Tractor
Self	11	23	23	0
Hired	54	65	58	85
Neighbor	35	12	19	15
Total	100	100	100	100

Source: Survey in April 2006

Current materials for rice production such as seeds and fertilizer were obtained by farmers in Bungoma as shown in table 8. Maize seed, chemical fertilizer and pesticide were bought by farmers generally. Manure used to take by themselves in most cases. On the other, rice seed obtained 50% from the neighbors and 20% by themselves. Farmers bought only 30% at market. When people try to disseminate NERICA technology, this kind of farmers' behavior should be thought about.

In addition, making good soil fertility contributes to better harvest in agriculture, as well known. Farmers in Bungoma used to feed livestock for tanking meat and manure shown in table 9.

Cattle feeding is very general for farmers. They use not only cattle's draft for their farming but also take meat, milk and manure. So farmers do not necessarily have manure the amount of manure maybe insufficient to increase rice yield or less developed skill for soil fertilization.

Table 8 Response to sources of farm inputs

Farm Input	Response (%)		
	Self	Buy	Neighbor
Maize Seed	15	81	4
Rice Seed	19	30	51
Chemical Fertilizer	-	85	15
Manure	73	12	5
Pesticide	1	96	3

Source: Survey in April 2006

Table 9 Type of livestock and their feeding purposes

Type of Livestock	Mean number Kept	Purpose for keeping livestock (○)				
		Meat	Milk	Eggs	Manure	Draft
Chicken	14	○		○	○	
Cattle	4	○	○		○	○
Goats	1	○			○	
Sheep	1	○			○	
Pigs	1	○			○	

Source: Survey in April 2006

4. Conclusions

1) An analysis of decision making regressed on selected variables indicated that interest, experience and sex can positively affect to acceptance of NERICA significantly, on the contrary age and production costs suppose to affect negatively efficient dissemination of NERICA technology.

2) Rice production in Bungoma has not been stable and high productivity comparing other crops, even though paddy farmers have positive attitude to rice farming. Rice production was considered as both food and cash crop with emphasis laid on self consumption.

3) Farmers obtain rice seed mainly from neighbors. It suggests that there is no organized seed production system.

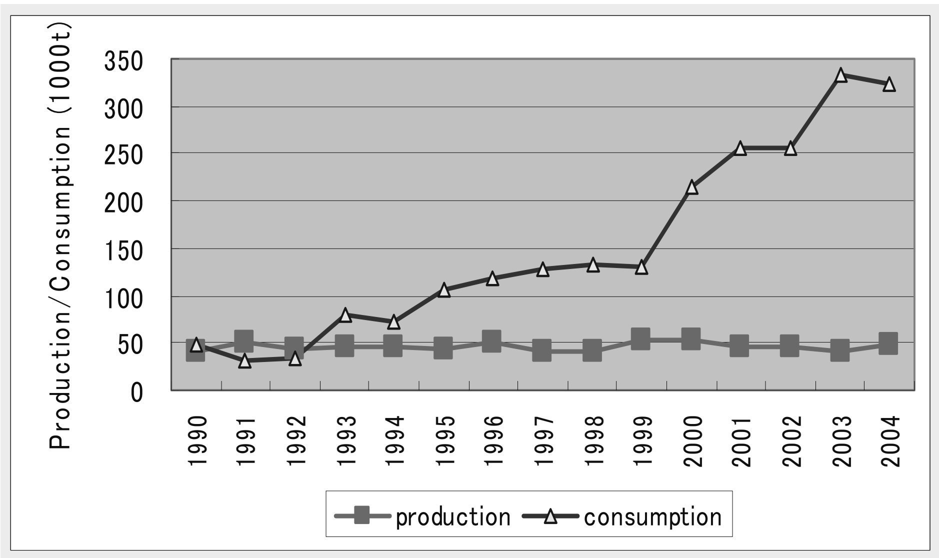
4) Farmers have not yet understood NERICA technology in almost. They require skill, knowledge and market as well as milling machine. So to achieve effective diffusion of NERICA technology, there are needs not only to ensure availability of high quality seed, but also to provide sufficient workshops through extension works. Opportunities are available for increasing rice production through participatory and effective diffusion of NERICA technology.

5) To achieve these Governmental interventions is therefore necessary to address identified constraints which include lack of knowledge of NERICA, inadequate farmer support policies, high cost of farm inputs and lack of appropriate equipment.

Socioeconomic Factors Needed for NERICA Dissemination in Kenya

20th October, 2006
Hiroyuki Takeya, Nagoya University
&
Newton Okech, KARI Kibos

Fig. 1 Production and consumption of rice in Kenya



Rice production has rapidly increased for these years and become a main food commodity in many Kenyan households, due to its urbanization and increase in population.

1. Background situation

The production and consumption of rice in 2005 in Kenya stood at 85,000 and 310,951mts, respectively. The deficit of approximately $170 million (CBIK, 2005) was covered by import.

The low rice production can be explained on the one hand by the limited cultivated land for rice and on the other hand the low average yields of conventional varieties, Dourado Precoce (1.5 tons/ha) and IR2793-80-1(3.5tons/ha), under the rainfed and irrigated cultures, respectively.

There are potential areas of 400,000 and 650,000 ha, for upland and lowland/irrigated environments, respectively.

Most of Kenyan farms range from 0.5 ha to 2 ha under their subsistent farming.

2. Necessary survey to clarify preconditions of NERICA diffusion

2-1. Where has the research of rice in Kenya comes up to?

- Rice research in Kenya was initiated in 1980's at Kibos and Mwea Tebere. The adaptive rainfed rice research conducted between 1991 and 1995 resulted in the evaluation and selection of 6 upland and 4 lowland rainfed cultivars for grain yield and cooking quality (Kouko *et al* 1995).
- In a continued effort to develop high yielding rainfed rice varieties, NERICA was introduced from West Africa Rice Development Association (WARDA). The NERICA cultivars have the potential to increase rainfed rice yield to 3.5 tons/ha and irrigated rice yield to 6.0 tons/ha. KARI and its partners have carried out NERICA adaptability tests focusing on yield and drought tolerance in 11 sites, then resulted in selection of NERICA 11 and 4 that were being considered for release in 2006.

2-2. Necessary survey

Following the selection of NERICA 11 and 4, it became necessary to carry out analysis of the preconditions of diffusion as a strategy geared towards achieving high adoption rate.

2-3. To get common understanding about the purpose of the survey

- To clarify socioeconomic preconditions for NERICA dissemination in Kenya at farms, communities and in district levels.
- To find the target farmers/groups/communities with positive characteristics and thinking.
- To plan strategies for NERICA dissemination into the target areas.

2-4. Referable information in Uganda

Factors producing positive and significant effects on NERICA yields (Y. Kijima, et al. 2005)

– Experience in growing rice, especially in NERICA

– Farmers can learn about desirable cultivation practices from their own experience under less extension service.

– Maintenance of soil fertility through proper crop rotations (soil-nutrient responsive)

– Timing of planting rice under rainwater shortage (large variations depending on the rainfall)

– Favorable access to market and rice millers

– Flat areas

2-5. Referable information (continued)

Community-based seed system

- The African Rice Center developed a three-year process so that farmers could evaluate the NERICA varieties for themselves under their own climatic conditions. This consisted of establishing a rice garden in a respected farmer's village that compared many varieties of rice including NERICA. At the end of the season, this plot provided seed for farmers to try five varieties on their own acreages.
- After the second growing season, farmers were asked to select only three varieties and to pay for the seed. Their experience was compared during harvest time, and the key learning about agronomic practices were shared. By the third year, the superior characteristics of NERICA rice were appreciated and adopted from their agronomic and economic perspectives.
- A farmer told me "if somebody yields a good result, he goes, observes and learns quickly how to take it from the farmer's farming" in Busia. Aug. 11, 2005.

2-6. Objective conditions survey

1) Natural conditions in each area for possibility of growing NERICA
   Rainfall: volume, deficit seasons
   Soil: fertility in each land block (low, middle, high)
   Topography of farmlands such as slope: flat
   Temperature: cultivation times, taste
2) Technical factors of NERICA
   Input-output coefficient on a variety of natural conditions
3) Social conditions
   Extension activities, community-based organization, availability to micro credit
4) Infrastructural conditions
   Availability of seeds and fertilizer, access to rice millers

2-7. Farmers' conditions survey

1) Land ownership (paddy, upland, fallow, virgin; size, topography), land borrowing and lending
2) Time period of land use per year, kinds of crops, crop rotation, purpose of production (self-consumption or to make cash)
3) The number of family members/labors, workforce members for agriculture and outside jobs
4) Purchase and input of production materials (seeds, fertilizer, insecticides, tools, machines), employment contracts
5) Technological level (experience in rice or NERICA production, schooling years, yields of main crops)
6) Sales channel of agricultural products (city, town, rural market, middleman, contract)
7) Business size (product sales and material purchase in money or credits, risk management)
8) Collection of information (from who/which media)
9) Group or corporate activities (training, workshops, cooperative works, cooperative sales, rehabilitation of canals/roads)

2-8. Farmer's subjective conditions survey

Concerning NERICA:

1) Interest: high, moderate, no-interest
2) Need for: cash, self-consumption
3) Knowledge: good, moderate, not good
   soil-nutrient responsive, yields, cost
4) Technology: high, moderate, low
   drill-seeding, timing, water management, crop rotation
5) Crop relations: competitive, complements, supplements
6) Important matters for success: ranking
   technology, seeds, fertilizer, water, millers, markets

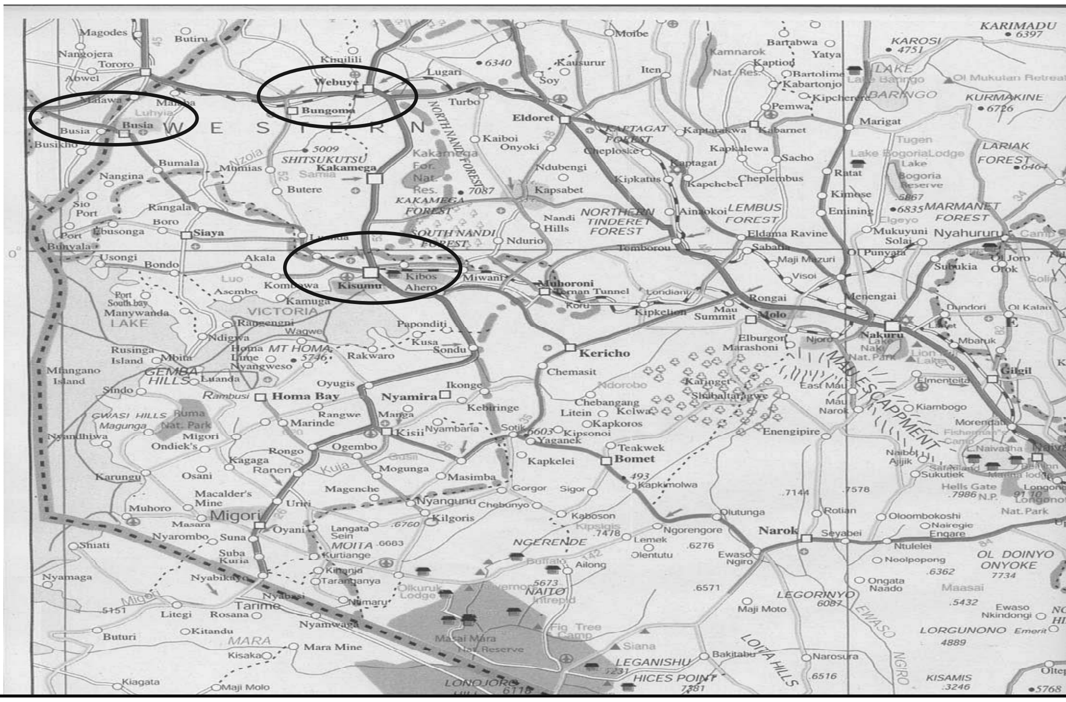
2-9. Farmer's subjective conditions (2)

Important constrains: ranking

- Less availability of improved varieties
- Lack of knowledge
- Lack of technology
- Lack of water management and conservation systems
- Lack of low-cost equipment for land preparation, sowing, weeding, harvesting, threshing.
- Lack of extension services
- Lack of rice millers
- Lack of credit for farmers
- Low price

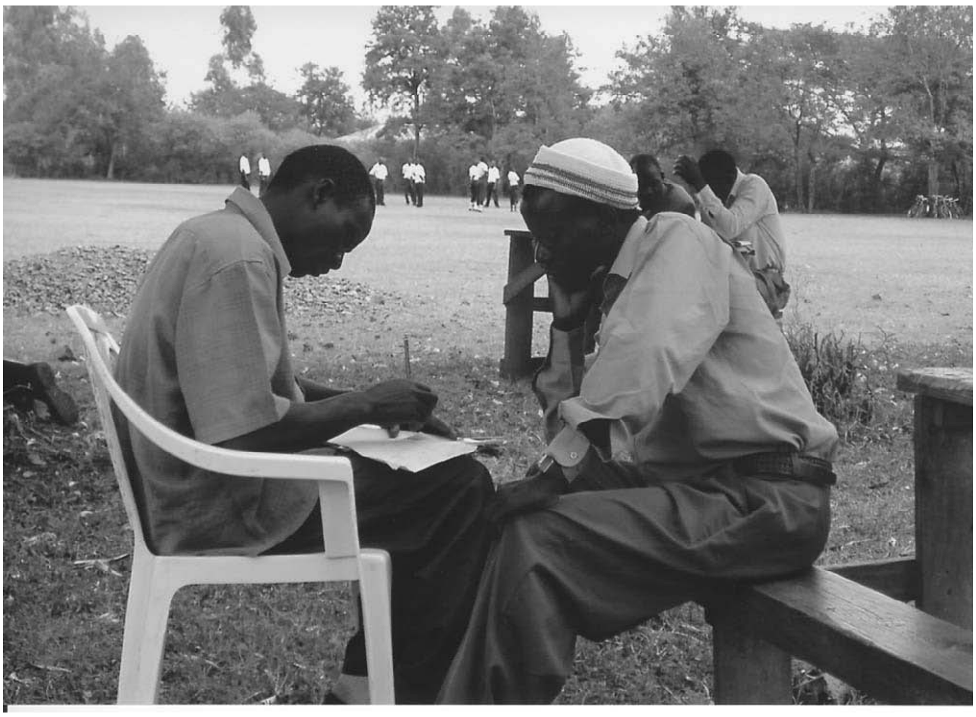
  Competitiveness in the market: price or taste

3-1. Locations of survey areas: Bungoma, Kisumu, and Busia

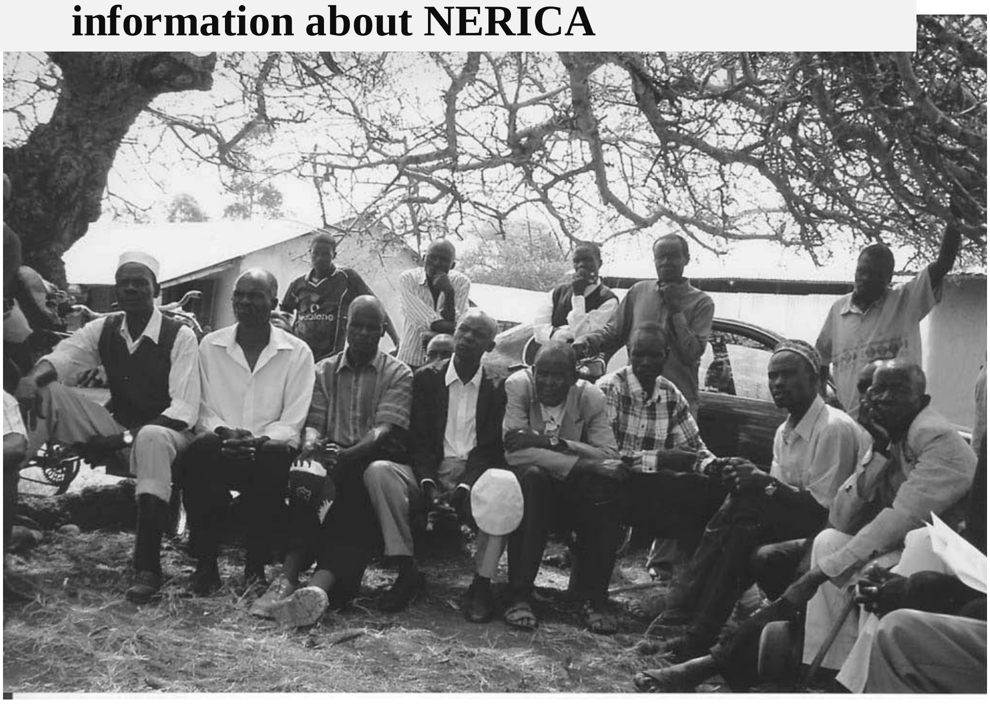


3-2. Training enumerators

3-3. Interviewing farmers



3-4. Farmers Meeting for exchanging information about NERICA



3-5. Data analysis

Table 1 Paddy and non-paddy farmers in Bungoma

	Household members	Adult family members	Age of decision maker	Male (%)	Secondary or higher education (%)	Non-agr. Job (%)
Paddy Farmers	7.7	3.5	42.7	76.9	53.8	53.8
Non-Paddy Farmers	11.0	6.1	44.8	84.6	46.2	38.5

Source: Survey in April 2006

Note: The number of samples: paddy and non-paddy farmers are 13 and 13 respectively.

Table 2 Time periods of agricultural experience and training in Bungoma

	Working days per year	Working days per year in agriculture	Agriculture (years)	Paddy rice (years)	Upland rice (years)	Training	
						(%)	(Times)
Paddy Farmers	335	270	21.8	6.1	0.6	46.2	1.4
Non-Paddy Farmers	336	284	20.8	2.3	1.5	30.8	0.9

Source: Survey in April 2006

Table 3 Farmland areas owned/managed by farmers

(acres)

Farmland		Paddy Farmer	Non-paddy Farmer
Paddy		1.77	0.85
Upland	Flat	0.31	0.31
	Middle	0.77	1.39
	Steep	0.00	0.10
Fallow		0.62	0.35
Virgin		0.04	0.35
	Total	3.51	3.35
Crop rotation		100%	100%

Table 4 Ranking of commodity items based on the mean land allocations and associated mean gross-incomes in each areas

Crop	Mean land allocation (Acres)	Rank	Mean gross income (KShs)	Rank
Maize	2.5	1	14030	1
Beans	1.1	2	2853	4
Sorghum	0.5	3	1143	9
Sweet potatoes	0.2	4	1956	6
Bananas	0.19	5	378	13
Soybean	0.16	6	926	11
Finger millet	0.15	7	2659	5
Tomatoes	0.14	8	7708	2
Rice	0.13	9	3193	3
Cassava	0.1	10	1061	10
Groundnuts	0.09	11	1162	8
Kales	0.06	12	615	12
Sugarcane	0.03	13	1921	7
Cotton	0.01	14	23	14

Source: Complied by the researchers

Table 5 Maize production in Bungoma

	Maize Area (acres)	Maize production (t)	Maize yileds (t)	Home consumption	Sale		Channel (%)		
					(KSs)	(%)	town	middleman	consumer
Paddy Farmers	2.9	17.3	5.96	44	14,275	56	18	55	27
Non-Paddy Farmers	2.1	22.8	10.86	52	14,885	48	18	64	18

Source: Survey in April 2006

Table 6 Factors possibly affect farmer's decision-making to accept and adopt NERICA

Variable	Coefficients
Interest	0. 586***
Production Costs	−0. 255***
Experience	0. 260**
Age	−0. 790**
Sex	0. 420*
Education	0. 002*

Source: Survey in April 2006
Note: The significance levels are indicated as *** 1%, ** 5%, and * 10%.
Adj. R^2: 0.73

Table 7 Type of livestock and their feeding purposes

Type of Livestock	Mean number kept	Purpose				
		meat	milk	eggs	manure	draft
Chickens	14	*		*	*	
Cattle	4	*	*		*	*
Goats	1	*			*	
Sheep	1	*			*	
Pigs	1	*			*	

Source: Survey in April 2006
* Purpose of keeping livestock

Table 8 Response percentage on sources of farm inputs

Farm Input	Response percentage (%)		
	Self	Buy	Neighbors
Maize seed	15	81	4
Rice seed	19	30	51
Chemical fertilizer	-	85	15
Manure	73	12	5
Pesticide	1	96	3

Source: Survey in April 2006

Table 9 Response percentage on equipment ownership

Ownership	Equipment (%)			
	Pumps	Milling	Threshing	Tractor
Self	11	23	23	0
Hire	54	65	58	85
Neighbors	35	12	19	15
Total	100	100	100	100

Source: Survey in April 2006

Table 10 Important factors and major constraints regarding NERICA

Important factor for NERICA	Number of high ranking	Major constraint	Number of high ranking
Skill	10	Skill	7
Fertilizer	3	Knowledge	9
Water	0	Water resource	2
Soil	3	Extension service	2
Crop rotation	2		
Threshing machine	3	Threshing machine	2
Milling machine	4	Milling machine	6
Credit	3	Credit	1
Selling price	7	Market	7

Source: Survey in April 2006
Note: The numbers in this table indicate the high ranked responses from interviewees who belong to the paddy-farmers' group with 13 samples.

4. Conclusions

1) Factors regressing their decision making on the selected variables indicated: interest, experience, sex and education can positively affect their decision making to accept NERICA; and age and production costs can significantly and negatively affect that.

2) Rice is considered as a food and also a cash crop; their purpose in generating income is emphasized. Rice is ranked 9th and 3rd in terms of land use and income generation respectively.

3) Farmers can obtain the rice seeds mainly from neighbors; it is suggested that there is no organized seed production system.

4. Conclusions (continued)

4) In order to achieve effective diffusion of NERICA, it is required to ensure the availability of high quality seeds. Opportunities are available for increasing rice production through participatory and effective diffusion of NERICA.

5) Achieving these government interventions therefore needs to address identified constraints such as lack of knowledge about NERICA, inadequate farmer support policies, high cost of farm inputs, and lack of appropriate equipment.

5. Necessary analysis on marketing and competitiveness of rice sugarcane as a cash crop in the Migori district

質疑応答
Question and Answer Session

ケニヤにおけるネリカ米普及に具備すべき社会経済的要素
Socioeconomic Factors for NERICA Dissemination in Kenya

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司会：　杉本　充邦　　Chair person: Mitsukuni Sugimoto
名古屋大学農学国際教育協力研究センター　准教授
Associate Professor, ICCAE, Nagoya University

Sugimoto, Chair:

Thank you very much Professor Takeya, about how the Kenyan farmers are introducing NERICA varieties. From the floor, are there any questions for Professor Takeya?

Ishii:

Your background situation, the Kenyan situation, you have potential areas of 0.4 million for upland and 0.65 million for lowland. My question is, though I know your target is NERICA dissemination, for sustainable rice production, how do you think about the priority when comparing the upland and lowland?

Takeya:

It's really difficult question for me, because this information comes from KARI Kibos and I'm not sure about the actual conditions of targeting areas with high possibility. I'm sorry for that. At least I can say that the staff of KARI Kibos which is the major research institution want to disseminate NERICA broadly not only into lowland but also upland. MAFF of Kenya has been thinking to disseminate NERICA to upland because NERICA can have high possibility to grow well even on upland.

Dr. Onyango, could you help me, if you have some ideas or information on this question?

Sugimoto, Chair:

Are there any questions or comments from other participants?

Yamauchi:

In Table 6, you showed us the results, how and what factors the farmers took when they accept NERICA varieties. The results of your survey showed that the factors such as lower cost, longer experience, and younger age would positively affect their decision making on selecting NERICA varieties. That is how I understand. You also showed the factor of sex, men and women. Which are more interested in introducing NERICA?

Takeya:

For the factor of 'sex' which would affect farmer's decision as to whether or not they accept and adopt NERICA, we put '1' to men, and '0' to women. So, the results of this multi-regression analysis is read as: '0.42' means 'positive' effect on their adoption of NERICA cultivation with the coefficient of 0.42 when the decision maker in cultivation is a male farmer. When the decision maker is a female farmer, this calculation does not indicate anything. I should try another calculation putting '1' to women and '0' to men. But I am sorry I don't have such results here.

Yamauci:

I think the most important factor is their interest in NERICA. And my question is, what causes or what makes the farmers interested in NERICA? What is the factor that makes the farmers interested in it? What does the "interest" mean here?

Takeya:

Thank you for the important question. When we interviewed the farmers to question on NERICA cultivation, some farmers did not have much information about NERICA. But they have little information such as drought tolerance or early maturity. Even if they don't have such information, they would have keen interest in NERICA introduction. In our interviews to some farmers, they showed their interest in NERICA and asked us, 'What is NERICA?', 'What is the main characteristics of NERICA?' etc. Once they are given such information of NERICA characteristics, they would think they want to introduce NERICA as early as possible. So, if the farmer answered so, we put '1' to this factor, 'interest'. If they didn't have any interest even if they heard of such information, we put '0'. Then, we calculated like this result.

Sugimoto, Chair:

Any other questions? Regarding Professor Yamauchi's question, Professor Onyango will give us additional comments.

Onyango:

Thank you. I would like to make a comment about Prof. Yamauchi's comment about men and women. Actually the problem we have is that, it is the women who are actually more active in agriculture. The women according to our statutory set up do not own land. In other words you might have groups of women who want to participate in NERICA cultivation. Since they don't have land, they have to get permission from their husbands. If you look at my abstract where I am talking about the land tenure system which needs to be changed, women can be empowered to own land. That's one of the major reasons, which is the land ownership and production. But NERICA activities are more active with women groups than men groups. Women are the main NERICA cultivators. The other question about the land acreage:

I think the trend is going towards the upland production rather than irrigated. The kind of infrastructure which goes with the paddy rice production is rather expensive for most small holder farmers. Because these problems, most farmers tend to go for upland rice production, based on rainfall but if there is any irrigation, it will be by gravity from rainfall harvested water or from small streams. The are three rice irrigation systems for lowland rice in Kenya which are situated in Ahero, West Kano and Bunyala in Western Kenya, Mwea Tabere in Central and Bura in North Eastern Kenya, but all of them are performing under capacity. In Western Kenya electricity if used to pump water and as the cost of electricity goes up, it becomes expensive to supply water while in Central and North Eastern Kenya, gravity irrigation is used but during droughts the level of rivers go down. In a nut shell, we are moving towards upland condition.

Sugimoto, Chair:

Thank you very much. Any other questions? Thank you very much, Professor Takeya.

Profile

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1973 年名古屋大学大学院農学研究科博士課程農学専攻満了。1973 年 4 月日本学術振興会奨励研究員になった後、1973 年 10 月名古屋大学農学部助手に採用され、都市化・工業化と農民層分解の研究で 1976 年農学博士(名古屋大学)を授与された。次いで農村労働市場と兼業農業の再編の研究、並びに農業・農村基盤整備投資の経済効果の研究に従事。1989 年 4 月名古屋大学農学部助教授に昇任し、水田農業の担い手研究などに従事。1992 年 4 月同学部教授に昇任した。1998 年 4 月から 2000 年 3 月名古屋大学評議員を務め、1999 年 4 月大学院重点化に伴い、名古屋大学大学院生命農学研究科教授となる。1999 年 4 月から 2007 年 3 月まで名古屋大学農学国際教育協力研究センター長を併任し、2009 年 3 月の定年退職後も精力的に研究活動に携わっている。専門分野は農業経済学・国際地域開発学、現在日本農業市場学会会長、日本農業経済学会副会長、日本国際地域開発学会副会長。

Academic career

Professor Hiroyuki Takeya received Ph.D. from Graduate School of Agriculture, Nagoya University, in 1976.

Professional career

Professor Hiroyuki Takeya was a research fellow of Japan Society for the Promotion of Science in 1973. In October of the same year, he started to work for School of Agriculture, Nagoya University, as Assistant Professor in agricultural economics. He studied developing processes of Japanese farming and mechanisms for capacity building of farmers, and on part-time farming related to development of Toyota Automobile Industry, etc. He was promoted to Associate Professor in 1989 and to Professor in 1992, School of Agriculture, Nagoya University, and Professor, Graduate School of Bioagricultural Sciences of the same university in 1999. Professor Takeya served as a council member of Nagoya University from 1998 to 2000. He supervised more than 19 Japanese and international students for their doctoral thesis since 1992. Professor Takeya assumed International Cooperation Center for Agricultural Education, ICCAE, as Director from 1999 to 2007. Even after his compulsory retirement in 2009, Professor Takeya has been actively working on his research fields and as an expert of policy making and evaluation for central and local governments in Japan.

Profile

ジョセフ・ニュートン・O・オケチ　Joseph Newton O. Okech

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オケチ氏は、1978 年、ケニア国立農業研究所（ナイロビ）に圃場試験指導監督技術補佐として採用された。1984 年同研究所に在籍しつつ、エジャートン大学農学部に入学、1987 年同学部を卒業、同年圃場管理主任に昇格し、圃場試験の技術面と資源有効利用の面から圃場管理運営を担当した。1990 年に社会経済学研究助手となり、1992 年、ケニアの主要稲作地帯にある同研究所キボス試験場に異動し、天水条件下における稲作適応研究の主任として 1996 年まで指導監督に当たった。1997 年から 1999 年まで、ギボス試験場の社会経済学研究に関わる立案・実施を指導し、2000 年には社会経済学研究部長に昇格した。この間、1997 年ロンドン大学大学院修士課程農業経済学コース入学、2002 年同コースを修了し、農業経済学修士を得ている。2001 年から現在まで、研究普及活動の統括者として、また農業技術・情報普及イニシアチブ・コーディネーターとして技術普及に携わり、現在に至っている。

Academic career

Mr. Joseph Newton O. Okech graduated from School of Agriculture, Egerton University of Kenya in 1987.

Professional career

Mr. Joseph Newton O. Okech joined KARI in 1978 as a technical assistant, before he pursuing his degree at the School of agriculture of Egerton University in 1984. After his graduation he was simultaneously promoted to a farm manager of KARI in 1987 where he ensured efficient resource allocation through development of farm plan for research and revenue generation activities. He became an officer in charge of on-farm rainfed rice trials in West Kenya in 1992; he then served as an assistant socio economist in 1997. He was again promoted to a coordinator at Agricultural Technology and Information Response Initiative (ATIRI) in 2001 and also worked in charge of research extension liaisons during 2001 to 2006. He has collaborated with ICCAE staff as a research fellow for technology dissemination research of NERICA in Kenya in 2006. Mr. Joseph Newton O. Okech is currently the head of Socio Economic Section in Kenya Agricultural Research Institute (KARI) Kibos Center where he is mainly facilitating priority setting for rice and cotton research and conducting impact assessment/adoption studies on cotton and rice technologies on farmers' fields.

サブサハラアフリカでは何故緑の革命の実現が遅れたか？：水田仮説（１）
Why was the Green Revolution not Successful in Sub-Sahara Africa?: Sawah (Suiden) Hypothesis (1)

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Abstract

The green revolution has yet to occur in SSA due to the lack of the necessary prerequisite conditions. The lacking of the concept and appropriate technical term, therefore lacking appropriate research and the development of “sawah” technology made confusion in the research and development of rice cultivation in SSA. Contrary to Asian farmers’ fields, farmers’ fields in SSA, and specifically their farming technologies, are not ready to accept irrigation, fertilizer and high yielding varieties (HYV). Although research and development on irrigation, fertilizers and HYV has been discussed for the last thirty years, the discussions have not touched on whether the prerequisite conditions are lacking in SSA. The concept and technologies of sawah is such an example. The term “sawah” refers to leveled and bunded rice fields with inlet and outlet connecting irrigation and drainage. The term originates from Malayo-Indonesian. The English term, Paddy or Paddi, also originates from the Malayo-Indonesian term, Padi, which means rice plant. In order to avoid confusion between upland paddy fields and man-made irrigated rice growing environment, lowland paddy fields, the author proposes to use the term “sawah” in West Africa.

Simply speaking, the basic infrastructures for green revolutions are lacking. The potential of sawah based rice farming is enormous in SSA, especially in West Africa. Ten to twenty million ha of sawah can produce additional food for more than 300 million people in future. The sawah based rice farming can overcome both low soil fertility and scarce water resources through the enhancement of the geological fertilization process, conserving water resources, and the high performance multi-functionality of the sawah type wetlands. Irrigation without farmers’ sawah farming technologies has proved inefficient or even damaging because of accelerated erosion and waste of water resources. In the absence of water control, fertilizers cannot be used efficiently. Consequently, the high yielding varieties perform poorly and soil fertility cannot be sustained hence green revolution cannot take place.

Although the upland was the major rice ecology 15 years ago, it seems now upland is not and will not be the major rice production ecology in Sub Sahara, especially in West Africa. This is the very promising change to complete the green revolution finally in this region. Between 1984 and 1999/2003, annual paddy production dramatically increased from 3.4 to 7.7 million tones in West Africa. Major increases were from the expansion and yield increases of rainfed lowland, mainly inland valley, i.e. 0.75 to 3.4 million tones of annual paddy production during the same period. Expansion and the yield increase of irrigated lowland were the second contributors. From 1984 to 1999/2003, annual paddy production from irrigated ecologies has increased from 0.64 to 1.9 million tones. Only very minor contributions were from the rainfed upland, i.e. 1.5 million tones of paddy in 1.5 to 1.8 million tones of paddy during the same period.

These trends clearly show natural resource management technology, especially through the improvement of water control in lowland, especially rainfed lowland, also played a major role in increasing rice production last 15 years. If this good intensification trend will be enhanced properly, the green revolution will be realized in this region within next 10-20 years.

Materialization of African Rice Green Revolution by Sawah Eco-technology: Concept Paper of New Sawah Project, 2007-2011

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Abstract

Even 40 years after the success in tropical Asia and Latin America, the green revolution is yet to be realized in Sub Sahara Africa (SSA). The materialization of rice green revolution is the major target of the millennium development goals of the United Nations. Although the breeding of high yielding varieties (HYV) by biotechnology was the core technology in Asian and Latin American green revolution and which the African Rice Center, WARDA, has innovated in NERICA technologies, the successful path to the green revolution in SSA is still unclear. The paper discussed the Sawah hypothesis (I) and (II). The first Sawah hypothesis (I) explains that the central to the realization of the rice green revolution in SSA is eco-technologies, which can improve farmers rice growing environment, such as lowland sawah eco-technologies. The second Sawah hypothesis (II) explains that sustainable rice productivity of lowland sawah is more than 10times than that of upland rice fields, if appropriate lowlands are selected, developed and managed. Contrary to Asian farmers' fields, the majority of farmers' rice fields in SSA are not ready to accept the three basic components of the green revolution technologies, i.e., (1) irrigation for water supply, (2) fertilizer for soil nutrient supply, and (3) high yielding varieties (HYV). Although researchers have worked seriously on the effect of irrigation, fertilizers and HYV for the last forty years, the researchers have not touched on whether the prerequisite conditions which can accommodate the three basic components of the green revolution exist or not in SSA. The concept and technologies of Sawah is such an example. The term sawah refers to leveled, bunded, and puddled rice field with water inlet and outlet to control water and manage soil fertility, which may be connecting irrigation and drainage facilities including sawah to sawah irrigation and drainage. The term originates from Malayo-Indonesian. The English and French terms, Paddy or Paddi, also originated from the Malyo- Indonesian term, Padi, which means rice plant. In order to avoid confusion between upland paddy fields and man-made leveled, bunded and puddled rice fields, i.e., typically irrigated rice ecology, which is inappropriately used as lowland paddy fields, the authors propose to use the term "Sawah" in SSA. Simply speaking the basic infrastructures for the green revolution are lacking in the farmers' fields of SSA. Irrigation without farmers' sawah farming technologies has proved inefficient or even damaging because of accelerated erosion and waste of water resources in SSA. In the absence of water control, fertilizers cannot be used efficiently. Consequently, the high yielding varieties perform poorly and soil fertility cannot be sustained, hence the green revolution can not be achieved. The potential of Sawah based rice farming is enormous in SSA, especially in West Africa. Ten to twenty million ha of sawah can produce additional food for more than 300 million people in future. The sawah based rice farming can overcome both low soil fertility and scarce water resources through the enhancement of multi-functionality of sawah type wetlands as well as geological fertilization processes in watersheds. The sawah systems can even enhance the restoration of degraded watershed through the sustainable expansion of afforestation to form a watershed agro-forestry, which will combat global warming in future.

Introduction

The green revolution has yet taken place in West Africa and Sub Sahara Africa (SSA)(FAOSTAT 2006, Evenson and Gollin 2003). Although food crops are very diverse, per capita total production of major food crops has been stagnating between140-170kg in SSA as seen in Table 1. In tropical Asia, because of the green revolution, the figures increased from 205kg in 1961-1965 more than 280kg in 1996-2000 (Table 1). This is the foundation of high difference of economic growth between SSA and Asia at present. Now Asia is a global center of economic growth thanks to the green revolution that started in 1970s.

Due to high water content (60-70%) of root and tuber crops, such as yam and cassava, the energy per kg is one third of cereals, such as rice, wheat and maize. In addition, the protein and minerals content of yam and cassava are only one fourth to one fourteenth in comparison with cereals. Therefore, the production data of FAO are shown after division by the factor of 8 for cassava and 5 for yam. These factors of 8 or 5 are only tentative, which were used only for reach to the estimation of reasonable cereals' equivalents for comparison in the Table 1 (FAOSTAT 2006, Kiple and Ornelas 2000, Sanchez 1976). Also the following historical observation in Asia adds to the argument. Root and tuber based food had changed to cereals based food, such as rice and wheat. In future, cereals, especially rice, will be more important than now in SSA (FAOSTAT 2006). Although the cereals' equivalents are tentative values, the trend data show the difference of Asia and SSA during 1960-2003. As shown in (Fig. 7) later, mean rice yield has increased from 1.8 t/ha to 4.0 t/ha in Asia, but the yield has stagnated between 1.2 to 1.5 t/ha in SSA during 1960 - 2005.

Table 1 Five years' means of major cereals' production and importation per person last 40 years in Asia and Sub-Sahara Africa (FAO STAT 2006).

Note: Because of water content of Cassava and Yam are high (60-70%) and low mineral & protein content in comparison with the other cereals, the production data of FAO were divided by 8 for Cassava and 5 for Yam to estimate cereals equivalent (Sanchez 1976, Kiple and Ornelas 2000).

Africa - South of Sahara: Food Production (kg/person)

Year	1961-1965	1966-1970	1971-1975	1976-1980	1981-1985	1986-1990	1991-1995	1996-2000	2001-2003
Rice, Paddy	16.3	17.5	18.2	17.6	17.3	19.2	19.2	19.9	18.1
Wheat	8.1	8.4	7.7	6.8	6.7	6.8	6.2	6.3	6.2
Maize	42.5	44.3	45.0	43.4	40.3	50.6	46.6	46.2	42.2
Cassava (1/8)	18.8	18.6	18.4	18.1	17.6	18.0	20.2	19.5	19.7
Yams (1/5)	7.8	10.8	8.8	6.6	5.6	6.6	11.5	11.9	11.6
Sorghum	44.7	38.3	34.0	31.5	31.1	30.8	31.2	31.3	31.9
Millet	31.7	29.3	27.8	23.3	21.2	23.0	22.1	22.3	21.8
Paddy Rice-Import	3.8	3.8	4.3	7.7	10.3	8.8	9.0	8.3	9.9
Wheat-Import	4.5	6.0	7.4	9.7	11.8	10.2	11.2	13.1	15.7
Total*	169.8	167.2	159.9	147.4	139.5	154.9	157.1	157.3	151.6

Asia: Food Production (kg/person)

Year	1961-1965	1966-1970	1971-1975	1976-1980	1981-1985	1986-1990	1991-1995	1996-2000	2001-2003
Rice, Paddy	124.5	131.8	134.2	137.4	148.8	149.8	147.1	149.8	141.1
Wheat	41.6	44.2	49.6	57.6	67.0	70.6	79.0	78.4	72.2
Maize	19.6	23.9	26.1	31.3	34.0	38.0	41.8	45.0	43.3
Cassava (1/8)	1.4	1.4	1.5	2.1	2.2	2.1	1.9	1.7	1.8
Yams (1/5)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Sorghum	9.6	9.7	8.3	8.2	7.1	5.9	5.0	3.8	3.0
Millet	8.6	9.5	7.8	6.6	6.3	4.9	4.2	3.8	3.6
Paddy Rice-Import	3.7	3.4	3.1	3.0	2.4	2.2	2.3	3.9	3.7
Wheat-Import	10.7	11.4	11.7	12.0	13.7	14.6	15.0	13.5	11.7
Total*	205.3	220.4	227.6	243.1	265.4	271.4	279.0	282.5	265.3

West Africa: Food Production (kg/person)

Year	1961-1965	1966-1970	1971-1975	1976-1980	1981-1985	1986-1990	1991-1995	1996-2000	2001-2003
Rice, Paddy	18.4	21.1	21.9	22.1	23.8	27.4	29.3	31.4	28.2
Wheat	0.3	0.3	0.2	0.2	0.4	0.6	0.3	0.4	0.3
Maize	27.1	27.2	23.5	18.6	21.9	42.6	48.7	41.4	38.6
Cassava (1/8)	16.6	17.3	16.4	16.7	14.8	16.8	25.3	25.3	24.7
Yams (1/5)	17.8	25.0	20.5	15.2	12.8	15.4	27.4	28.3	27.6
Sorghum	70.6	56.7	47.0	40.3	42.1	46.5	48.6	47.9	47.2
Millet	59.8	54.0	52.7	42.4	41.6	48.0	45.7	45.4	44.6
Paddy Rice-Import	5.3	5.8	6.2	13.2	17.4	15.3	16.7	15.7	19.1
Wheat-Import	4.0	5.8	8.0	13.3	14.3	9.6	11.4	13.8	16.7
Total*	210.7	201.6	182.2	155.5	157.3	197.3	225.3	220.1	211.3

Total*: Excluding the imports of paddy rice and wheat.

As seen in Table 1, West Africa is a core region of SSA in terms of the rice production and importation as well as rice consumption. Therefore the authors discussed mainly West Africa in this strategic paper.

As shown in Table 2, although upland was the major rice ecology 15 years ago, it is no more the largest rice production ecology in West Africa now. If this trend continues, upland rice production ecology will be very small in SSA especially in West Africa in the near future (Table 2: The data were compiled from FAOSTAT 2006, WARDA 1988, 2002, and 2004, JICA 2003). This is however very promising change to realize the green revolution finally in West Africa and SSA. Between 1984 and 1999/2003, annual paddy production increased dramatically from 3.4 to 7.7 million tones in West Africa. Major increases were from the rainfed lowland rice ecology, mainly inland valley, which expanded the area from 0.53 to 1.8 million ha and yield increased from 1.4 to 2.0 t/ha. Thus, the annual paddy production increased from 0.75 to 3.4 million tones during the same period. Irrigated lowland was the second contributor. The annual paddy production from irrigated ecologies increased from 0.64 to 1.9 million tones during the same period through the expansion of area from 0.23 to 0.56 million ha and yield increased from 2.8 to 3.4 t/ha. Only very minor contributions came from the upland rice ecology, i.e., the increase of paddy production was from 1.5 to 1.8 million tones and the increase of the cultivated area from 1.5 to 1.8 million ha, but no yield increased during the same period. Although the NERICA technology was released, the upland rice strategy of WARDA for 1993-2003 (WARDA 1988) did not contribute to the rice production during the same period in West Africa.

These trends clearly show that the improvement of the natural resource management technology, especially through the improvement of water control in rainfed lowland played a major role in increasing rice production during last 15 years. If this trend is supported by adapting the sawah eco-technology strategy proposed in this paper, the green revolution will be realized in this region by 2015.

Table 2 Estimation of rice production trends by rice ecology in West Africa during 1984-1999/2003 and 2015.
Estimation by the author(JICA 2003, WARDA 1988, 2002, 2004, FAOSTAT 2006)

	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	1.0	1.0	1.0
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

Table 3 Major soil distributions in the three tropics based on the Soil Taxnomy (Hirose and Wakatsuki 2002)

	Entisol	Spodosol	Histosol	Ultisol	Inceptisol	Andisol	Oxisol	Psamment	Alfisol	Mollisol	Vertisol	Aridisol	Total (excluding no-soil surface)
Soil Characterristics	Immature parent materials	Sandy, leaching	Peat wetland	Strongly weathered, acid	Young vitality	Volcanic ash, fertile	Aging, leaching	Quartz leaching	Eutrohpic, low activity	Grasslands, dry season	Black, semi-arid	Dry, desert	
Toropical Africa	50	3	2	190	240	5	440	340	320	4	100	810	2,504
Toropical America	90	0.5	5	330	130	90	660	20	120	15	20	50	1,531
Toropical Asia	250	3	22	300	200	50	tr	tr	80	tr	100	10	1,015
Total tropics (million ha)	620	7	30	820	570	145	1,100	360	520	19	220	890	5,050
Total (ratio in %)	11.7	0.1	0.6	15.5	10.8	2.7	20.8	6.8	9.8	0.4	4.2	16.6	100
Japan (ratio in %)	4	3.5	1.0	2.5	58	16	0	tr	tr	0	0	0	100

Soil distribution characteristics of SSA and soil fertility of West African lowland in comparison with that of Tropical Asia (Wakatsuki and Masunaga 2005)

Table 3 shows the estimated area of soil order in three major tropical zones in the world, i.e., tropical Asia, Africa, and America (Sanchez 1976, Kyuma 2004, Eswaran et al 1992 and 1997, Soil Survey Staff 1998, 1999, Hirose and Wakatsuki 2002). The combined area of the nutrients depleted Oxisols and Psamments as well as water deficient Aridisols accounts for 64% of SSA. In tropical Asia, although acid Ultisols are widespread, since the geology is much younger, Oxisols, Psamments and Aridisols are minor distribution. These soils are unsuitable for agriculture. In tropical America, Oxisols have wide distribution, 43%, but few distributions of Aridisols and Psammnets. Among the soil orders in the tropics, Andisols on upland and Inceptisols as well as Entisols in lowland have good moisture and fertility in general. While intensive and relatively sustainable farming systems are practiced on Andisol areas in all of the three tropical zones, the Inceptisols and Entisols in lowlands are not very much used in both tropical Africa and America. In tropical Asia, however, the lowland Inceptisols and Entisols are utilized more intensively for sawah based rice production systems. The sawah systems, total area of about 100 million ha, are producing rice food for more than two billion people in sustainable basis (Greenland 1997, Kyuma 2004).

During 1986 to 2007, the senior author conducted various surveys on the West African rice based farming systems in flood plains, inland valleys and various uplands. Those soils, mainly lowlands, were collected from most West African countries, including Senegal, Guinea, Sierra Leone, Liberia, Cote d'Ivoire, Mali, Burkina Faso, Ghana, Togo, Benin, Niger, Nigeria, and Cameroon as well as the Dem. Rep. of the Congo in central Africa. Soil fertility characteristics were evaluated and their fertility were compared with that of soils in tropical Asia and Japan. The results were summarized in Table 4 (Wakatsuki et al 1998, Issaka et al. 1997, Buri et al. 1999 and 2000, Kawaguchi and Kyuma 1977, Hirose and Wakatsuki 2002).

Total carbon and nitrogen content were low both for West Africa and tropical Asia. The mean values of available phosphorous and pH suggest that the phosphorous status of West Africa is very critical. Base status such as exchangeable calcium and potassium and effective cation exchange capacity were also very low in comparison with the tropical Asia. In addition, some micronutrients, such as sulfur and zinc are also generally very low and about 60-80% of lowland soils, both inland valleys and flood plains were in deficient level (Buri et al 2000). Comparison of soil fertility data of tropical America also revealed that the fertility of lowland soils in West Africa was the lowest among the three tropics (Hirose and Wakatsuki 2002).

Table 4 The mean values of fertility properties of inland valleys (IVS, about 200 sites) and flood plains (FLP, about 70 sites) of West Africa in comparison with lowland topsoils of tropical Asia (about 500 sites) and Japan (about 150 sites) (Hirose and Wakatsuki 2002)

Location	pH	Total C (%)	Total N (%)	Available P (ppm)**	Exchangeable Cations (cmol/kg)				Sand (%)	Clay (%)	CEC /Clay
					Ca	K	Mg	eCEC			
IVS	5.3	1.3	0.11	9	1.9	0.3	0.9	4.2	60	17	25
FLP	5.4	1.1	0.10	7	5.6	0.5	2.7	10.3	48	29	36
T. Asia*	6.0	1.4	0.13	18	10.4	0.4	5.5	17.8	34	38	47
Japan*	5.4	3.3	0.29	57	9.3	0.4	2.8	12.9	49	21	61

*Kawaguchi and Kyuma 1977, ** Bray 2

In high rainfall zones of West Africa such as equatorial forest in Liberia and Sierra Leone, Oxisols are widespread in upland areas. The typical toposequence of inland valley soils near Makeni in central Sierra Leone was Oxisols in flat upland, Oxisols/Ultisols in gentle slopes and Inceptisols in valley bottom. The eCEC of the topsoils were 1-5 cmol(+) /kg and exchange acidity percentages were 10-90% throughout the topesequnce (Smaling et al 1985 a and b, Hirose and Wakatsuki 2002). The upland soils have especially low carbon and nitrogen contents, less than 1% and 0.1% respectively. Available phosphorus (Bray II) was also lower than that of lowland soils. Exchangeable bases are also generally lower than those of soils in inland valleys and flood plains. In Savannah zones, such as Sudan and Guinea, although the upland soils are mainly Alfisols but the eCEC of these soils is also very low, normally less than 5 Cmol(+)/Kg. Low activity clay soils are predominant. In addition to the poor soil fertility, the recent shortage of rainfall also further makes it difficult to conduct sustainable upland rice cultivation.

Although organic matter management through agroforestry and cover crop systems are possible options to sustain soil fertility (Tian et al 2001), in order to overcome such difficulties and for effective and sustainable crop production in SSA, new farming systems that can restore and enrich these poor soils must be developed. In terms of sustainability, re-evaluation of traditional farming technology is important (Barrera-Bassols and Zinck, 2000). However, for the sustainable increase to cope with recent population expansion, only re-evaluation of traditional farming is not enough (Hirose and Wakatsuki 2002). As discussed in this paper, the new concept of ecological engineering technology is necessary. The African adaptive lowland sawah-based farming with adjunct small-scale irrigation scheme for the integrated watershed management will be the most promising strategy to increase sustainable and intensive food production and at the same time to restore the degraded watersheds in SSA.

Concept of sawah eco-technology

The concept and the term “sawah” refers to man-made improved rice fields with demarcated, leveled, bunded and puddled rice fields with water inlet and water outlet, which, if possible, can be connecting various irrigation facilities, such as irrigation canals, pond, spring, pump, water harvesting, and flooded sawah, etc (Fig.1-6). Just sawah to sawah irrigation as well as drainage are possible. Rainfed sawahs without any irrigation facilities are also far better than rainfed fields for rice growth and for rice green revolution because of the improvement of water and soil management. Drainage facilities are also useful in over flooded area. The term “sawah” originates from Malayo-Indonesian. The English and French terms, Paddy or Paddi, also originated from the Malayo-Indonesian term, Padi, which means rice plant. In order to avoid confusion between upland paddy fields and man-made leveled, bunded and puddle rice fields, i.e., typically irrigated rice growing environment, which is often un-appropriately used as lowland paddy fields, the authors propose to use the term “Sawah” in SSA (Wakatsuki et al 1998).

For the sustainable increase of rice yield and production, farmers have to control water on rice fields. If the degree of water control improves, sustainable rice yields will increase (Hiose and Wakatsuki 2002, Table 5 by Ofori et al 2005). In order to control water, sawah system has to be developed, improved and managed (Fig. 1). Taiwan team has played a pioneering role in technical cooperation for the introduction of the sawah based rice cultivation in Africa during 1965 to 1975 (Hsieh 2003). However as this technical cooperation continued only for some 10 years because of political reason, confusion and stagnation occurred on the technology transfer of the sawah based rice framings in the 1980s (Buddenhagen and Persley 1978 and IITA 1989/1990).

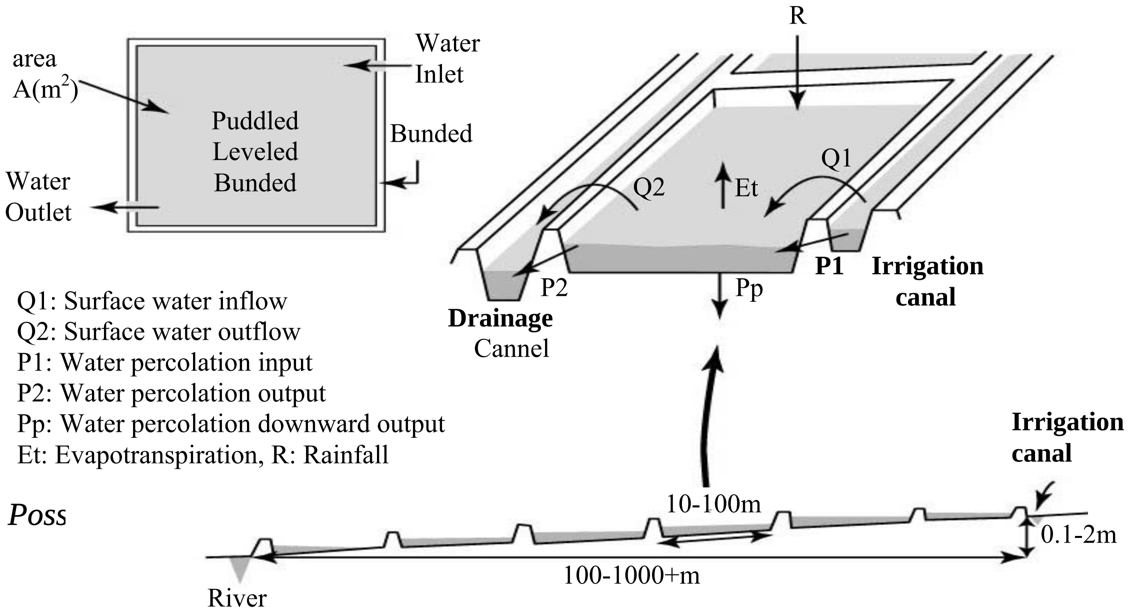


Fig. 1 What is "Sawah"?
"Sawah" is leveled, bunded and puddled rice field with inlets and outlets to control water.

Table 5 Mean gain yield of 23 rice cultivars in lowland ecologies at low (LIL) and high input levels (HIL), Ashanti, Ghana (Ofori et al 2005)

	Entry No.	Cultivar	ECOTECHNOLOGICAL YIELD IMPROVEMENT					
			Irrigated Sawah		**Rainfed sawah**		**Upland like fields**	
			HIL (t/ha)	LIL (t/ha)	HIL (t/ha)	LIL (t/ha)	HIL (t/ha)	LIL (t/ha)
BIOTECHNOLOGICAL IMPROVEMENT	1	WAB	4.6	2.9	2.8	1.6	2.1	0.6
	2	EMOK	4.0	2.8	2.9	1.3	1.4	0.5
	3	PSBRC34	7.7	3.5	3.0	2.1	2.0	0.4
	4	PSBRC54	8.0	3.7	3.8	2.1	1.7	0.4
	5	PSBRC66	5.7	3.3	3.8	2.0	1.8	0.4
	6	BOAK189	7.0	3.8	3.7	2.0	1.4	0.3
	7	WITA 8	7.8	4.2	4.4	2.1	1.8	0.5
	8	Tox3108	7.1	4.1	4.0	2.3	2.3	0.6
	9	IR5558	7.9	4.0	3.8	2.0	1.8	0.5
	10	IR58088	7.7	4.0	3.7	1.8	1.4	0.3
	11	IR54742	7.7	4.3	4.0	2.2	1.9	0.4
	12	C123CU	6.9	4.1	4.2	1.9	2.0	0.4
	13	CT9737	6.5	4.0	4.0	1.7	1.9	0.6
	14	CT8003	7.3	3.8	3.8	1.7	2.0	0.5
	15	CT9737-P	8.2	4.0	4.3	1.8	1.2	0.5
	16	WITA1	7.6	3.6	3.3	1.8	0.9	0.3
	17	WITA3	7.6	3.5	4.1	2.0	1.3	0.5
	18	WITA4	8.0	4.1	3.7	2.1	1.5	0.3
	19	WITA6	8.0	3.5	4.0	2.3	1.4	0.3
	20	WITA7	7.3	3.7	3.8	2.2	2.0	0.4
	21	WITA9	7.6	4.4	4.5	2.8	2.0	0.6
	22	WITA12	7.6	4.0	3.8	1.9	1.8	0.4
	23	GK88	7.5	3.8	3.5	2.0	1.8	0.5
	Mean (n=23)		**7.2**	**3.8**	**3.8**	**2.0**	**1.7**	**0.4**
	Range		(4.0-8.2)	(2.8-4.4)	(2.8-4.5)	(1.3-2.8)	(0.9-2.3)	(0.3-0.6)
	SD		1.51	0.81	0.81	0.45	0.44	0.12

Because of various costs of green revolution technology, the yields must be higher than 4 t/ha for sustainably adopting green revolution technologies.

It is now very difficult to build new irrigation project through the conventional ways of Official Development Assistance (ODA) because of the high cost of irrigation and its apparent low return in SSA. Especially, the large-scale irrigation projects are very costly. Even in the small irrigation schemes, the construction cost becomes comparable to large schemes as far as their development depends mainly on engineering works by construction companies. Although the total sale of produce is between 1,000 –2,000 dollars per ha, the running cost including maintenance of such systems, machinery for operation, agrochemicals become very high. Due to the high construction cost, the economic return has been negligible or rather negative for a long period of time, 20-30 years.

However, the most impressive achievements observed by the senior author in the past 15 years were that inland valley development for improving water control of the rice-growing environment through bunding and leveling, which are ongoing in West Africa despite the major negligence of the research in this area and scarce official funding (Table 2). These are based mainly on farmers' self-support efforts. Decreasing trend of rainfall in recent years might persuade farmers to shift partly from upland to lowland. The senior author observed that there were many upland rice fields around Bouake in 1987. In 2002, however, almost no upland rice fields were observed around the Bouake area.

These lowland development activities are called "intensified lowland", "partial water control", just "lowland development", "amenagement" or "system du Chinois" after the activities by Taiwan team" in some Francophone SSA, or "contour bund system". Although the quality of these systems is quite diverse, these are all covered by the "sawah concept and sawah

In addition to the construction cost of irrigation schemes, the management of the schemes has been a problem in SSA. Water use efficiency was very low because of the confusion between irrigation scheme and the sawah systems in SSA. The irrigation schemes are constructed and managed by government and/or communities, but the water condition in each irrigated rice field, i.e., sawah, has to be managed by each rice farmers. Actually water use efficiency in the whole irrigation schemes is dependent on the management skill of sawah fields of each rice farmer. The lack of eco-technologies of sawah in SSA, majority of irrigation schemes have never been sustainable for the last four decades. Therefore the official development of irrigation schemes, large and small, by governments is very slow.

technology and development" (Wakatsuki et al 1998). Some rice farmers as well as some West African and donor countries have realized the importance of soil and water management, especially the water management, through various sawah based rice cultivation technologies are not defined clearly (Figs. 1 and Table 2). WARDA's inland valley consortium (IVC) also contributed to encourage these developments partly. A USD$ 23 million inland valley rice development project (IVRDP, 2004-2009) is based on the sawah approach in Ghana financed by African Development Bank, is a good example, if it becomes successful (Wakatsuki et al 2001, Hirose and Wakatsuki 2002, Ministry of Food and Agriculture, Ghana, 2007 a and b). Massive irrigation scheme by office du Niger in Mali has been performing and now to reach the level of green revolution, 4-5ton/ha, in their full scheme of 50,000ha in last ten years after thirty years of very poor performance during 1960-1990 (JICA 2003).

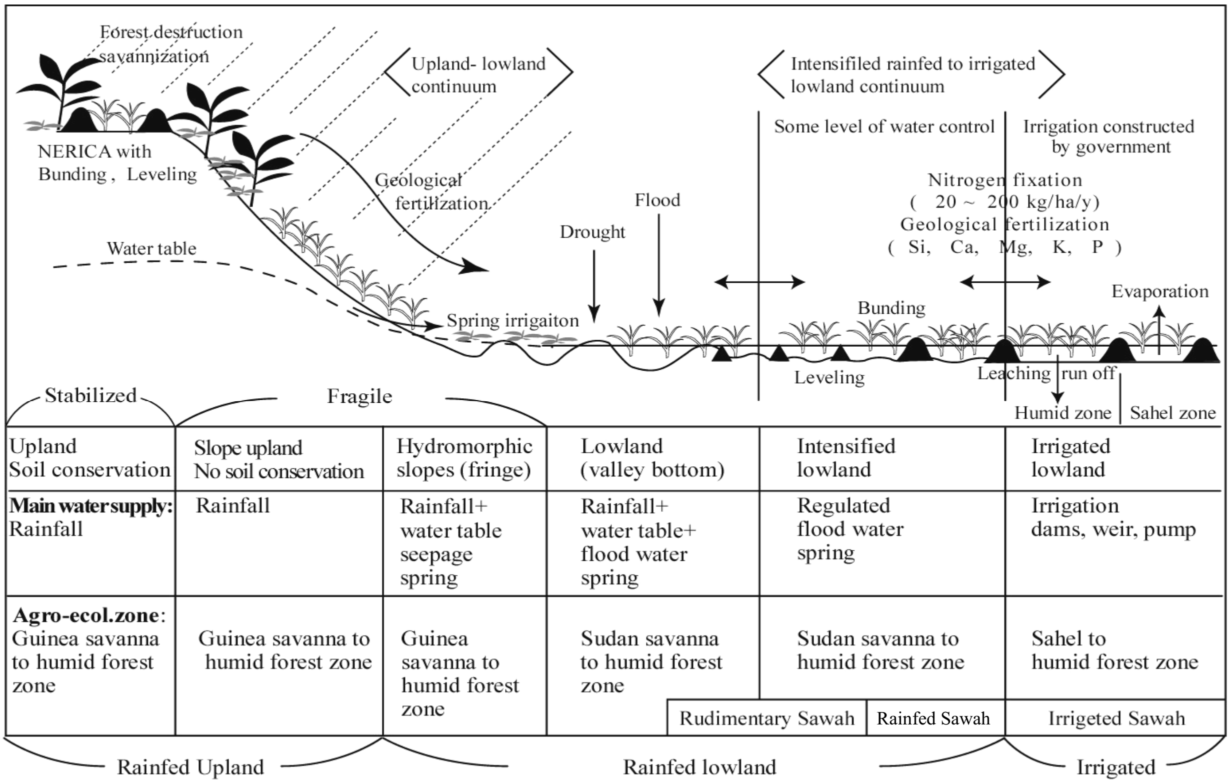
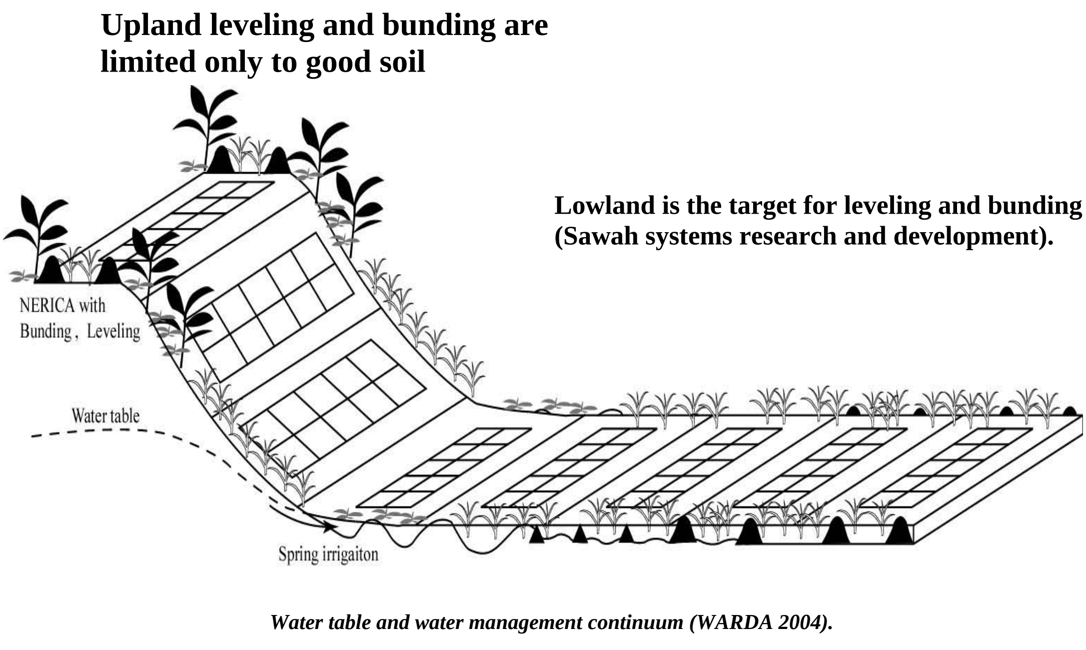
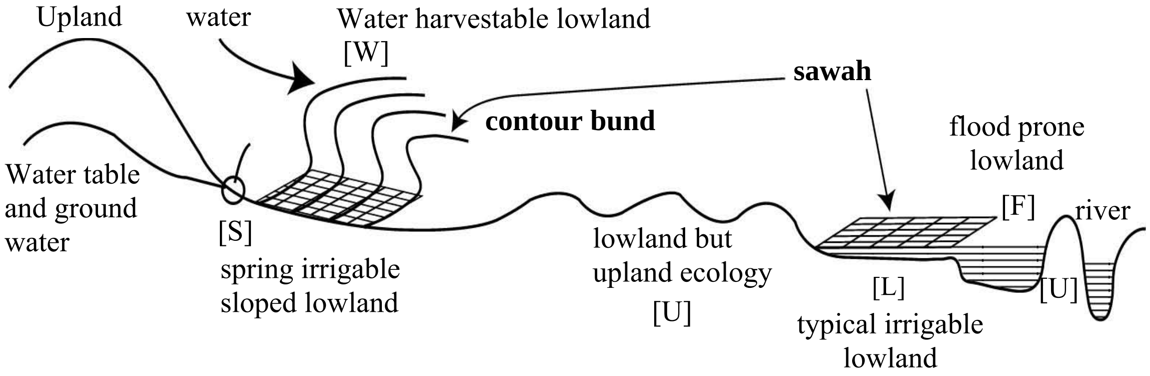


Fig. 3 Rice ecologies along upland-lowland continuum in West Africa (JICA 2003, WARDA 2004)



Water table and water management continuum (WARDA 2004).

Fig. 4 Rice farmer’s field demarcation based on soil, water and topography, such as sawah development, are the starting point for scientific observation, technology generation and application



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

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

Fig. 5　Strategy for sawah and irrigation development.
Various sawah (bunded, leveled, puddled rice land) development with various irrigation options depending on the characteristics of valley bottom diversity in each agro-ecological zone.

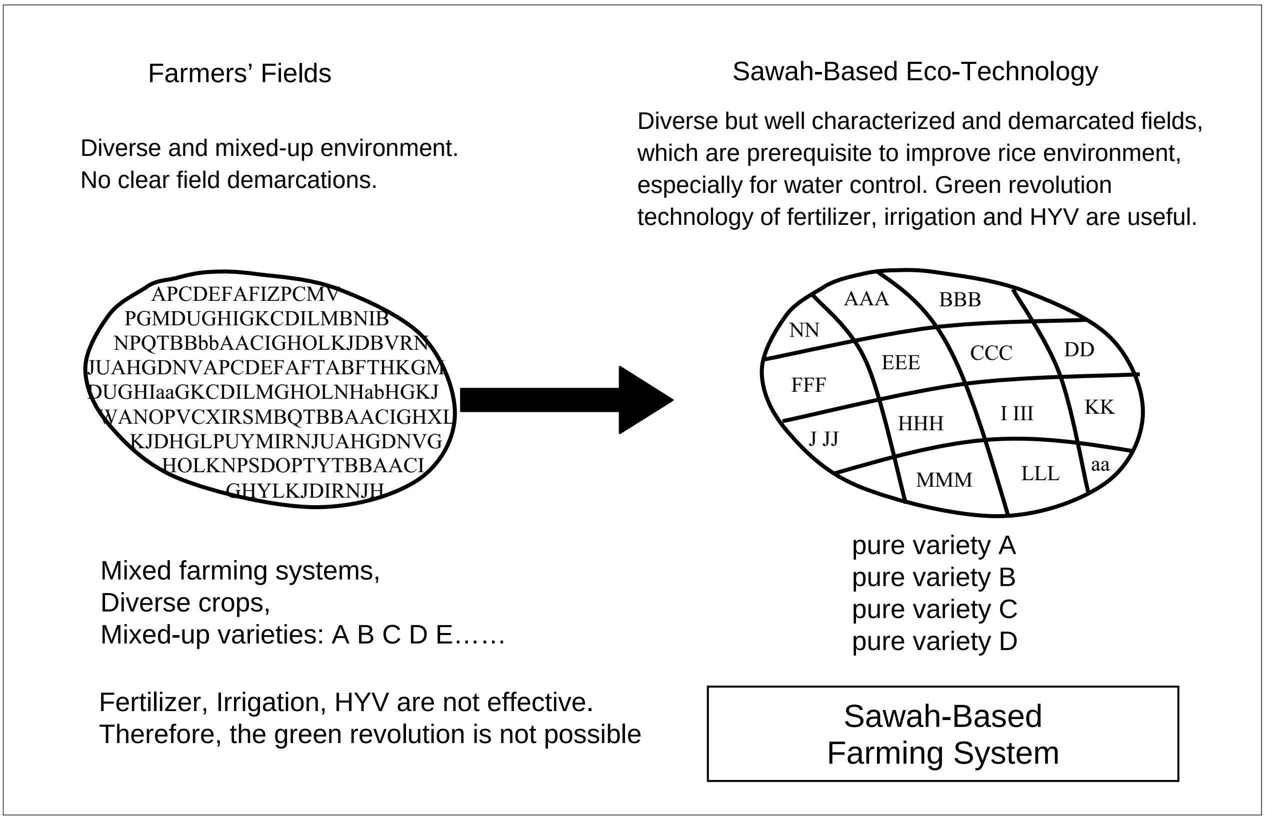


Fig. 6　Sawah Hypothesis (I) : Successful Integrated Genetic and Natural Resource Management (IGNRM) needs classified and demarcated land eco-technology.

Balanced approach between biotechnology and eco-technology

In order to strengthen these trend, the way for rapid expansion of eco-technology based low cost and self-support sawah fields have to be researched and developed in the rainfed lowland, especially in inland valleys (Wakatsuki et al 1998, 2001, Hirose and Wakatsuki 2002). SSA needs eco-technologies that can improve farmers' rice fields similar to the biotechnologies that can improve rice varieties (Fig. 2, Table 5 by Ofori et al 2005). Table 5 clearly shows that eco-technological improvement of farmers rice fields are critical compared to the biotechnological variety improvement in SSA. The technologies of genetic improvement of rice (variety) and the rice growing environment (sawah) must be researched and developed in good balance for integrated genetic and natural resources management (IGNRM) (Fig. 2 and Fig. 8). Because of the success story of the green revolution by HYV in Asia and Latin America by CG centers, our research activities have been too much one-sided focusing on HYV only for the last forty years in SSA.

Table 6 summarized the possible eco-technology options to improve rice yields in comparison with biotechnology options. The table shows that sawah eco-technology can give wide range of the improvement of rice yield, rice quality and ecological environment including carbon sequestration (Darmawan et al 2006a and b) through the improvement of water shortage, poor nutrient conditions, acidity, alkalinity, weed control, pest and diseases control, and food quality (Hirose and Wakatsuki 2002, Kyuma 2004). Therefore, in addition to the improvement of variety through biotechnology, the improvement of rice growing environment has to be done through eco-technology. Balanced research and technology development of biotechnology and eco-technology is very important.

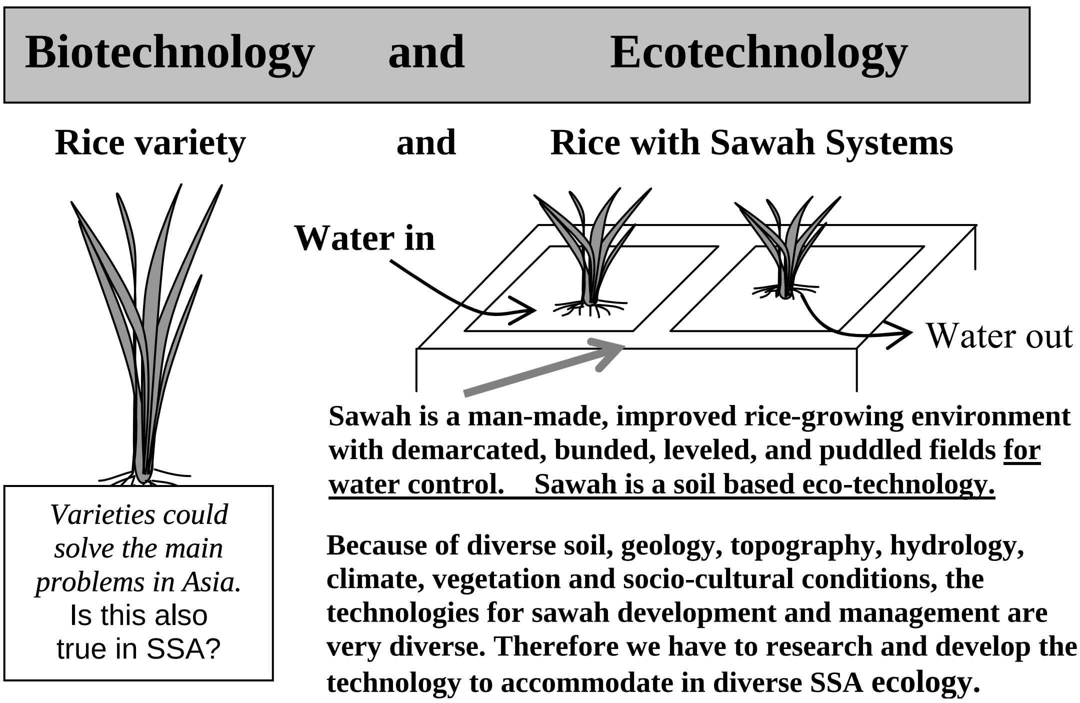


Fig. 2 Rice (variety) and environment (Sawah) improvement. Both bio- & eco-technologies must be developed in balance

Rice growing ecologies are extremely diverse in West Africa and SSA (Fig.3, JICA 2003, WARDA 2004). The appropriate bund layout, bunding and leveling quality, and size and shapes of sawah as well as appropriate site selection are different depending on the characteristics of targeted inland valleys and on the targeting farming systems. Because of obvious benefits of geological fertilizations (Fig. 11) as described later, lowland is the priority target for sawah development (Fig.4). Water harvesting and various simple irrigation technologies have to be integrated with the various sawah developments in diverse characteristics of the valley bottoms (Fig.5). Small machinery, such as power tiller, has to be examined to accelerate the sawah development. Tropical Asian experiments in collaboration for sawah development and for animal traction and power tiller operation for sawah based rice farming will be very useful (Fashola et al 2007 a and b, Hsieh 2003).

Sawah Hypothesis (I) For the Green Revolution

On December 26, 2004, the concept of and the term “TSUNAMI” were lacking in the vocabulary of people in Indian Ocean locations such as Sumatra, Indonesia, Sri Lanka, India and Thailand. This seriously exaggerated the tsunami disaster. The lack of the concept and appropriate technical term for improving and managing the rice growth environment, such as “sawah” creates confusion in the research and sustainable development of rice cultivation in West Africa. As seen from the success of publicity of NERICA by WARDA, a clear concept and key technical term are very important for integrated genetic and natural resource management (IGNRM). As discussed already, unlike in Asian rice farmers’ fields, Sub Sahara African farmers’ fields, and therefore the farming technologies, are not ready to accept various IGNRM technologies, such as irrigation, fertilizers, integrated pest management (IPM), and high yielding varieties (HYV) (Fig. 6 and 7). Rice farmers’ field demarcation based on topography, hydrology and soil is the starting point for scientific observation, technology generation and application, including the green revolution technologies (Fig.6). For efficient uses of fertilizers and irrigation water, rice farmers’ fields have to be demarcated based on topography, hydrology and soils (Fig. 5 and 6). Although there have been discussions on researches and developments on irrigation, fertilizers and HYV for the last forty years, the discussions have not touched on whether the prerequisite conditions are lacking in SSA (Fig.6 and 7). The concept and technologies of Sawah is such an example. Simply speaking, the basic infrastructures for the green revolution, such as sawah, are lacking in SSA (Fig. 1, 2, 6, and 7). Irrigation without farmers’ sawah farming technologies has proved inefficient or even damaging because of accelerated erosion and waste of water resources. In the absence of water control, fertilizers cannot be used efficiently. Consequently, the high yielding varieties perform poorly and soil fertility cannot be sustained hence the green revolution cannot take place. These are the Sawah hypothesis (I).

As shown in Fig.7, the majority of Asian rice farmers’ fields were already quality sawah fields in 1960s when the green revolution technologies were introduced. Therefore the three major components of the green revolution technologies were quickly adapted. However, the majority of rice farmers’ fields of SSA are lacking such sawah fields, therefore the three green revolution technologies have not been effective for the last forty years. The HYVs have never been performed successfully without sawah fields. Irrigation and other agronomic technologies also never performed well without sawah fields. But if the sawah eco-technolgy is adapted to the majority of rice farmers in SSA, the green revolution will be realized quickly as in the case of Asia. Contrary to Asian farmers’ fields, the farmers’ rice fields in SSA are not ready to accept the three basic components of the green revolution technologies, i.e., (1) irrigation for water supply, (2) fertilizer for soil nutrient supply, and (3) high yielding varieties (HYV).

As described as “African Statistical Error” in the yield trend of Sub Sahara Africa during 1960-2005 in Fig. 7, agricultural statistics are also not so reliable in SSA. There are many reasons, but lack of sawah as demarcated rice fields makes it difficult to estimate the yield too. Without reliable statistical data, appropriate rice development policy can not be established.

The sawah system development and management are the technologies that should be transferred to farmers. Since bunding, leveling and puddling need very hard, skilled and careful works as well as obvious additional benefits of geological fertilization, rainfed lowland will be the primary target for sawah development (Fig. 4 and 11). The ecology of the majority of rice farmers' fields is extremely diverse in naturally and farming systematically (Fig. 3), therefore even the good quality seeds cannot be evaluated properly without sawah systems (Fig.6). Sawah is also a means by which such ecologically diversified rice fields bringing into relatively homogenous and classified fields to evaluate appropriate variety. The successful IGNRM needs classified demarcated lands such as sawahs. The technology of rice variety improvement and dissemination has a clear concept and target such as high yield, pest, draught and poor nutrient tolerant, and high nutritive and quality varieties. The remarkable achievement of the breeding program at WARDA is clear. However there were no such clear concepts and targets in the researches of natural resource management in West Africa for the last 20 years.

The missing link for the green revolution is a sawah concept and technology, targeting the expansion of high quality but with low cost. If sawah systems are successfully introduced to farmers' rice fields, the integrated genetic and natural resources management (IGNRM) technology generations to deal with water, soil, and fertilizer management, low P availability problem, weed and striga management, IPM, control of CH_4 emission and carbon sequestration, animal traction and small machinery operation, fish and rice, vegetable after rice, and so on, will have clear target fields to apply and will therefore be accelerated (Fig.7 and 8). Long term experiments on the effect of cropping system investigations such as legume, biological nitrogen fertilizer (BNF) and organic manure will be possible. Iron toxicity has been often cited in West Africa that can be tackled only properly in sawah based IGNRM. Some pest and disease such as African rice gall midge (AfRGM) and rice yellow mottle virus (RYMV) problems may even be partly mitigated through enhancing the healthy growth of rice through the sawah type eco-technology. Water saving aerobic rice cultivation and Systems Rice Intensification (SRI) methods become only possible on sawah fields (Fig. 6 and 8).

African lowlands characterization in comparison with that of Asian lowlands in watersheds

Because of diversity in soils, hydrology, climate, vegetation, topography, and geology as well as socio economic, cultural and historical conditions, the technologies for sawah development and management must fit such diverse conditions. This is an important research and development target for sustainable rice production (Fig. 4-8). There is information on the potential area of lowland sawah development, such as 330,000 ha in Benin, 230,000 ha in Burkina Faso, 200,000 ha in Togo, one million ha in Ghana, 20 million ha in whole SSA (Hirose and Wakatsuki 2002) and so on. This area estimation is, however, still at the preliminary stage. Details survey and characterization targeting sawah type lowland development are necessary (Table 7, Fig. 3-5).

As shown in Table 7, the lowland area in SSA is enormous (Windmaijer and Andriesse 1993), but because of characteristics of natural environment, particularly scarce water resources, the potential area for sustainable sawah development cannot cover all the lowland of SSA. Lowland soil formation in SSA is much smaller than in tropical Asia (Fig 9 by Walling 1983, Wakatsuki 2002). This will be a basic ecological limiting factor to develop sawah systems in SSA. One of the reasons why the ecology of inland valleys in West Africa is so diverse (Jamin and Windmeijer 1995) can be explained partly from this (Fig.3, 5 and 9). Inland valleys have various micro-topographies as shown in Fig. 5, of which spring irrigable sloped land and typical irrigable lowland that can be easily irrigated using pump, simple weir and dyke have the highest priority for sawah development in SSA. The relative area distribution of these kinds of lowlands in various inland valleys is yet to be determined. Flood prone areas need the control measures. Many areas of inland valley bottoms that have upland hydrology have the lowest priority for sawah development. However, upland NERICA may fit into such upland-like ecology in lowland. Water harvestable lowland along the foot slopes can be developed as contour-bunded sawah systems with partially water controllable rice fields as seen in northern Ghana and Burkina Faso. The low cost technology to develop these systems has to be researched based on the field trials-and-errors approach. The lowland demarcation and area estimation can be done with help of geographical information system (GIS) technology.

Asian region has about 60-75% of global monsoon rainfall, while SSA has about 10-15%, which is about one fifth of Asia (Trenberth et al 2000, Qian et al 2001, Levinson 2004). Based on this amount of water cycling in the monsoon climate in comparison with Asia where it has about 100 million ha of irrigated sawah, the total potential irrigated sawah may be about 20 million ha in SSA (Table 7). Immediate target will be 10 million ha in SSA by 2050 (Fig. 7). However, more appropriate estimation has to be researched in detail coupled with real development through field trials-and-errors approach in each agro-ecology.

Historical and geographical consideration for sawah development

Undoubtedly natural environmental conditions, such as hot temperature and enough water during rice growing season and lowland soil sedimentation are the important factors for sustainable development of sawah system. As seen in Fig. 9 (Walling 1983), soil erosion and hence lowland soil formation in West Africa are very low in comparison with Asian watersheds. High rates of soil erosion and lowland sawah soil formation can be compensated by high rate of soil formation in Asia because of active geological formation and ample monsoon rainfall (Hirose and Wakatsuki 2002). Paradoxically, extreme diversity of lowland in West Africa (Fig. 5) may relate to the low rate of soil erosion and weak lowland soil formation.

As shown in Fig. 10, before the green revolution, there were long continued efforts to expand lowland sawah systems in the history of Japanese rice cultivation during the 6th to 20th centuries. The Fig.10 shows the trends of rice yields, sawah area, and population of historical path in Japan in comparison with rice yields in major Asian and African countries. Because of farmers' sawah fields had been developed and sawah-based eco-technology was traditional, Japan's green revolution happened immediately after the introduction of Euro-American's fertilizer technology at the end of the 19th century. The green revolution in turn encouraged the rapid expansion of sawah area more than one million ha within 50 years when population was less than 60 million (Fig.10). Although after the World War II, because of the expansion of the economy, industrialization, and urbanization, the sawah area had decreased rapidly, more than 1.5 million ha within 40 years, 1960 to 2000. The Japanese population is estimated to decrease almost 50% during 21st century. These are the crises in current Japan and near future. On the other hand, SSA and the world are expecting rapid population explosion during the 21st century, the green revolution and the expansion of sawah area are necessary to cope with the forthcoming peak population.

Apart from the above natural geographical reasons, the background of the cause of lack of the prerequisite for the green revolution can be found in the tragedies many years ago. The slave trade by European countries for as long as 400 years, the 16th to 19th centuries, destroyed African communities. Young Africans had to work for the nation building of the new worlds not for SSA. Subsequent colonization continued for additional 150 years until 1960. These are probably the main reasons why the basic nation building, i.e., typically the farmers' fields, is still stagnating. Thus the farmers' fields lack basic infrastructures to accept the green revolution technologies in SSA (Wakatsuki 2002).

Sawah Hypothesis (II) for intensive sustainability

Sustainable yield of lowland sawah system is very high. Although this is based on the long history and experience (not experiments) of sawah based rice farming in Asia, there is no scientific quantitative confirmation yet. Lowland sawah can produce about 2 t/ha without any chemical fertilizer application (Fig. 10 and Table 8). In addition the lowland sawah based farming can support rice cultivation continuously for decades or more without any fallow. However sustainable upland slush-and-burn rice yield without fertilizer never exceeds 1 t/ha. In addition to the lower yield, the upland rice fields need a fallow period to restore soil fertility, such as two years of upland cultivation and eight, sometime more than 15 years, of fallow. This means 1 ha of sustainable upland rice cultivation need at least 5 ha of additional land. Therefore sustainable upland rice yield is actually not 1 t/ha but less than 0.2 t/ha. Therefore as shown in the Table 8, sustainable productivity of sawah based rice farming is more than ten times higher than that of the upland slush-and-burn rice farming (Sawah Hypothesis II). This hypothesis II has to be examined quantitatively under SSA conditions. This is the reason why the upland rice cultivation destroys forest and degrades the land in SSA. Accordingly, the development of 1 ha of lowland sawah field enables the conservation or regeneration of more than 10 ha of forest area. Sawah fields can, therefore contribute to not only increased food production but also to conserving the forest, which in turn enhances sustainability of intensive lowland sawah systems through nutrient cycling and geological fertilization processes. Furthermore, they can contribute to the alleviation of global warming problems through the fixation of carbon in forest trees and sawah soils (Wakatsuki and Masunaga 2005, Darmawan 2006a).

Mechanisms of intensive sustainability of lowland sawah systems

(1) Geological fertilization theory

The upper part of Fig. 11 explains what is the geological fertilization. Although this is a kind of axiom process, quantitative data confirmation is lacking. West African conditions are quite different from Asia, therefore the watershed characterization in terms of upland and lowland connected sequences is important in relation to the geological fertilization as shown in Fig.3 and 11. The upper part of Fig. 11 shows a concept of macro-scale ecological engineering, i.e., watershed ecological engineering and watershed agroforestry. The soils formed and nutrients released during rock weathering and soil formation processes in upland are accumulated at least partly in lowland through geological fertilization processes, such as soil erosion and sedimentation as well as surface and ground water movements or colluvial processes. The sustainable integration of upland forestry, upland farming and lowland sawah systems in a watershed composed of a watershed agroforestry, can be a typical model of watershed ecological engineering. The optimum land use pattern and landscape management practices optimize the geological fertilization processes through the control of optimum hydrology. Irrigation, surface and subsurface water also contributes the increase of the supply nutrients, such as Si, Ca, Mg and K as well as sulfate. This is an eco-environmental basis for long-term intensive sustainability of sawah-based rice farming in Asia.

World scale sediment delivery data from various river basins in tones per ha per year were reported by Walling (1983). The Asian monsoon area, which has the major distribution of sawah based rice farming, has the highest delivery of sediments by soil erosion as shown in Fig.9. For the upland based farming, such soil erosion destroys biological productivity. For sawah-based rice farming, however, such eroded topsoil, although the amounts should be appropriate, from the upland is a source of fertile parent materials for lowland sawah soils. The appropriate soil erosion can be compensated by new soil formation in healthy sustainable ecosystem in a watershed. Major problem in terms of sustainability of the sawah systems in West Africa may be very limited rates of soil formation and erosion in comparison with Asian watersheds (Fig. 9, Wakatsuki 2002). The rates of both soil erosion and soil formation in West Africa may be one fifth to one tenth of those of Asia watersheds. There is, however, no simple appropriate scientific method to evaluate such geological nutrients flows in a given watershed, except a few examples (Wakatsuki et al 1992, 1993, Rasyidin et al 1994). Ecological engineering researches to evaluate the geological fertilization processes and to develop the technology to enhance and control the processes are important in future.

(2) Multi-functionality of sawah systems as constructed wetland

The lower half of the Fig. 11 shows the micro scale mechanisms of the intensive sustainability of the sawah system. The sawah system can be managed as multi-functional constructed wetland. Submerged water can control weeds. Under submerged conditions, because of reduction of ferric iron to ferrous iron, phosphorous availability is increased and both acid as well as alkaline soil pH is neutralized or mitigated. Hence, micronutrients availability is also increased. These mechanisms encourage not only the growth of rice plant but also the growth of various aquatic algae and other aerobic and anaerobic microbes, which increase nitrogen fixation in the sawah system through increase of photosynthesis as a functional wetlands. The technology development and quantitative evaluation of nitrogen fixation in sawah including the role of algae will be important future research topics. Although the amounts of nitrogen fixation under the submerged sawah systems are not well evaluated, the amounts could be 20-100kg/ha/year in Japan and 20-200kg/ha/y in tropics depending on the level of soil fertility and water management (De Datta and Buresh 1986, Kyuma 2004, Greenland 1997). The technology development of the nitrogen fixation by sawah systems, such as 50-200kg N/ha/y, through the integrated management of water, soil microbes, algae and rice plant is the very challenging research subject in SSA. Because of general very poor fertility of lowland soils in West Africa (Abe et al 2006, Buri et al 1999, 2000, Issaka et al 1997, Kyuma et al 1986), these various multi-functional mechanisms to enhance nutrient availability of lowland sawah systems are particularly important for intensive sustainability. The sawah systems are the field laboratory for research and technology generation and the factory for dissemination the technology developed. Rice green revolution will only be realized in the farmers' sawah fields (Fig. 7).

Acknowledgement

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Table 6 Comparison between biotechnology and eco-technology options for improvement of rice production

(1) For Water shortage and flooding
Biotechnology: Genes for deep rooting, tolerance in submergence, C4-nature, Osmotic regulation genes,
Eco-technology of Sawah based soil and water management, bunding, leveling, puddling, well, weir, tank irrigation, and System rice intensification. Dyke construction and drainage

(2) For Poor nutrition, acidity and alkalinity
Biotechnology: 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 agro-forestry, organic matter and fertilization. Use of birds feculent for the enrichment of P.

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

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

(5) For Food quality
Biotechnology: Vitamin rice gene.
Eco-technology of Sawah based nutrition control. Fish, duck and rice in sawah systems

(6) For Carbon Sequestration
Biotechnology: Breeding of high biomass productive genes
Eco-technology: High biomass production and conservation of soil organic matter in Sawah soil

Table 7 Distribution of lowlands in Sub Sahara Africa
Windmeijer and Andriesse (1993); Sawah area estimation by Wakatsuki (2002)

Classification	Area (million ha)		Percentage (%)	
Coastal swamps	16.5	(3-5)	7	(17)
Inland basins	107.5	(1-4)	45	(10)
Flood plains	30.0	(5-10)	12	(31)
Inland valleys	85.0	(5-15)	36	(42)

Figures in parentheses are the potential area of sawah development (million ha):
Maximum total area in SSA may be 20 million ha. This estimation is based on the data that the relative amount of rain fall in Asia Pacific monsoon is five times bigger than that of SSA and sawah area in Asia is 100 million ha currently.

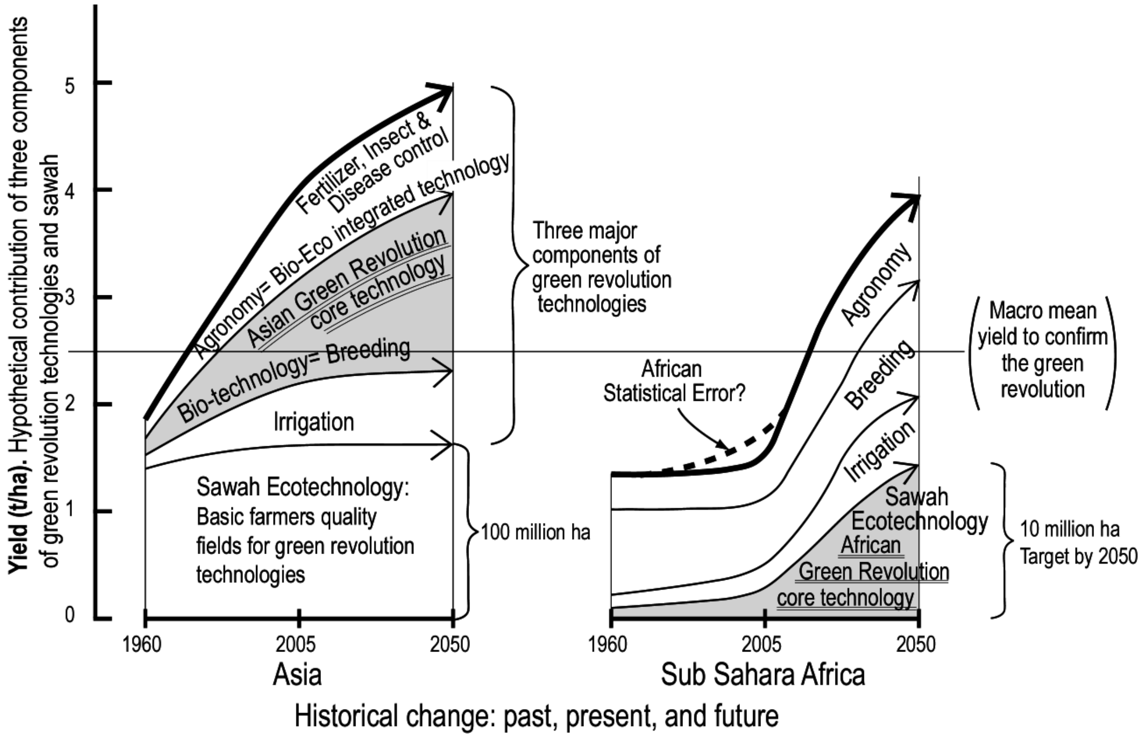


Fig. 7 Sawah hypothesis (I):
Hypothetical contribution of three green revolution technologies and sawah eco-technology during 1960-2005 and during 2005-2050 in Sub Sahara Africa and Asia.

The bold lines during 1960-2005 are based on mean rice yields based on FAOSTAT 2006. Bold lines during 2005-2050 are the expected or target trend based on the sawah hypothesis (I) by the authors.

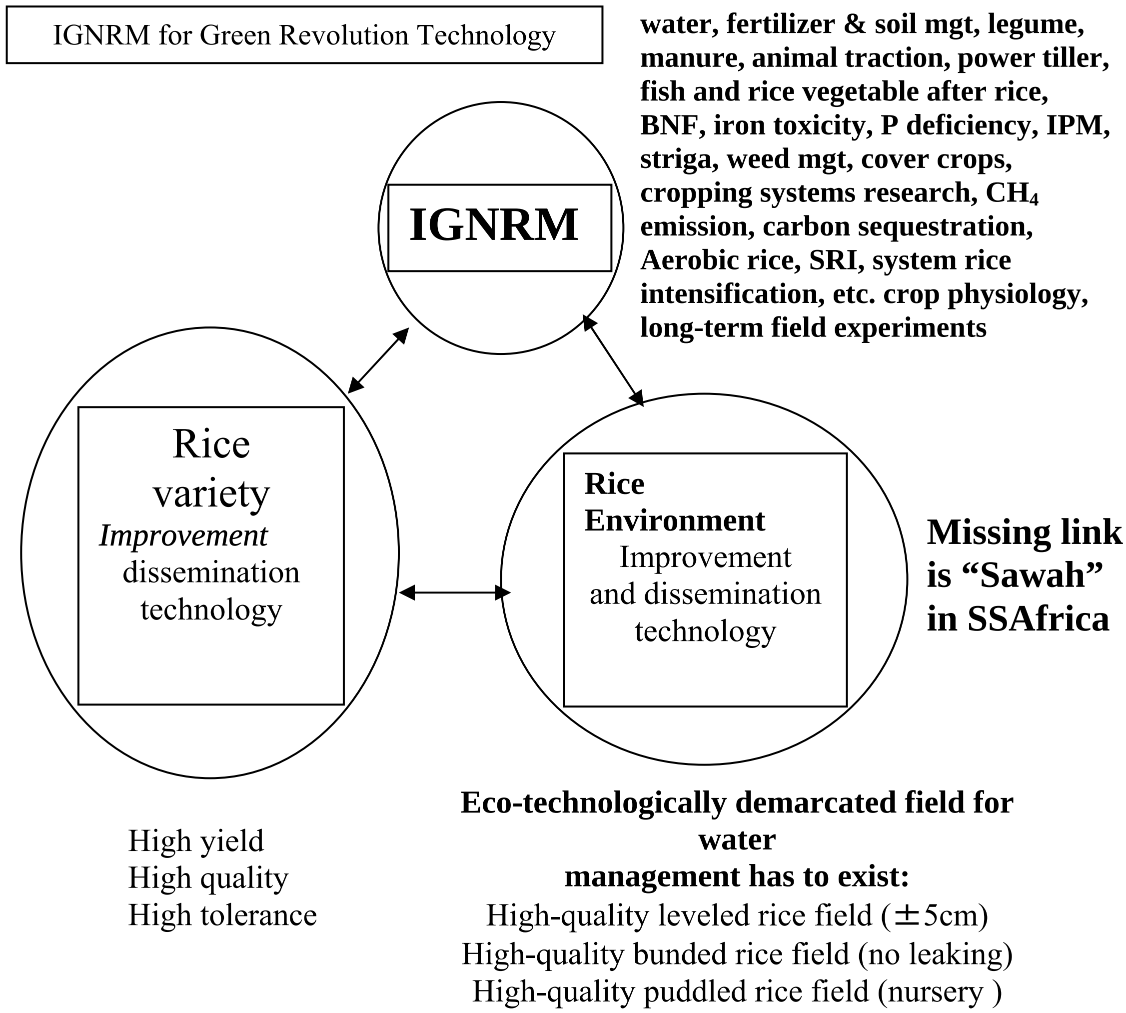


Fig. 8 Concept of "Integrated Genetic and Natural Resources Management (IGNRM)" for green revolution technology:
The missing link is Sawah which is lacking in the majority of famers' fields.

Can watersheds in SSA sustain the Sawah system?
The high rates of soil erosion and lowland sawah soil formation can be compensated by high rate of soil formation: Again, ecological balance is a Key

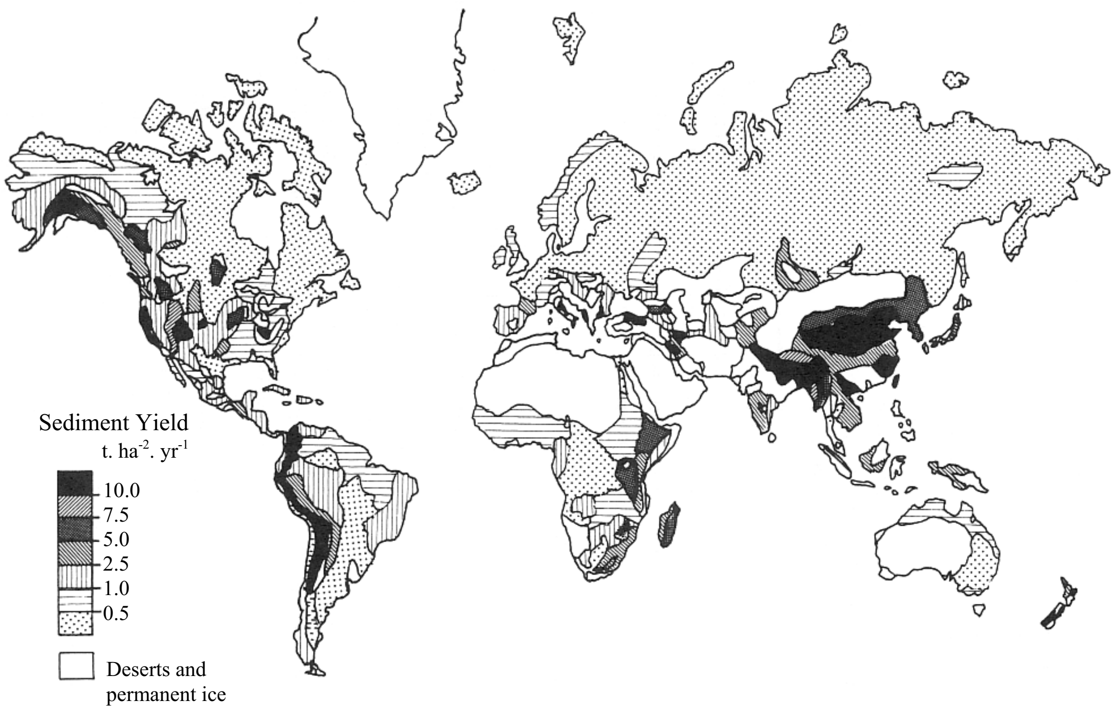
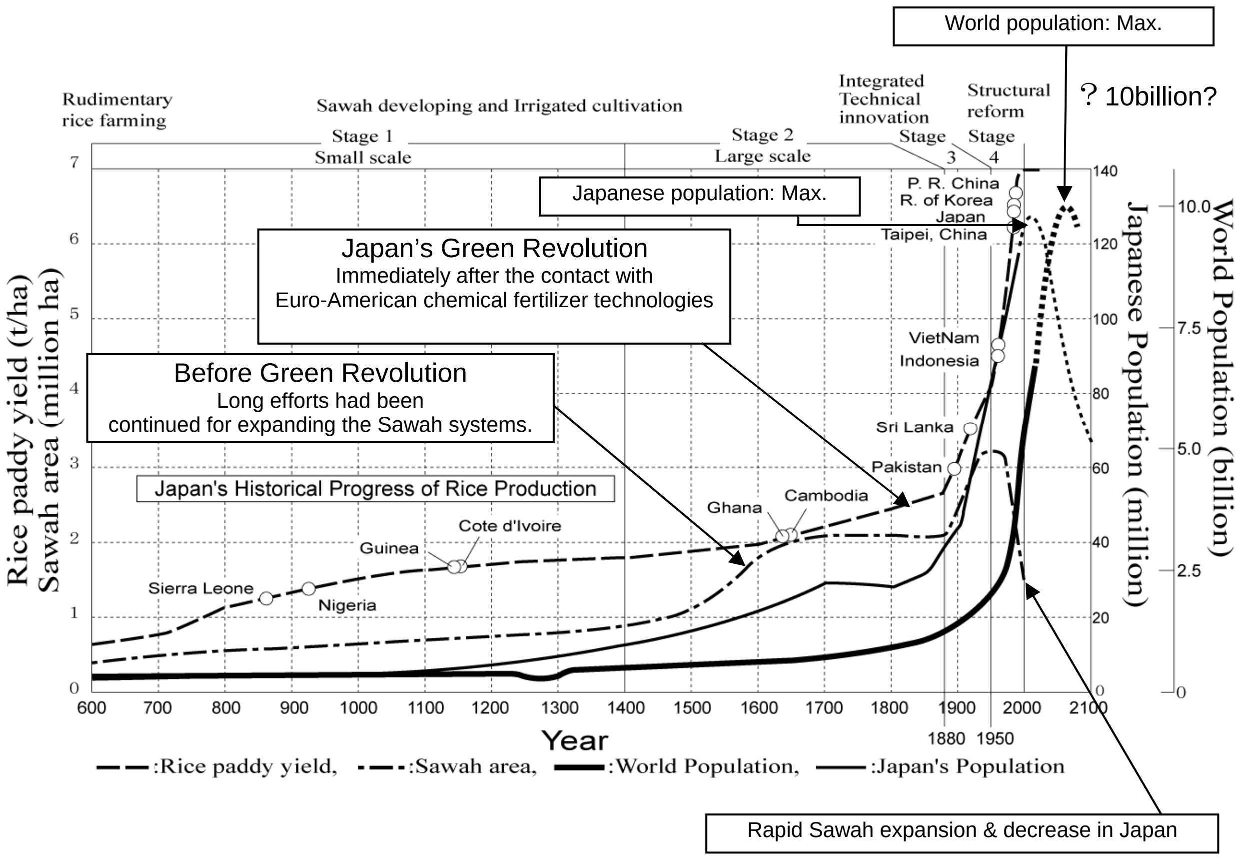


Fig. 9 Rates of soil erosion in the Worlds (Walling 1983)

Farmers' Sawah fields are the most important infrastructure.
Farmers' fields come first.

Japanese experience

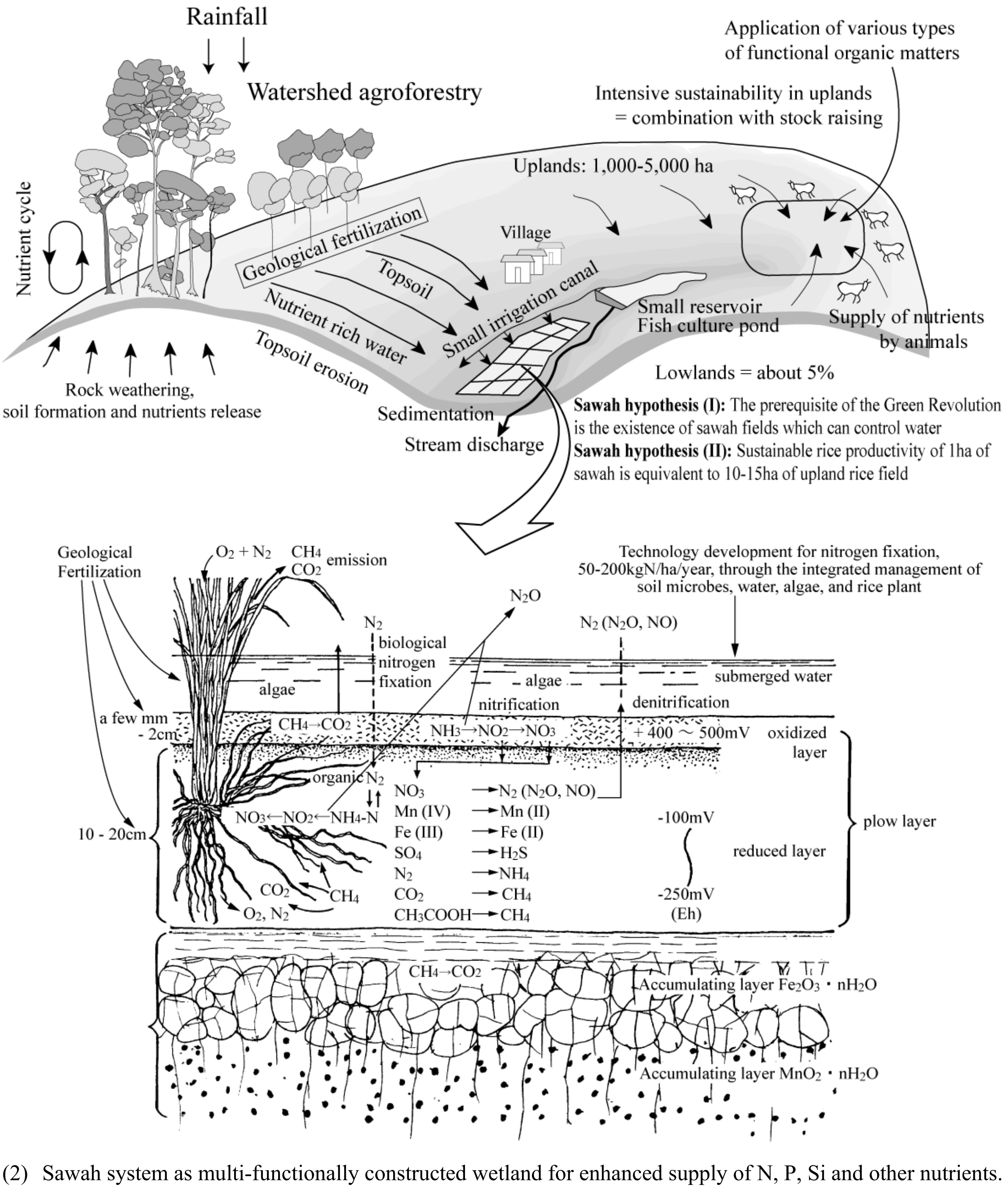


Transition of population, rice yields, and Sawah areas in Japan
in comparison with Asia and Africa
(Takase & Kano, 1969, modified)

Fig. 10 Historical paths of rice yields & Sawah areas in Japan in comparison with rice yields in Asia and Africa with Japanese and the world population trends in the past and near future. (JICA 2003, modified)

(1) Concept of "Watershed Ecological Engineering" and "Watershed Agroforestry"

The optimum landuse pattern and landscape management practices optimize the geological fertilization through the control of optimum hydrology in watershed. Because of geological fertilization, lowland can receive water, nutirents, and fertile topsoils from upland. Sawah system enhances to utilize such geological fertilization flows.

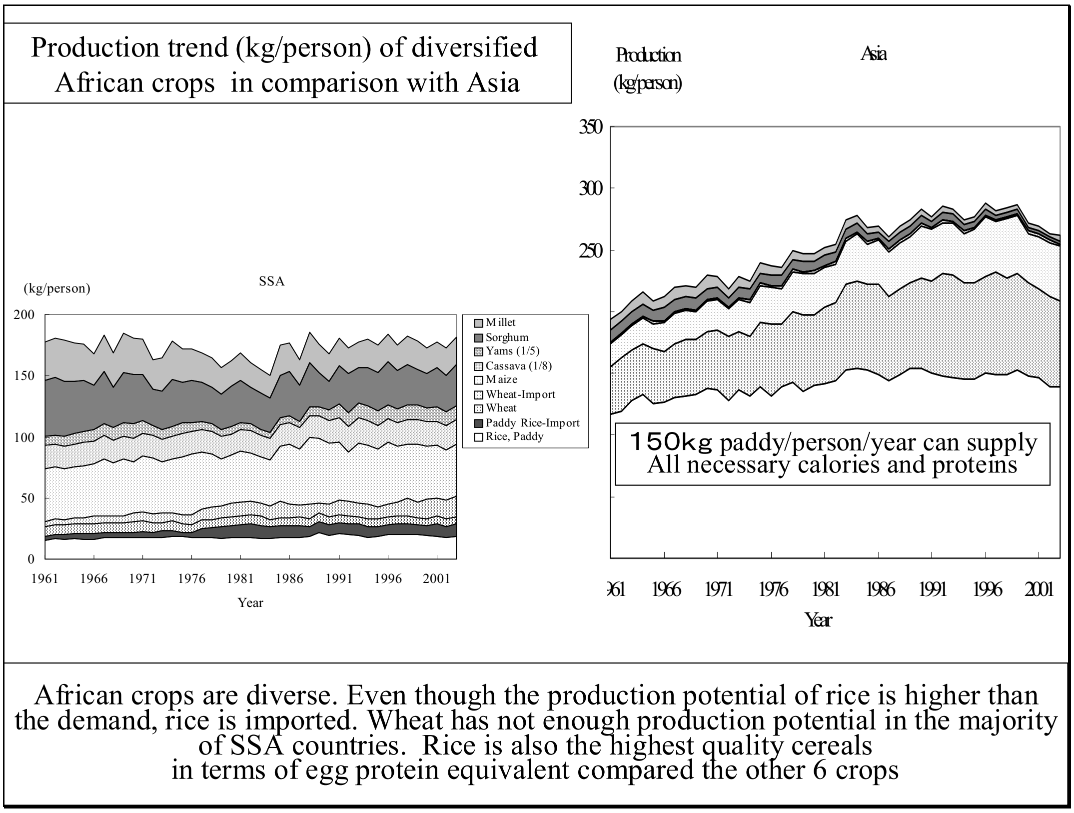


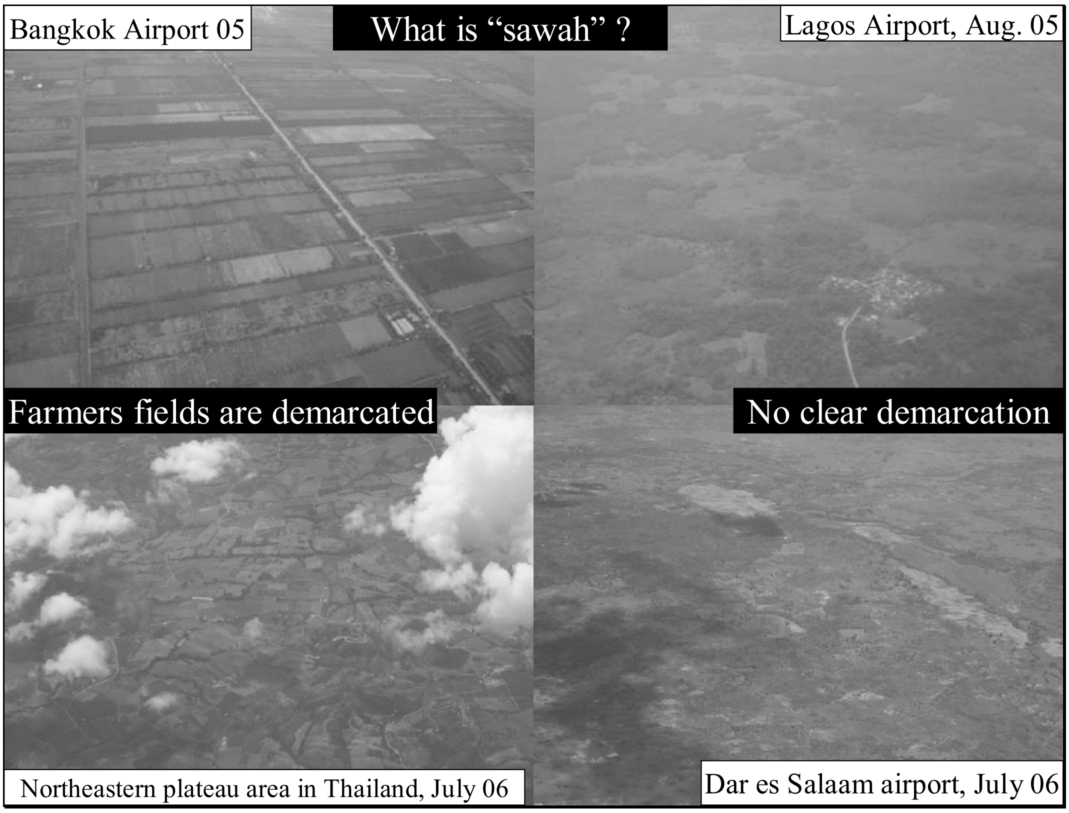
(2) Sawah system as multi-functionally constructed wetland for enhanced supply of N, P, Si and other nutrients.

Technological development for enhancing multi-functionality of wetland sawah in a diverse agro-ecologies for SSA is a key in IGNRM.

Fig. 11　(1) Macro- and (2) Micro-scale ecological mechanisms of intensive sustainability of lowland sawah systems


Why was the Green Revolution not Successful in
the Sub-Saharan Africa?: Sawah (SUIDEN) Hypothesis (1)
T. Wakatsuki, Kinki University
Guinea, Aug.03
No Sawah, No Green Revolution
Inland valley, Sierra Leone, Jan.89
Water control through sawah system is a prerequisite for Green Revolution in SSA
Fish & Rice
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
(kg/person)
SSA
Millet
Sorghum
Yams (1/5)
Cassava (1/8)
Maize
Wheat-Import
Wheat
Paddy Rice-Import
Rice, Paddy
Year
Production (kg/person)
Asia
Year
150kg paddy/person/year can supply All necessary calories and proteins
African crops are diverse. Even though the production potential of rice is higher than the demand, rice is imported. Wheat has not enough production potential in the majority of SSA countries. Rice is also the highest quality cereals in terms of egg protein equivalent compared the other 6 crops



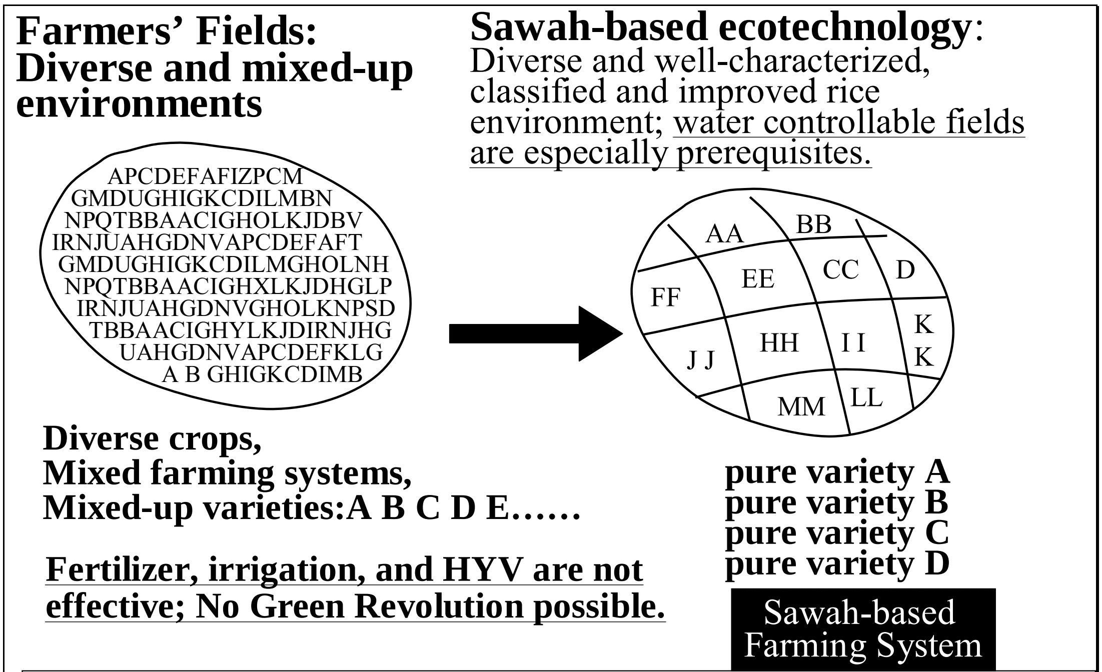


Fig. 7 Successful Integrated Genetic and Natural Resource Management needs classified and demarcated land ecotechnology.

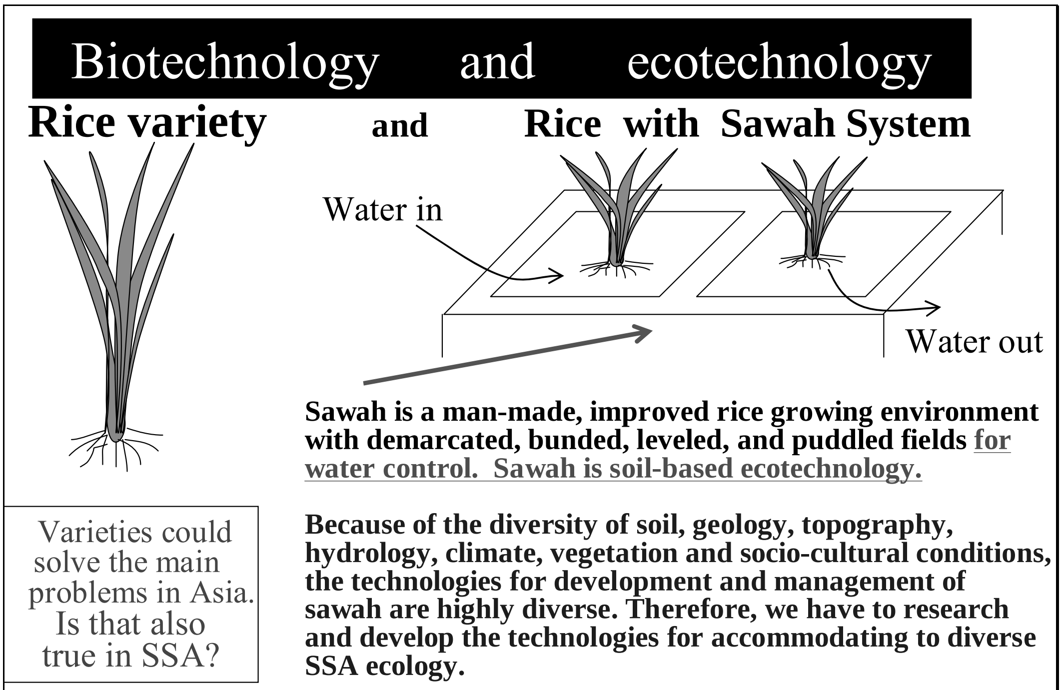


Fig. 2 Rice (variety) and environment (Sawah) both in bio & ecotechnologies must be improved and developed in a balanced manner.

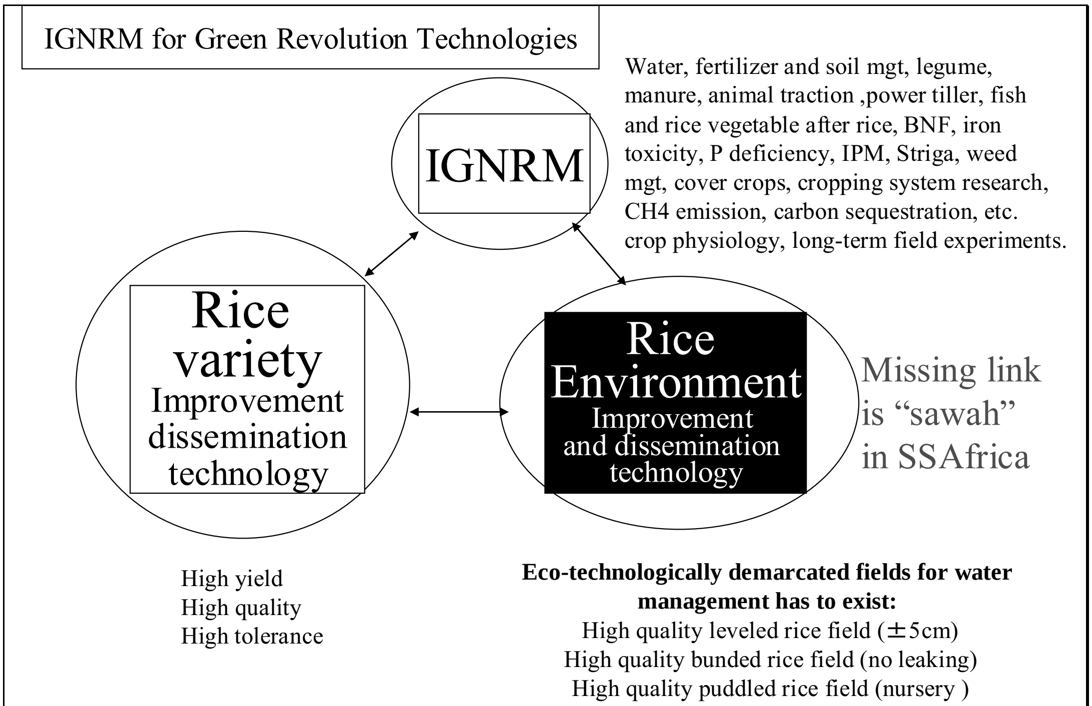
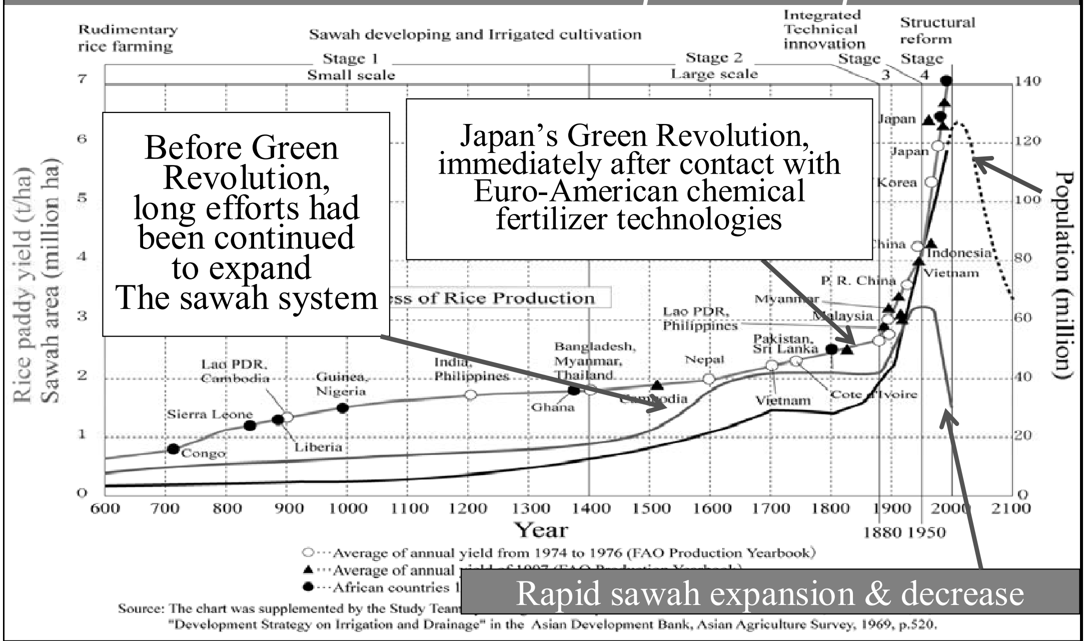


Fig. 8 Concept of Integrated Genetic and Natural Resources Management (IGNRM) for green revolution technologies
The missing link is Sawah which is lacking in the majority of famers' fields

Farmers' sawah fields are the most important infrastructure.
Farmers' Fields come First. *Japanese Experience*



Population, rice yields & sawah areas of historical path in Japan in comparison with Asia & Africa Takase & Kano,1969, modified

Sawah: Lacking in the Concept, Terms and Ecotechnologies

This has been disturbing the balanced approach for rice development in West Africa and SSA in the last 30 years.

Confusion about paddy, irrigation, water control, and the sawah system

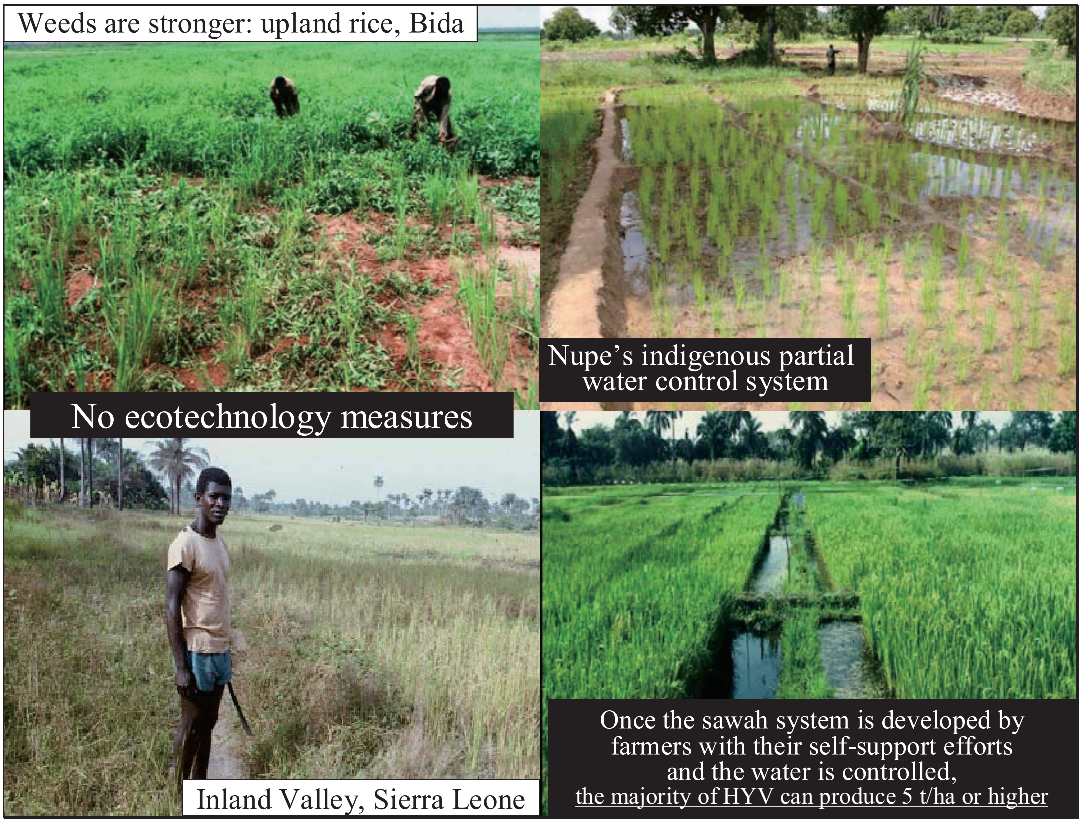
Farmers' work　　Governmental work

- Sawah Hypothesis (1): Prerequisites for Green Revolution:
  Are the farmers' field conditions ready to accept
  the irrigation water, fertilizer and HYV, or not?
- Sawah Hypothesis (2): We have to overcome the scarce nutrients and water. Sustainable rice productivity under the sawah system is 10-15 times higher than those in upland rice fields.
- We must remember that lack of the concept & terms made the "Tsunami" disaster enormous in Sumatra.

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

Suiden =SAWAH (Malay–Indonesian)

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



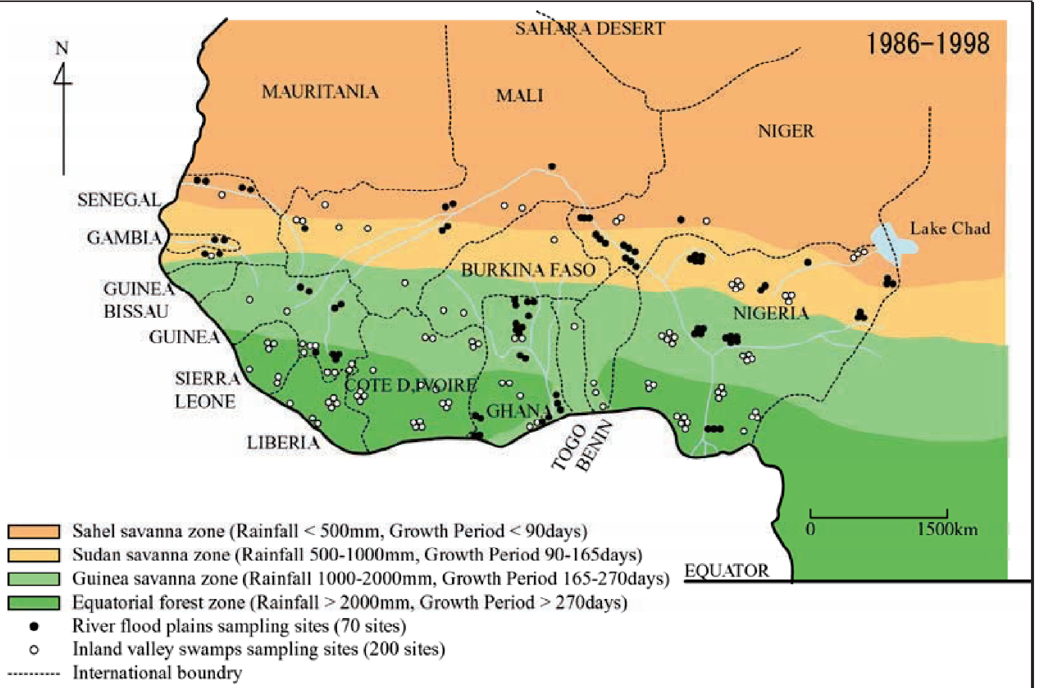
The mean gain yields of 23 rice cultivars in lowland ecologies at low (LIL) and high input levels (HIL), Ashanti, Ghana (Ofori & Wakatsuki, 2005)

← 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

Due to the cost of green revolution technology, the yield must be higher than 4 t/ha

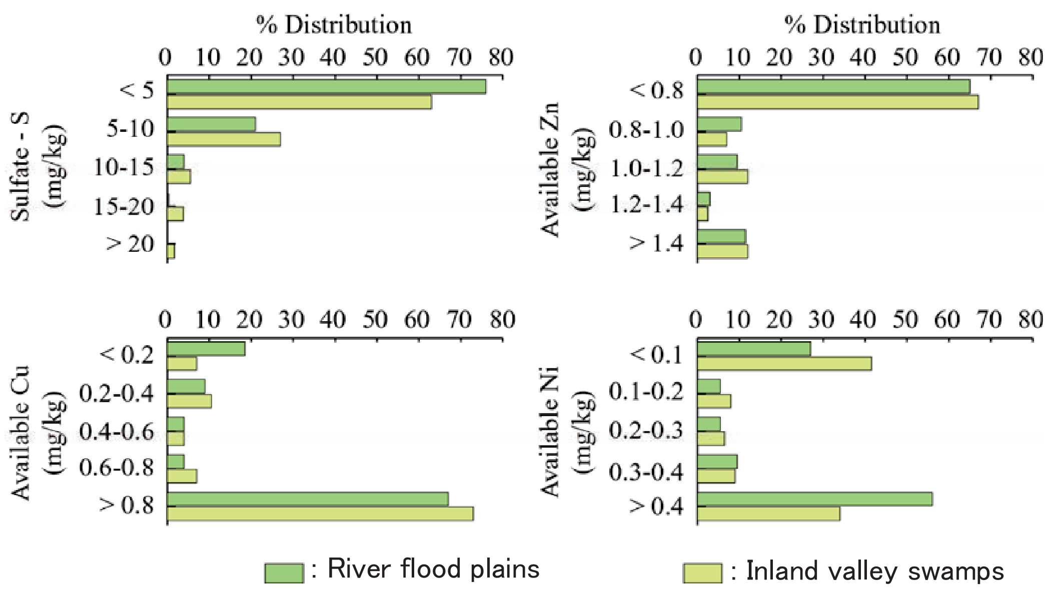


West Africa Map showing the selected sampling sites of lowland soils. (Buri and Wakatsuki, 2000)

The 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: The 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?

- Developing lowland sawah is the answer.
- The integrated management of lowland & upland such as watershed agro-forestry is also the key ecotechnology.
- The core region of West Africa has similar climate, soil, hydrology and crops to those in the northeastern Thailand; the important site in Asian-African collaboration in the future.

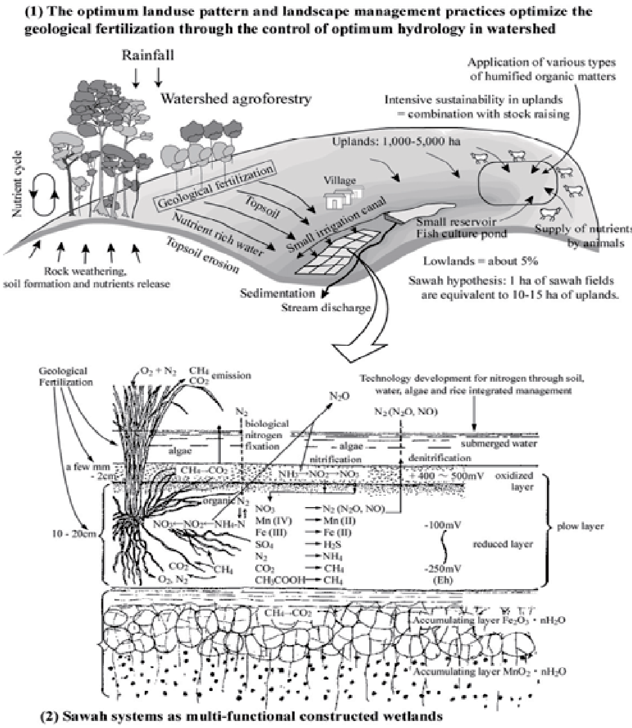
Sawah hypothesis (II): Sustainable productivity of lowland sawah fields are more than 10 times higher than the upland fields; This is not scientifically experimented results, but experienced results in Asia

1 ha sawah = 10-15ha of upland

	Upland		Lowland (Sawah)
Area (%)	95 %		5 %
Productivity (t/ha)	1-3 1≦**		3-6 2**
Required area for sustainable 1 ha cropping	5 ha	:	1 ha

* Assuming 2 years cultivation and 8 years fallow in sustainable upland cultivation, while no fallow in sawah

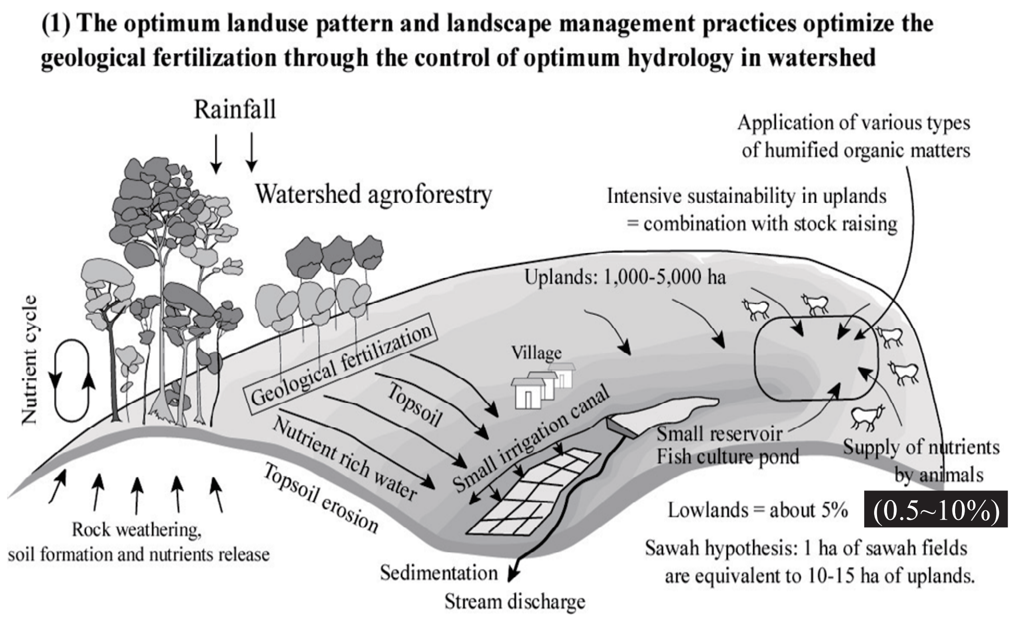
**In the case of no fertilization



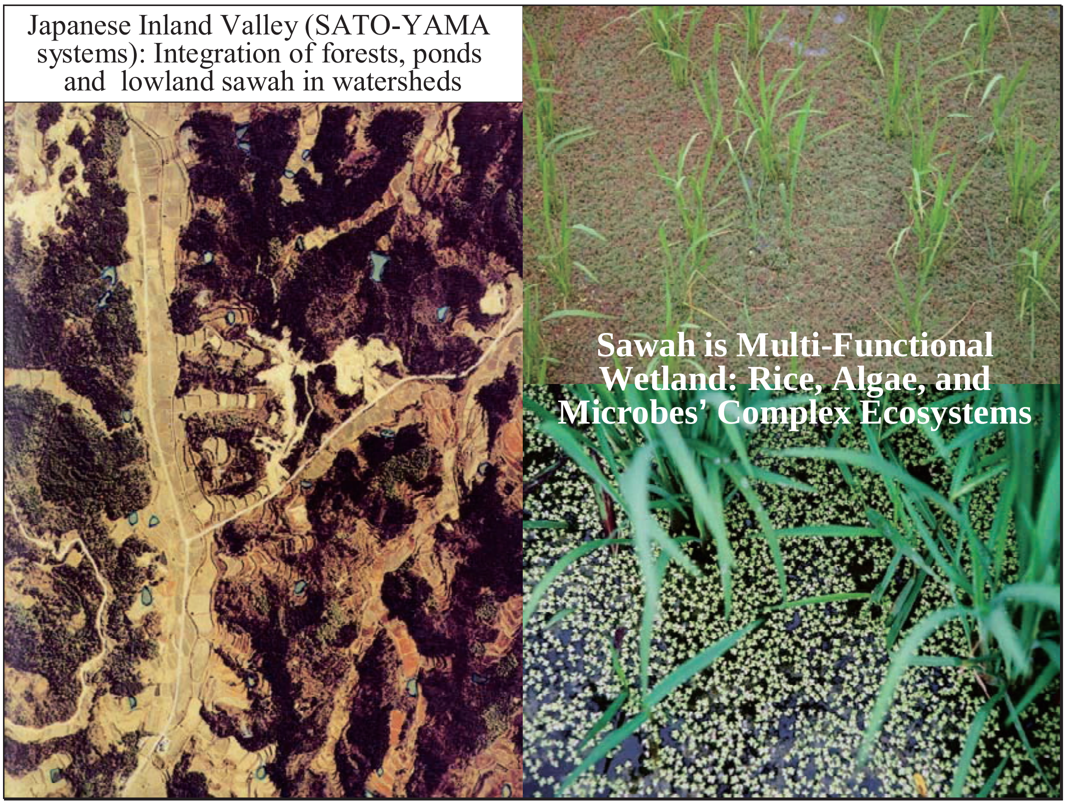
Macro- and Micro-scale Ecological Mechanisms of Intensive Sustainability of Lowland Sawah System

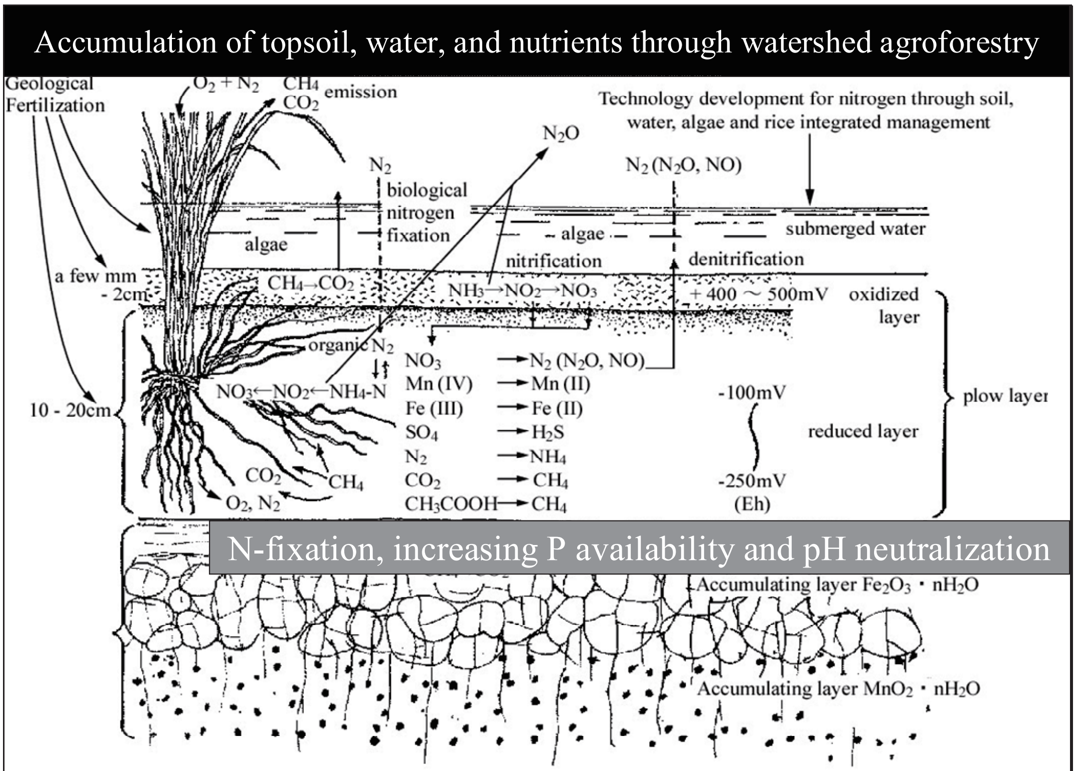
(1) Geological Fertilization: the lowland can receive water, nutrients, and fertile topsoil from the uplands.

(2) Multi-functional Constructed wetlands for controlling weeds and enhancing supply of N, P, Si, and other Nutrients



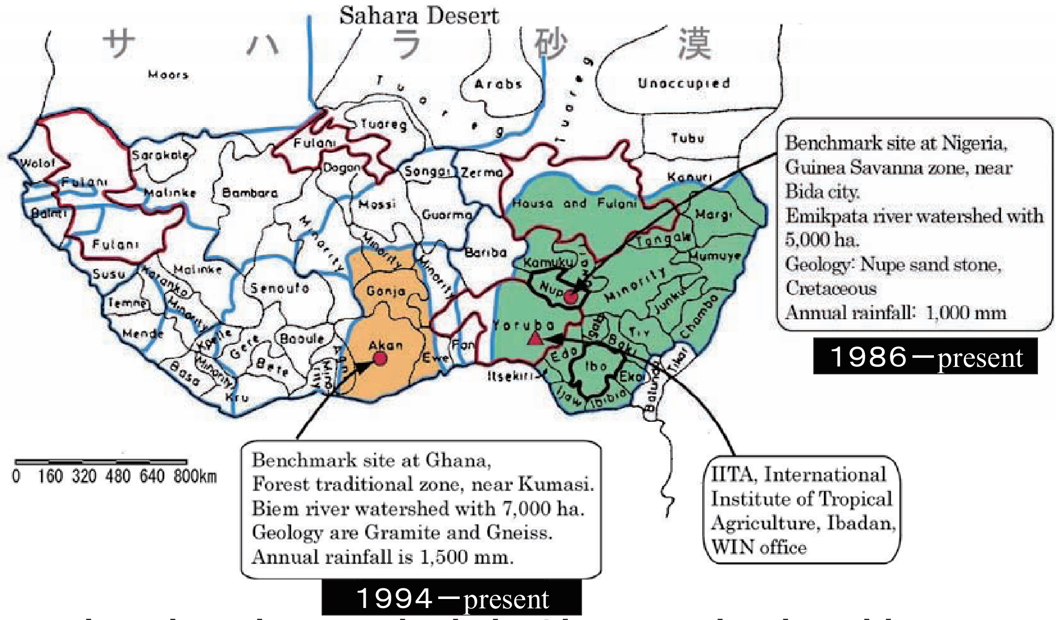
The concept of Watershed ecotechnology.
i.e.,(1)Watershed Agro-forestry and
(2)Multi-functional sawah-type wetland are the key components





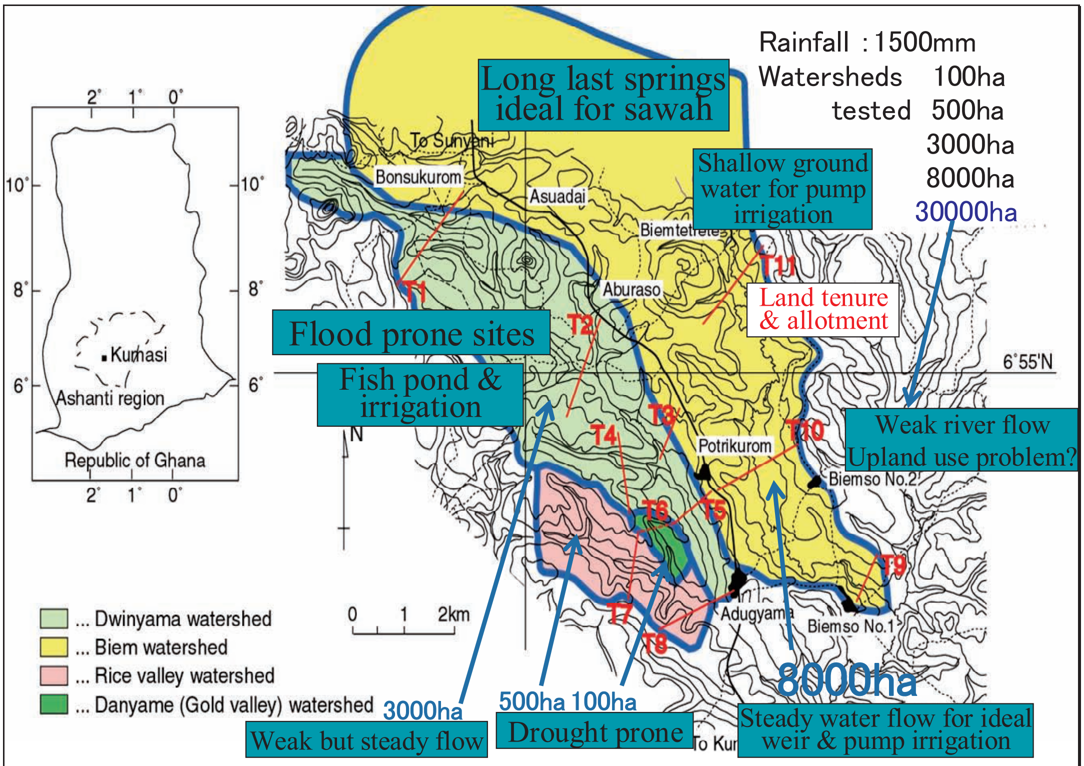
(2) Sawah systems as multi-functional constructed wetlands

Examples of eco-technological research & development



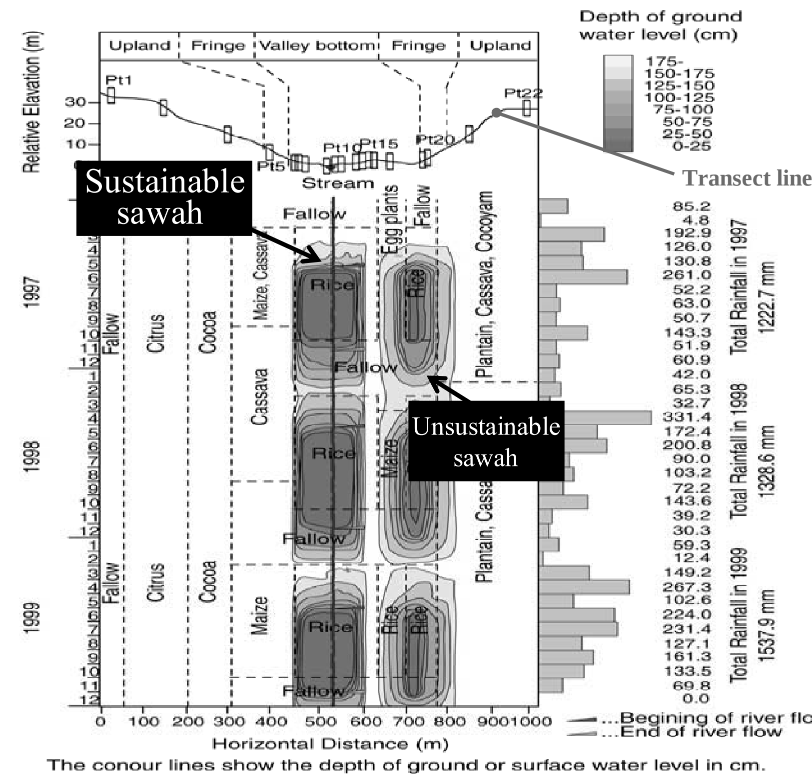
Two benchmark watersheds in Ghana & Nigeria. This map shows the countries with the major ethnic groups in West Africa

CRI-CSIR/JICA Sawah Project for integrated watershed management, 1997-2001

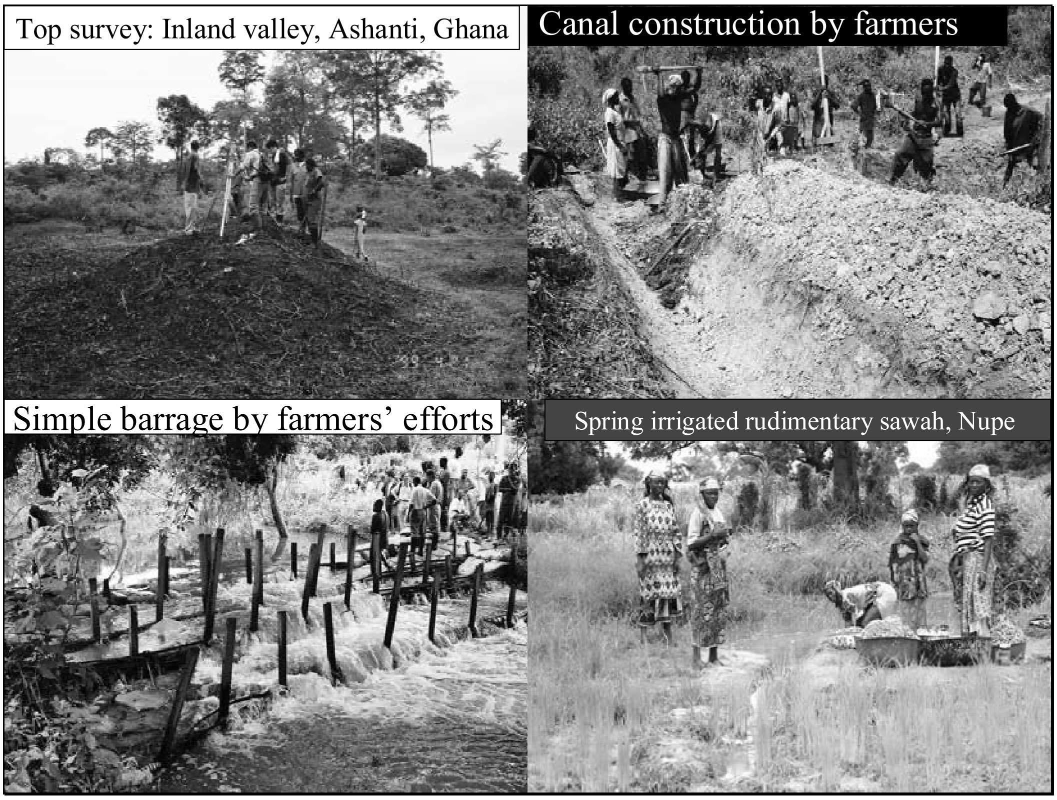


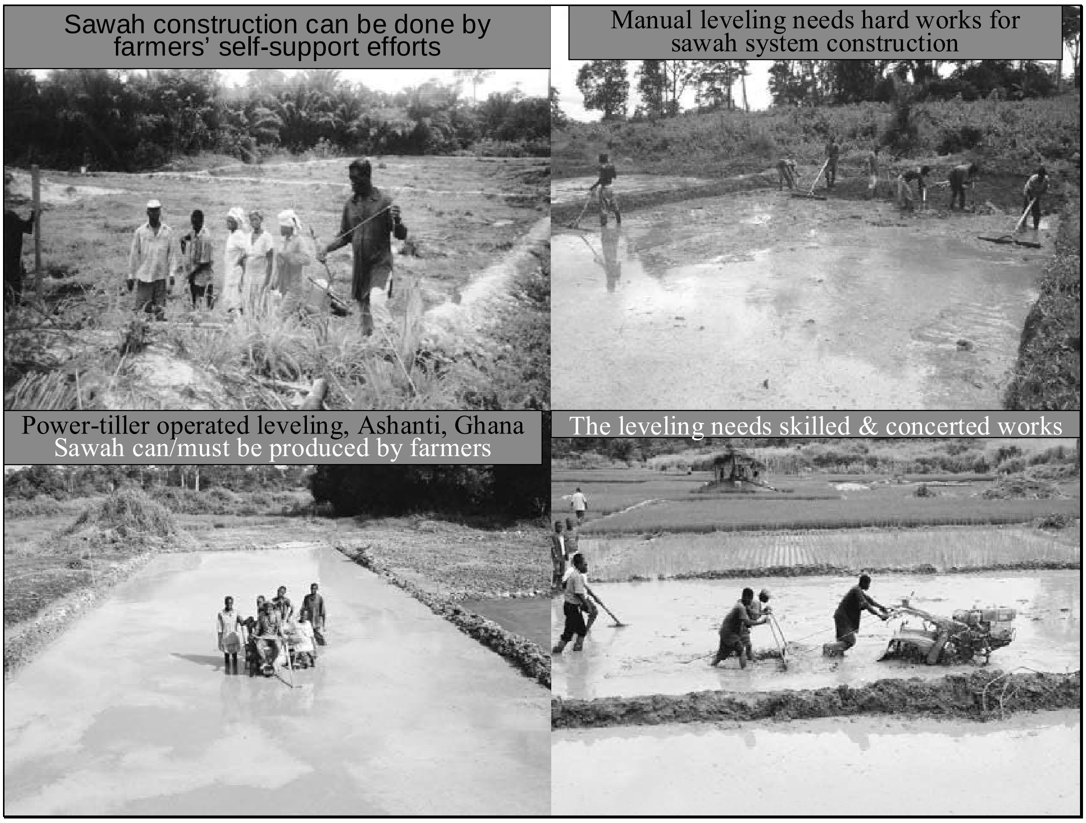
Research sites showing the location of transects in the watersheds.

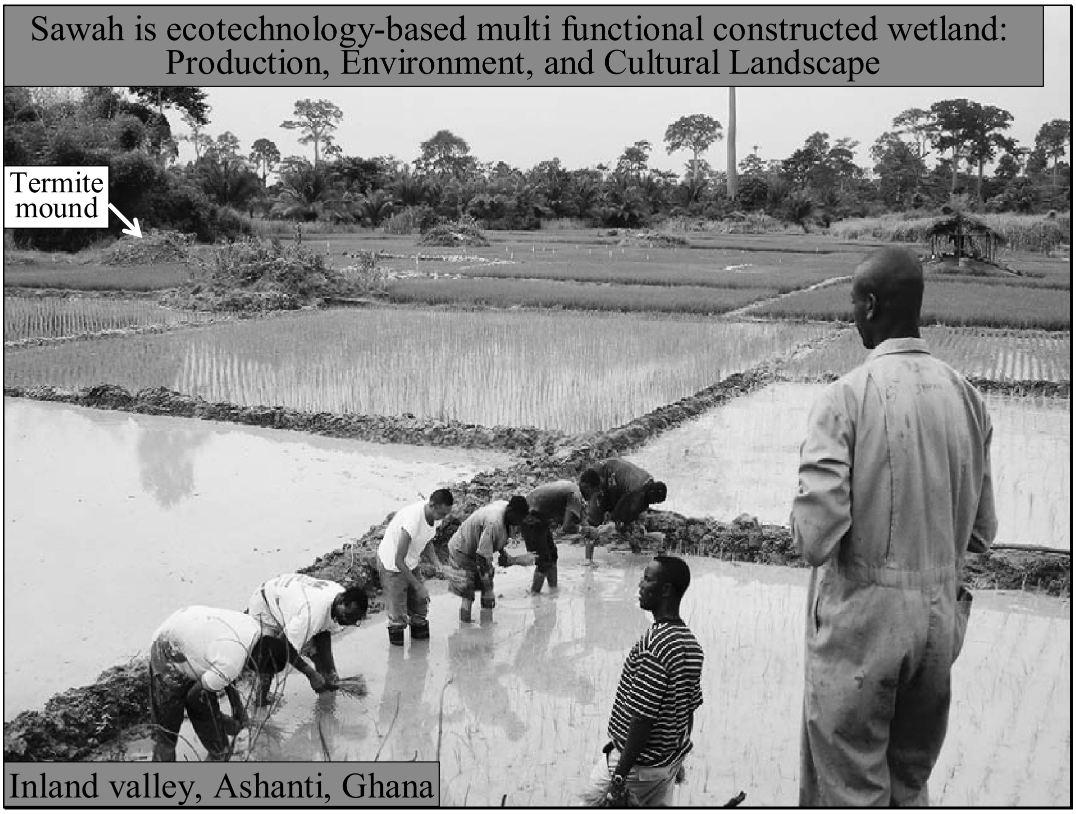
Although hydrology is the base for success of sawah, the performance of various ecotechnologies in watershed can be evaluated by water flow.

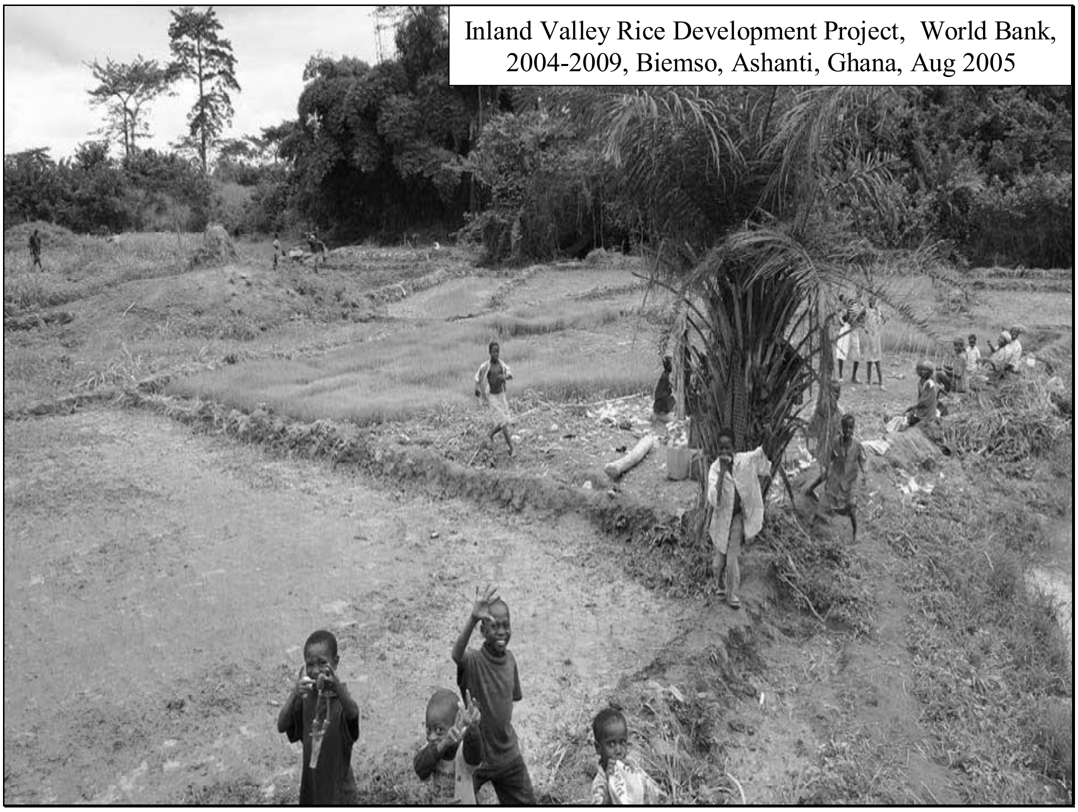


Cross-section of topography, rainfall pattern, ground/surface water and land use dynamics in stream flow inland valley (Transect 5), Dwinyan watershed, Ashanti Region, Ghana.

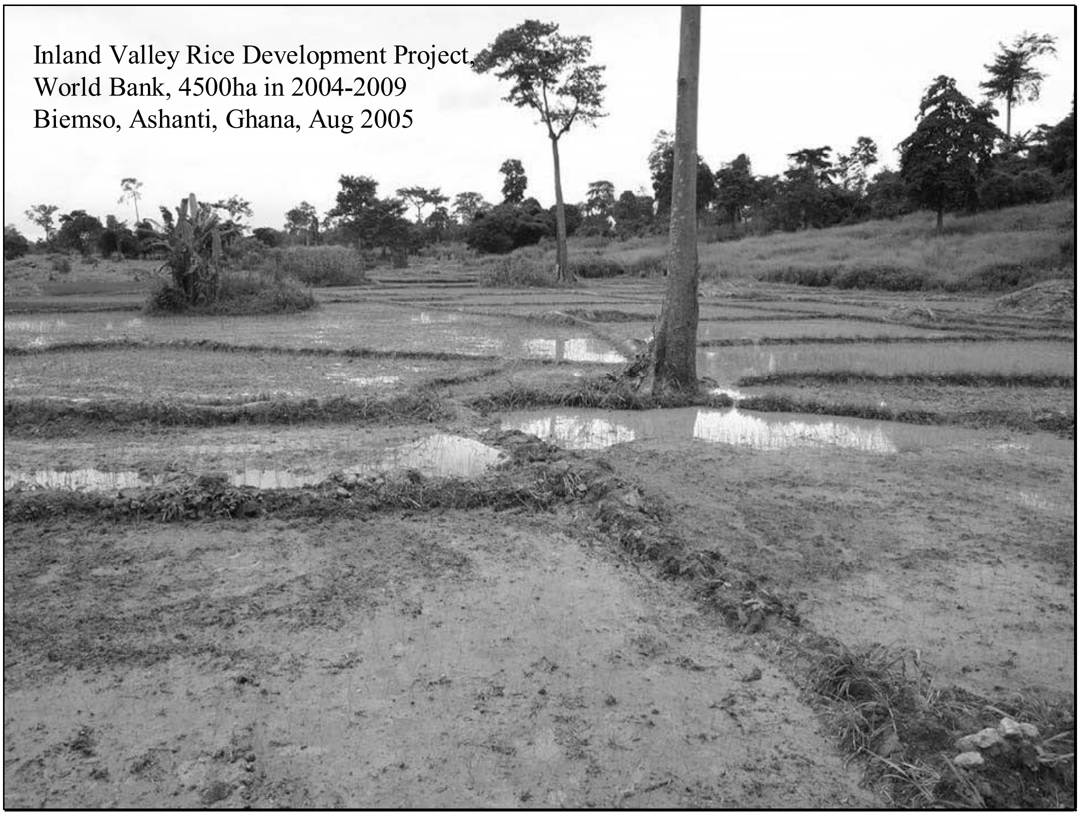



Sawah construction can be done by farmers' self-support efforts
Manual leveling needs hard works for sawah system construction
Power-tiller operated leveling, Ashanti, Ghana
Sawah can/must be produced by farmers
The leveling needs skilled & concerted works

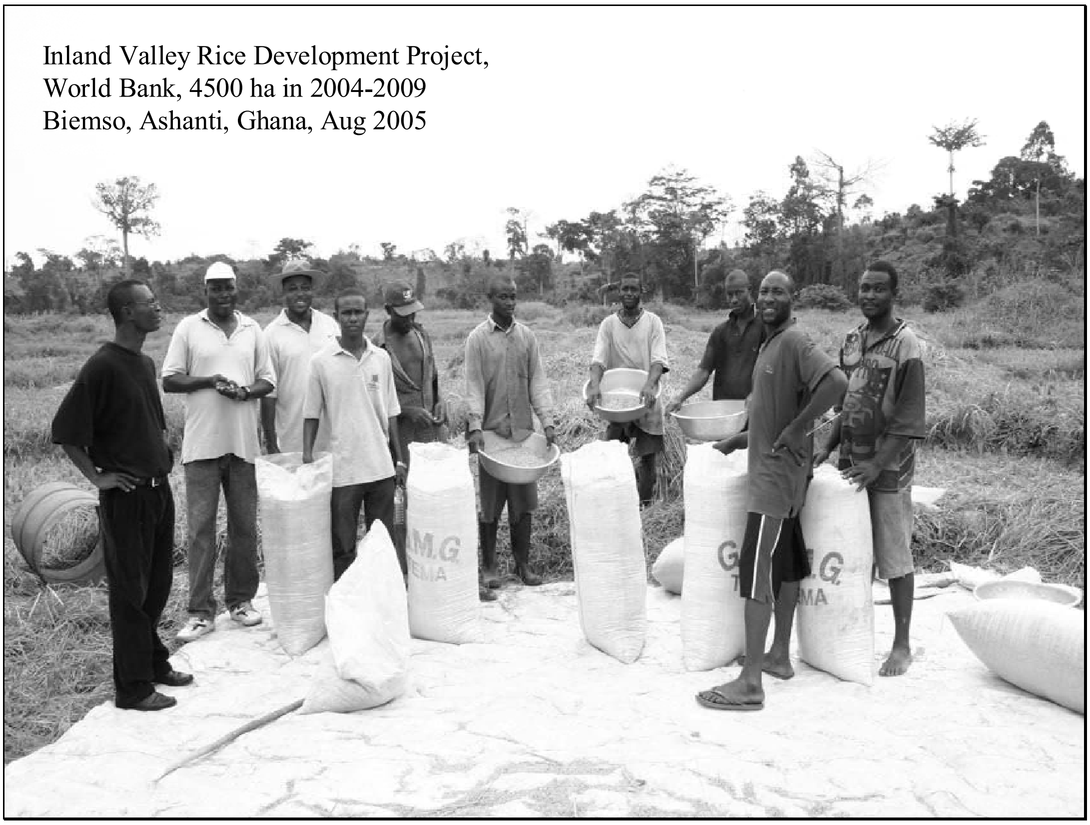

Sawah is ecotechnology-based multi functional constructed wetland: Production, Environment, and Cultural Landscape
Termite mound
Inland valley, Ashanti, Ghana

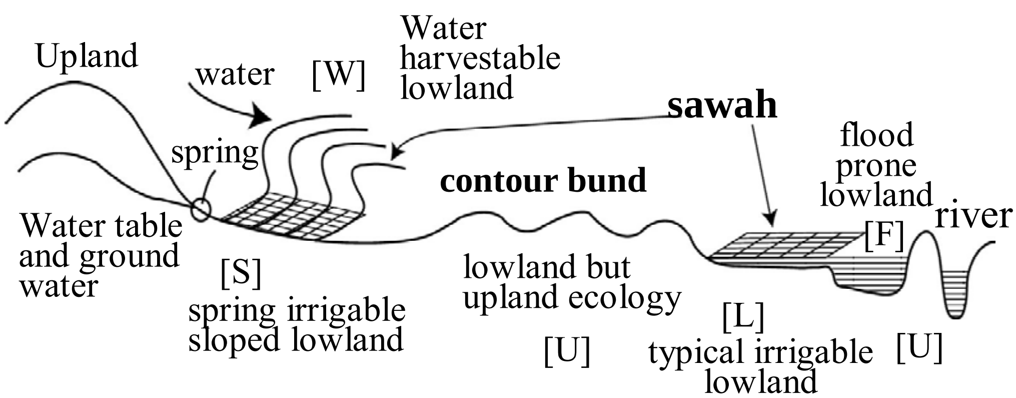


Inland Valley Rice Development Project, World Bank, 2004-2009, Biemso, Ashanti, Ghana, Aug 2005



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





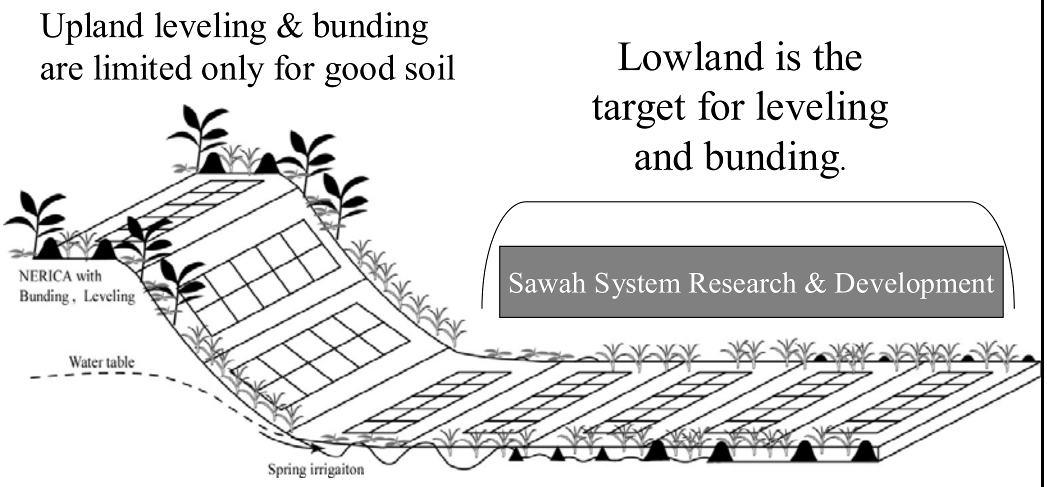
Irrigation options: Sawah to sawah/contour bund water harvesting, spring, dyke, river, pump, peripheral canal, interceptor canal, tank

Lowland sawah development priority

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

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

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



Water table and water management continuum (WARDA2004, 2006)

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

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

Table 2 Estimation of rice production trends by each rice ecology in West Africa during 1984-1999/2003

The **2015** estimation is by the author
(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**

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

Classification	Area (million ha)		Percentage(%)
Coastal swamps	16.5	(3-5)	10-30%
Inland basins	107.5	(1-4)	1-3%
Flood plains	30.0	(5-10)	10-30
Inland valleys	85.0	(5-15)	3-10

Possible areas of sawah development (million ha)

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

Conclusions

- Different from Asia, SSA's Green Revolution will be led by sawah type ecotechnology.
- The upland rice should be given low priority and be discouraged if lowland sawah development is possible.
- Major Constrains are:

(1) Demarcation of appropriate lowlands for sawah development

(2) Land-ownership systems to encourage sawah development

(3) Small machinery to accelerate the sawah development

(4) Education and training systems for sawah development and management

Conclusion:
Integrated ecotechnology and biotechnology are the base for
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 the past 15 years. The prerequisites will be soon satisfied therefore within 10-20 years, and the green revolution will be realized in SSA, especially in West Africa, if properly balanced strategy & policy were adopted for African green revolution.

質疑応答
Question and Answer Session

サブサハラアフリカでは何故緑の革命が遅れたか？： 水田仮説（1）
Why was the Green Revolution not Successful in Sub-Sahara Africa?: Sawah (Suiden) Hypothesis (1)

若月　利之　　Toshiyuki Wakatsuki
近畿大学農学部教授
Professor, Faculty of Agriculture, Kinki University, Japan

司会：　杉本　充邦　　Chair person: Mitsukuni Sugimoto
名古屋大学農学国際教育協力研究センター　准教授
Associate Professor, ICCAE, Nagoya University

Sugimoto, Chair:

Thank you very much, Professor Wakatsuki. Professor Wakatsuki has mentioned about utilization of water system in Africa and Asia. He mentioned about the difference of the Green Revolution in Africa and that in Asia. I'd like to ask the participants. Are there any questions?

Iijima:

Thank you very much for your presentation. Initially, you have mentioned that it is farmers who can develop the sawah system. However, I understand your conclusion as the government or donors should develop the sawah system. Which do you think is the case?

Wakatsuki:

I said the big irrigation scheme should be led by the government. On the other hand, works for the farmers' fields including the sawah system development should be led by the farmers. Fortunately in the case of Ghana, we have developed quality sawah systems which secure paddy yield higher than 4 t/ha, through farmers' self-support efforts. However, the sustainability of the sawah systems developed may be affected by the landowner systems. Therefore, we have to research in order to adjust or to modify the present landowner systems for sustaining and encouraging the sawah development.

Iijima:

Do you mean that the farmers themselves can solve their landownership problems? Because it's a very legal system, it must be the government which can solve this kind of landowner system.

Wakatsuki:

Since sawah systems can give much higher yield comparing to traditional rice production, some sawah farmers get some money power to solve the land tenure problems. But the other farmers may loss shortly after the sawah systems developed by the request of landowner. The important point is how we can adjust/modify/change such an African way of landownership system to encourage sawah system development.

Maybe we had better to ask Professor Onyango. Is there any possibility of encouraging African people to develop their own landowner systems to encourage agricultural development?

Onyango:

I think it is possible. The presentation was very productive and you indicated that the problem of sawah system is with the government especially on the infrastructure which is the same as the conclusions I reached in my presentation. The land ownership system if at all it has to be done legal must be done by the government. Therefore the government still comes in as the as farmer can not work in a vacuum. A farmer cannot develop the Sawah system you are talking about if they are not sure whether they will own that land tomorrow or not. Therefore the government still comes in. The idea you are trying to put up is correct but you need to integrate them, so that we know which part the farmer can play and which part the government plays. It is the government which has to come in first, because they have to demarcate land, issue title deeds transferring the ownership to farmers whether male or female. After that the Sawah system can be developed and the green revolution will take off. I think that is the approach. Thank you.

Iijima:

Thank you very much for your presentation. I think even if the land tenure problems are solved by changing the policy of the government, what is the mechanism to disseminate or to accelerate the lowland development by farmers. That is my first question. And the second is, what do you mean by the word "discouraging lowland rice systems through the active promotion of upland NERICA"? Do you mean that they might abandon their upland rice? And my third question is, at first you said the farmers are not ready to accept the green revolution technologies. What does the "accept" mean? Does it mean that the farmers still can not accept the green revolution technologies? Or, is it merely a problem of availability or something like that? What do you mean by "accept"?

Wakatsuki:

Actually, I don't know much about the approach of the dissemination of sawah technologies regarding your first question. Establishing an institutional organization is very important for developing the sawah system. However, the most important thing will be how we can organize the mechanisms or systems to give the training for sawah technologies to many, maybe ten million Sub-Sahara African farmers, and encourage them to improve their yields through sawah systems. How can we do this in a relatively short time?

I think the key issue is training farmers in sawah technologies. We have to train numerous leading farmers in each country. Then such leading farmers will train the groups of their neighboring farmers. This farmer-to-farmer training system will be important. To train the leading farmers, I suggest the massive collaborative and integrated action research should be implemented. The most effective way of training is the on-the-job training in sawah technologies, skills, and knowhow with the international organizations such as Africa Rice, and national scientists as well as engineers, extension officers, and leading farmers in diverse agro-ecosystems in each country.

As shown in Fig.10, the sawah area expansion has taken long history of millennium years in Japan. The majority of the other Asian countries also have developed their sawah systems in historical years of hundreds or more. Because of extremely rapid expansion of population, we have to find out the way for rapid expansion of sawah systems in Sub-Sahara Africa in a short time, within 50 years or so.

As shown in Fig. 10, there are two eras of rapid expansion of sawah area in Japan, i.e., during 1500-1650 of the Sengoku era and 1900-1950 of the Meiji restoration era. About one million ha of sawah area was developed in each of the period.

The upland rice cultivation rapidly degrades the soil if proper soil and water conservation measures are not given. This is the important fact in relation to the second question. If we want to develop soil and water conservation measures, the sawah system development in lowland should be given priority. Therefore, if we stress too much on upland rice cultivation, lowland sawah development will be delayed because of scarce resource allocation for new sawah development. However, of course when no lowlands are available, upland rice would be an only selection.

Concerning the third question, if no sawah system exists, three green revolution technologies, i.e., high yielding varieties, fertilizer, and irrigation, are not accepted by farmers. The sawah system is the missing prerequisite to accept the green revolution technologies. This is the main topic of this presentation, which is described as the Sawah Hypothesis (I).

Iijima:

For the integration, although rice is very important, there are many other important crops such as yam and cassava. How can yam and cassava cultivation be integrated into the lowland sawah systems.

Wakatsuki:

Since yam and cassava cultivations are mainly done in the uplands, there would be no friction with lowland sawah. In some areas like Nupe and Bida, cassava is grown after rice in the lowlands. In some areas like Abakaliki in the south eastern Nigeria, cassava is planted in the upper part of toposequence, and yam is at a lower slope, and rice is cultivated at the valley bottom in a watershed.

Iijima:

Although maize and cassava can be integrated in agro-forestry systems, do you think that maize and cassava cultivations should be discouraged eventually?

Wakatsuki:

I don't think so. As I have just mentioned, maize cultivation could degrade soils in the long run if no adequate soil conservation measures are given. However, concerning the upland rice, I think the upland cultivation should be discouraged if lowlands are available. If only uplands are available, an upland NERICA can be grown. In summary, although there may be priority crops depending on the agro-ecology and environment, we need to implement balanced research and technological development for improving rice growing environment such as sawah systems, in comparison with that for improving rice varieties.

Iijima:

Thank you very much.

Sugimoto, Chair:

Thanks for your discussion.

Profile

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1977 年京都大学大学院農学研究科博士課程修了。1981 年から 2003 年まで島根大学、ついで 2004 年から近畿大学農学部教員、現在に至る。この間、1986 年 3 月から 1989 年 2 月まで、国際熱帯農業研究所(IITA)で、国際協力機構(JICA)派遣の長期及び短期水田稲作専門家として西アフリカ全域の稲作生態の調査研究を実施。又、西アフリカに適した水田システムの実証的研究に従事。帰国後、1992 年から現在まで、文科省（日本学術振興会）の科研や JICA の研究協力プロジェクト等により、ナイジェリア中央部のヌペ人地域とガーナのアシャンテイ地域の集水域（各 1 万 ha 規模）をベンチマークサイトとして、持続可能な水田システムの実証的開発研究を実施している。研究テーマは西アフリカにおける緑の革命の実現による食料増産と劣化環境修復のための集水域生態工学。専門分野は土壌学、生態工学、アフリカ水田開発分野における国際協力研究。

Academic career

Professor Toshiyuki Wakatsuki graduated from Post-Graduate School of Kyoto University in 1977.

Professional career

Professor Wakatsuki worked on Sawah (“suiden” in Japanese) based rice culture in West Africa as a JICA expert at the International Institute of Tropical Agriculture (IITA), Nigeria, from 1986 to 1989. Since 1992, Professor Wakatsuki has been funded by JICA, JSPS, FASID and MESIC and has organized various long-term on-farm research and development projects at two benchmark watersheds in Nupe of Central Nigeria, Guinea Savanna zone, and Ashanti in Ghana. His main research field is sustainable increase of food production and restoration of degraded environment through ecological watershed engineering in West Africa. Soil science, ecological engineering and African Sawah development are his professional research fields. Professor Wakatsuki worked as a professor of the faculty of agriculture, Shimane University, Japan, and has been a professor of the faculty of agriculture, Kinki University, Japan.

西アフリカ稲作の拡大、集約化、持続性：コートジボワールとガーナの天水低湿地稲作の例[1]

Expansion, Intensification, and Sustainability of Rice Production in West Africa: The Case of Rainfed Lowland Rice in Côte d'Ivoire and Ghana[1]

櫻井　武司　Takeshi Sakurai
農林水産省 農林水産政策研究所 主任研究官[2]
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要　約

西アフリカ諸国の政府は、増大するコメの需要に対処するためにコメを増産しようとしている。同地域でコメの生産拡大に大きなポテンシャルを持つのは、内陸にある低湿地（inland valley lowlands）である。そこで、コートジボワールのブアケ市とガーナのクマシ市という内陸にある 2 つの大きな商業都市の周辺で、低湿地稲作に関する大規模な調査を実施した。本稿は、その調査の結果に基づき、低湿地における稲作の面的拡大、生産技術の集約化、生産の持続性、それぞれに影響する要因を明らかにする。調査では、まず少なくとも 1 ヶ所は領域内に低湿地のある村を無作為に選んだ。その結果、ブアケ市周辺地域では 157 ヶ村、クマシ市周辺地域では 60 ヶ村が選ばれた。調査対象村落にある低湿地の数は、合計するとブアケ市周辺地域で 317 ヶ所、クマシ市周辺地域で 60 ヶ所にのぼる。

ブアケ市周辺地域の低湿地のうち約 83%では、今までに少なくとも 1 回は稲作が行われたことがあり、約 37%では調査時にも稲が栽培されていた。一方、クマシ市周辺では、それぞれ約 85%と約 57%である。多変量解析の結果によると、ブアケ市周辺地域において低湿地稲作の実施確率を高める要因は、市場への近接度と人口圧であった。しかし、クマシ市周辺地域ではそれらは有意な影響を持たず、その代わり移民の数が稲作実施の確率を高めている。

水管理は、低湿地における稲作の集約化に非常に重要な技術である。しかし、クマシ市周辺地域の低湿地では、稲作はもっぱら天水に依存しており水管理技術は採用されていない。一方、ブアケ市周辺地域では、都市の近くに立地する低湿地ほど畦や水路を構築して水管理を実施する傾向にある。分析の結果、畦や水路の構築を促進する要因は、市場への近接度と移民の数であることが判明した。また、水路のある低湿地では放棄されずに稲作が持続している。

ブアケ市周辺地域で多数派を占める民族はバウレ、クマシ市周辺地域ではアシャンティである。両者ともアカン語族に属するため、文化や慣習については共通点が多い。両民族にとってコメは伝統的な作物ではないため、ブアケ市周辺とクマシ市周辺の両地域で稲作に従事しているのは、たいてい北部のサバナ地帯から来た移民である。移民が低湿地で稲作をする理由は、移住する以前に低湿地稲作の経験があること、移民には畑地が配分されない場合があることなどがある。このように両地域では類似性が高いが、稲作技術とりわけ水管理技術の採用は両地域で異なっている。ブアケ市周辺地域の方が土地の相対価格が高いこと、ブアケ市周辺地域では過去に政府や国際援助機関により技術普及が行われたことが理由であると考えられる。とりわけ、今回の分析対象からは除いてあるが、ブアケ市周辺地域内で実施された灌漑水田プロジェクトから技術が周辺地域に拡散した可能性が高い。一方、クマシ市周辺地域の土地所有制度は、移民が土地に長期的な投資をすることを妨げている可能性がある。

キーワード：内陸低湿地、コメ、集約化、土地制度、移民

[1] 本論文は、2006 年 10 月の講演内容を踏まえて、内容を拡大、発展させたものである。内容にあわせて、タイトルも変更してある。
This paper is based on the one presented in October 2006, including contents extended and developed. The paper title has been also changed in accordance with the content modification.

[2] 2006 年 10 月講演当時。2010 年 2 月現在は一橋大学経済研究所教授。
At the time of presentation in October 2006. The present title is Professor, Institute of Economic Research, Hitotsubashi University.

Expansion, Intensification, and Sustainability of Rice Production in West Africa: The Case of Rainfed Lowland Rice in Côte d'Ivoire and Ghana

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Abstract

Governments of West African countries try to enhance rice production to cope with the increasing demand. Inland valley lowlands constitute a huge potential for rice production. Based on large-scale field surveys around two big inland markets in Côte d'Ivoire (Bouaké) and Ghana (Kumasi), this paper explores factors affecting the expansion, intensification and sustainability of lowland rice production. We randomly selected villages that have one or more lowlands within the village territory. The number of villages selected was 157 around Bouaké and 60 around Kumasi. We identified 317 lowlands in the Bouaké sample villages and 188 lowlands in the Kumasi sample villages.

About 83% of Bouaké lowlands were used at least once for rice cultivation, and 37% of total lowlands were under rice cultivation at the time of study. Corresponding figures for Kumasi were 85% and 57%. Multiple regression analyses revealed that market accessibility and population pressure increased the probability of lowland utilization in the Bouaké area, whereas they had no significant effect in the Kumasi area. In the Kumasi area, on the other hand, immigrant population positively influenced the use of lowlands.

Water control is an important technology for intensification of lowland rice production. In the Kumasi area rice cultivation is purely rainfed, but lowlands located closer to Bouaké tend to be equipped with bunds and canals. Bund and canal construction was found to be influenced positively by market accessibility and number of immigrants. The adoption of water control technologies enhanced the sustainability of lowland rice cultivation.

Dominant ethnic groups are Baoulé in Bouaké and Ashanti in Kumasi, both of which belong to the Akan language group that shares similar cultural heritage. For them rice is not a traditional crop. Usually, migrants from the Savanna zone are cultivating rice in lowlands because they are familiar with lowland rice production and they are sometimes not allowed to use upland fields. Hence we would attribute the differences in rice cultivation methods to the higher relative price of land in the Bouaké area as well as past governmental and/or foreign intervention. Particularly modern irrigation projects around Bouaké (which are excluded from our analyses) may have had spill-over effects of technologies. In addition, we hypothesize that the land tenure systems in the Kumasi area are discouraging migrant tenant cultivators to make a long-term investment in lowlands.

Keywords: inland valley lowlands, rice, intensification, land tenure, immigrants

1. Introduction

Demand for rice in West Africa has been growing since the 1970s not only due to population growth, but also because of a shift in diet away from traditional coarse grains caused by a number of factors such as urbanization (Lançon and Erenstein, 2002). Rice production in this region has grown fast relative to other cereals, but the gap between regional supply and demand for rice is steadily increasing. As a result rice imports reached an average of 2.6 million tons in the early 1990s (WARDA, 1997). This has raised concern about the future food security in this region and policymakers are taking measures to enhance rice production.

Rice production can be increased by area expansion and/or intensification, i.e. increase in yield per unit area. Rainfed lowland ecology, one of the five important rice production ecologies in West Africa,[1] is considered to have relatively high potential for both expansion and intensification. The lowland ecology occupies an estimated 20 million to 50 million hectares in West Africa, but only 10 to 25% of the lowland area is under cultivation (WARDA, 1998). Moreover, due to lack of water control, current rice yield in rainfed lowlands is 1.4 tons per hectare on average. Because potential yield is estimated to be 2.5 – 5.0 tons per hectare, potential for intensification is enormous (WARDA, 1999).

In spite of the huge potential for expansion and intensification of West Africa's rainfed lowland ecology, past studies have been limited to describing a few cases and no quantitative analysis on a representative sample has been done. In order to fill this gap and to generalize the observations to formulate policies, we have conducted surveys on lowlands randomly sampled from a large area and constructed a representative data set. Based on this data set, this paper is to identify quantitatively factors that determine the use of lowlands for rice cultivation (i.e. expansion), the adoption of water control technologies (i.e. intensification), and the continuation of lowland rice cultivation (i.e. sustainability).

2. Methods

2.1 Study Sites in Côte d'Ivoire and Ghana

It is generally believed that market access influences the intensification of rainfed lowland rice production. Hence, we selected two large inland cities in West Africa for the study sites in order to examine the effect of market access. The cities are Bouaké in the Bandama Valley region of Côte d'Ivoire and Kumasi in the Ashanti region of Ghana. They are the second largest cities in each country with a population of 333,000 in 1988 and 385,000 in 1984 respectively. Both cities have a large, regional market where locally produced rice as well as imported rice is being traded. Although both cities are not prohibitively far from coastal port cities, local rice should have advantage in terms of transportation costs over imported rice. In 2001 local rice sold at 250 to 300 FCFA/kg and imported rice sold at 250 to 600 FCFA/kg in Bouaké's retail market. Corresponding figures were 2600 to 3200 cedis/kg and 2600 to 6000 cedis/kg in Kumasi's retail market (according to our own survey). Because the exchange rate between FCFA and cedi was about 1 FCFA = 10 cedis in the same period, nominal rice prices were almost equivalent in the two inland markets. Note that the price of locally produced rice was the same as the lowest price of imported rice in those markets.

With respect to agro-ecology, Bouaké is situated in the transitional zone between the humid forest and the savanna zones and its annual rainfall is about 1000mm on average. Kumasi, on the other hand, is in the humid forest zone with an average of 1400mm annual rainfall. Annual rainfall pattern is bimodal in both areas, but the period of the rainy season is longer in the Kumasi area. In both areas rice is mainly produced in lowlands during the rainy season without modern irrigation technologies, that is, in rainfed lowland ecology. Upland rice is rarely cultivated. Instead uplands are used for yam, maize, and cassava, which are traditional staple foods. Rice cultivation in lowlands was introduced in these areas relatively recently.

2.2 Sampling in Côte d'Ivoire

In Côte d'Ivoire we selected 11 contiguous sub-prefectures around Bouaké. We obtained the village list of the 1988 census for each sub-prefecture from the National Institute of Statistics in Bouaké, and randomly selected 179 from 857 villages in the list. The number of villages sampled in each sub-prefecture was determined so that it would be proportional to the total number of villages in each sub-prefecture (sampling rate was about 21 percent). From December 1999 to May 2001, we visited all the 179 sampled villages several times to collect village level information on lowland use as well as village characteristics by means of group interview of village leaders. Out of the 179 sampled villages, we found that 157 villages had at least one lowland. These 157 villages were used for the analyses in this paper.

2.3 Sampling in Ghana

In Ghana we numbered all the villages within the 60km radius from the center of Kumasi on topographic sheets issued by the Survey Department of Ghana. The total number of villages amounted to 1586. Then 40 villages were randomly drawn from the villages along the highways, and another 40 villages from the villages off the highways. We visited all of them, and confirmed whether there were lowlands in the village area. Forty villages were deleted because there were no lowlands in the village area. The remaining villages were stratified based on the distance from the center of Kumasi: 10-20km, 20-40km, and 40-60km. Then, we re-sampled another 20 villages so that there were 12 samples from 10-20km stratum, and 24 samples from 20-40km stratum and 40-60km stratum respectively while keeping the numbers of villages on the highways and off the highways equal. This brought the total number of sample villages to 60 (i.e. 30 located along highways and 30 located off highways).[2] We conducted group interviews with the village leaders to obtain information on the village and its lowland areas from September to December 2000.

2.4 Data

Table 1 summarizes the variables that we constructed from the survey data. The number of immigrants is a critical variable in this study because it creates population pressure particularly on lowlands (i.e. effective population pressure) and also because the immigrants are considered to have brought lowland rice cultivation in the study sites. But since we could not obtain reliable information with respect to the number of immigrants, we used proxy variables: the ratio of male to female population in the case of Côte d'Ivoire and a dummy variable indicating whether a village is producing cocoa or not in the case of Ghana. In the Kumasi area, cocoa farms have been the main providers of job opportunities for immigrants. In the Bouaké area there is no such dominating industry, but it is obvious that villages with labor demanding industry have more males than females due to influx of male labor force, while villages without such industry loose males because of their temporal departure for other regions such as cocoa and/or timber zones in Côte d'Ivoire.

Because the use of lowland is affected by cultural background, we use dummy variables for ethnic group. The majority is Baoulé in the Bouaké area and Ashanti in the Kumasi area. Both belong to the Akan language group, and share similar cultural heritage. In the Kumasi area 56 of 60 sample villages are Ashanti villages. In the Bouaké area, there are enough villages that belong to other ethnic groups than Baoulé, such as Tagbana, Djimini, and Dioula. Therefore, in addition to the dummy variable for Baoulé, one for Tagbana was created. Ashanti, Baoulé and Tagbana people generally do not have a tradition to cultivate lowlands.

Whether the village was established by people from within the region (i.e. the Bandama Valley region in Côte d'Ivoire or the Ashanti region in Ghana) or by people from outside the region captures some characteristics of the village. In general, an old village has its origins outside the region because its founders migrated from other regions several hundreds years ago. Since then, new villages have been established by separation from the original villages. Therefore, relatively new villages have their origin within the region. Such new villages sometimes do not have enough uplands and consequently tend to cultivate in marginal lands, i.e. lowlands.

With respect to market accessibility, we use direct distance between the village and the capital cities, which does not depend on infrastructure development and does not change over time. The mode, cost, and time of transportation may be better indicators for current market access, but we do not use them because they depend on infrastructure development and cannot reflect accessibility in the past.

3. Statistical Analyses

3.1 Use of Lowlands

Of the 179 sample villages, 157 villages have access to lowlands in the Bouaké area, while 40 villages of the 80 villages investigated have access to lowlands in the Kumasi area. The share of villages with lowlands in all sample villages was much higher in the Bouaké area than in the Kumasi area. The total number of lowlands accessible from the 157 villages was 317 in the Bouaké area and it was 188 in the sampled 60 villages in the Kumasi area, suggesting that the average number of lowlands per village with lowlands was greater in the latter than the former. However, if we include villages without access to lowlands, the average number of lowlands per village becomes 1.8 in the Bouaké area and 1.6 in the Kumasi area.[3] This means that the average number of lowlands per village does not differ much between the two study sites, but the distribution of lowlands is more skewed in the Kumasi area.

Table 2 compares the use of lowlands in the rainy season between the two sites. In the Bouaké area more than half of the all sample lowlands are

Table 1 Variables Constructed for Regression Analyses

Variables	Unit	Description
Village Level Variables		
Village population	1000	1988 and 1998 census (Côte d'Ivoire). 1984 census and our own survey as of 2000 (Ghana)
Immigrant indicators		
Ratio of male to female	%	Male population divided by female population in the village multiplied by 100. 1988 and 1998 census data are used (Côte d'Ivoire only)
Cocoa producing village	dummy	If the village produces cocoa, the value is 1 (Ghana only)
Dominant ethnic group		
Akan	dummy	If the dominant ethnic group in the village is Baoulé (Côte d'Ivoire) or Ashanti (Ghana), the value is 1
Tagbana	dummy	If the dominant ethnic group in the village is Tagbana, the value is 1 (Côte d'Ivoire only)
Origin of the village	dummy	If the ancestors came from outside the region (the Bandama Valley region in Côte d'Ivoire or the Ashanti region in Ghana), the value is 1
Hamlets of ethnic minorities	dummy	If ethnic minorities form hamlets in the village, the value is 1
Education at village level		
Existence of primary school	dummy	If a primary school had been established in the village as of 1980, the value is 1
Years since the establishment	years	Number of years since the establishment of the first primary school in the village
Access to the Markets		
Regional capital	km	Distance to the village from Bouaké in Côte d'Ivoire and Kumasi in Ghana
Sub-prefectural capital	km	Distance from the sub-prefectural capital to the village. There are 11 sub-prefectural capitals (Côte d'Ivoire only)
Village along a highway	dummy	If the village is located along a highway, the value is 1. There are 6 highways from Kumasi (Ghana only)
Lowland Level Variables		
Access to the village	km	Distance from the lowland to the village center
Acreage of lowland area	$100m^2$	Estimated acreage of lowland area (Côte d'Ivoire only)
Water source		
Permanent stream	dummy	If the water source is a permanent stream, the value is 1 (Côte d'Ivoire only)
Seasonal stream	dummy	If the water source is a seasonal stream, the value is 1 (Côte d'Ivoire only)

Table 2 Current Lowland Use in Rainy Season (% of number of lowland)

	No use	Rice	Vegetables	Maize	Tree Plantation	Rice + Vegetable	Rice + Maize	Rice + Tree Plantation
Bouaké area	59.3	36.6	13.3	0.6	1.9	9.8	0.3	0.3
Kumasi area	18.3	56.6	11.8	11.7	59.0	3.5	4.4	39.0

Total number of lowlands is 317 in the Bouaké area and 188 in the Kumasi area. The percentages do not add up to 100% for each sites because of multiple use. In the case of the Kumasi area, the original figures obtained from the survey data are corrected based on the weight of each sampling stratum shown in footnote 2.

Table 3 Current Lowland Use in Dry Season (% of number of lowland)

	No use	Rice	Vegetable	Maize	Tree Plantation	Rice + Vegetable	Rice + Maize	Rice + Tree Plantation
Bouaké area	88.6	4.1	7.3	0.9	1.9	0	0.3	0
Kumasi area	6.4	0	71.1	57.3	59.0	0	0	0

Total number of lowlands is 317 in the Bouaké area and 188 in the Kumasi area. The percentages do not add up to 100% for each sites because of multiple use. In the case of the Kumasi area, the original figures obtained from the survey data are corrected based on the weight of each sampling stratum shown in footnote 2.

Table 4 Expansion and Reduction of Rice Cultivation (% of number of lowland)

	Rice has never been cultivated	Rice was cultivated in the past	Average years passed since last rice cultivation	Rice is currently cultivated (i.e. at the time of this study)
Bouaké area	17.4	46.0	15.5 years	36.6
Kumasi area	14.6	28.5	12.7 years	56.6

Total number of lowlands is 317 in the Bouaké area and 188 in the Kumasi area. In the case of the Kumasi area, the original figures obtained from the survey data are corrected based on the weight of each sampling stratum shown in footnote 2.

not currently utilized (i.e. at the time of study), and rice cultivation is the single dominant use in the rainy season. On the other hand, in the Kumasi area more than 80 percent of the lowlands are currently utilized: the major crop in the rainy season is rice while tree plantation is the major perennial use of lowlands. Palm trees were planted in almost all the cases of tree plantation, and teak and cocoa trees were observed in a few cases. In about 40 percent of the lowlands both rice and trees were grown. Rice is sometimes intercropped with trees while they are still small, but otherwise rice and trees are planted separately. In the Bouaké area, palm, teak, and cocoa trees are planted mainly on uplands.

In the dry season, no rice is grown at both sites except for a few lowlands equipped with modern irrigation facilities in the Bouaké area as shown in Table 3. In the Kumasi area the second rainy season in the bimodal rainfall pattern, or so-called minor season, is considered part of the dry season. Hence, most of the lowlands profit from the additional rainfall to grow vegetables and maize in the dry season. This does not mean that rice in the rainy season and vegetables and maize in the dry season are cropped on the same plot in a rotation. Rather, those crops usually occupy different plots within the same lowland. On the other hand, since the Bouaké area has less rainfall, almost 90 percent of the lowlands are not cropped during the dry season.

3.2 Expansion of Rice Cultivation

Lowland without water control can be classified as “marginal land” because the profitability of lowland rice production may not be as high as crop production on uplands such as maize considering high labor input for lowland rice production.[4] Therefore, with respect to the expansion of lowland rice cultivation, **hypothesis 1** is that population pressure reduces the availability of upland, and hence induces the utilization of lowlands, and **hypothesis 2** is that immigrants who are often not allowed to use uplands tend to cultivate lowlands.

As shown in Table 4, there are several lowlands that have never been used for rice cultivation, and the share of such lowlands is 17.4% in the Bouaké area and 14.6% in the Kumasi area. By analyzing factors that distinguish lowlands utilized at least once for rice cultivation and those never utilized, we can identify the determinants of the expansion of lowland rice cultivation. Hence, a binary dummy variable for "utilized lowland" is used as the dependent variable: lowlands utilized at least once take the value of 1, while lowlands never utilized take the value of 0. Note that the explanatory variables used in the regressions are either time invariant (e.g. distance to the regional capital) or predetermined in the past (e.g. existence of a primary school as of 1980) because in the analyses on the expansion we are concerned with decisions made in the past.

Table 5 presents the regression results. Village population had a positive, significant effect in the Bouaké area, and cocoa production, proxy for immigrants, had a positive, significant effect in the Kumasi area. Therefore, hypothesis 1 is supported in the Bouaké area, while hypothesis 2 is supported in the Kumasi area. Distance from Bouaké had a negative effect, which suggests that lowland rice cultivation has been disseminated from the capital, either informally or formally through extension agency, and/or market access may have promoted the expansion of rice cultivation. But in the Kumasi area distance to Kumasi had no significant effect.

Table 5 Determinants of Utilization of Lowlands for Rice Cultivation[1]

Explanatory Variables	Bouaké	Kumasi
Village Level Variables		
Village population as of 1988 / 1984	+ +	0
Immigrant indicators		
Ratio of male to female population as of 1988	0	na
Cocoa producing village	na	+ + +
Dominant ethnic group in the village		
Akan	- -	na
Tagbana	- -	na
Origin of the village is outside	0	+ +
Ethnic minorities live in hamlets	- -	0
Existence of primary school as of 1980	0	0
Location of the village		
Distance to regional capital	-	0
Distance to sub-prefectural capital	0	na
Village on highways	na	0
Lowland Level Variables		
Distance from village center	+	0
Acreage of lowland area	0	na
Water Source		
Permanent stream	0	na
Seasonal stream	0	na
Constant	+ + +	0
Pseudo R squared	0.16	
Total number of sample lowlands	304[2]	187[3]
Number of lowlands ever utilized for rice cultivation	249	158
Fraction of correct predictions	0.85	0.84

+ (-), + + (- -), and + + + (- - -) indicate that the coefficient is estimated to be positive (negative) at significance level 10%, 5%, and 1% respectively. 0 indicates the coefficient is not statistically significant at the 10% level.

[1] Dependent variable is binary dummy, whose value is unity if the lowland was utilized for rice cultivation at the time of this study or in the past, and zero otherwise. Probit model was used to estimate the coefficients, but only signs of coefficients are presented in the table. Regression results are available from the author upon request.

[2] Thirteen lowlands with modern dam irrigation facilities are excluded from the 317 lowlands identified.

[3] Total number of sample lowlands in Ghana is 188, but one lowland was dropped due to missing information.

3.3 Intensification of Rice Cultivation

The single most important biophysical constraint to lowland development is lack of water control. Therefore, water control is the critical intensification technology for lowland rice production. In addition, with improved water management, subsequent intensification becomes possible, i.e. it may no longer be too risky for farmers to use external inputs, such as fertilizer. Based on this consideration, we focused on the adoption of water control technologies at lowland level as an indicator of intensification of rice cultivation in lowlands. In the Bouaké area a significant number of lowlands were equipped with bunds and canals. But we found no lowland with water control technologies in the Kumasi area.

Table 6 shows that, in the Bouaké area, 13 lowlands, or 4.1%, of 317 total sample lowlands are equipped with modern dam irrigation facilities with canals and bunds. Except for these lowlands, rice is grown under rainfed conditions. Of all sample lowlands, about 71% have no water control technologies (Table 6). Bunds are more frequently adopted than canals, implying that in some cases farmers create bunds without canals. If we take into account only lowlands under cultivation, the share of lowlands without water control becomes 43% of 129 lowlands. This means that lowlands without water control technologies tend to be abandoned more frequently than those with water control technologies. On the other hand, lowlands with modern irrigation facilities have not been abandoned, though the irrigation is not necessarily fully functioning.

According to Boserup (1965), population pressure causes intensification of agricultural production. In the same line, the induced innovation theory predicts that intensification should be induced by high price of land relative to that of labor (Hayami and Ruttan, 1985). Therefore, **hypothesis 3** is that higher population induces intensification, if the population increases demand for lowlands as well as supply of labor force. Note that this is the case where land is scarce and consequently population pressure cannot cause an expansion but rather induce an intensification. On the other hand, because water control technologies are not indigenous in the study sites, they may have been disseminated from the cities. In addition, market accessibility increases profitability of rice production and consequently enhances the probability of the technology adoption. Hence, **hypothesis 4** is that the distance from the markets has a negative effect on technology adoption.

Table 7 shows the results of Probit analyses on the determinants of the adoption of water control technologies in the Bouaké area. The regressions are done for bunds and water supply canals simultaneously by bivariate Probit method since the adoption of these technologies should be correlated. In fact, 37 of the lowlands have both bunds and water supply canals. First, the ratio of male population has a positive significant effect on both bunds and canals. Since this is an indicator of immigrant population, the results support the hypothesis 3. On the other hand, village population has no significant effect on the adoption of bunds and canals. This suggests that intensification is induced not simply by increased population, but rather by increased lowland users and labor force, or “effective population pressure” as indicated by the ratio male to female population. Second, the distance to capital cities reduces the probability of the adoption of water control technologies, as expected. That is, hypothesis 4 is supported.

3.4 Economic Sustainability of Rice Cultivation

As shown in Table 4, the share of lowlands never utilized for rice cultivation is higher in the Bouaké area than in the Kumasi area, but the difference is not so large as that for rice cultivation at the time of study (‘current cultivation’). This indicates that in about 85% of the lowlands, rice cultivation has been attempted in both sites but rice cultivation was more frequently abandoned in the Bouaké area. Table 4 also shows that the average number of years since rice was cultivated last is greater in the Bouaké area than in the Kumasi area (15.5 years and 12.7 years respectively), but they do not differ very much. With respect to sustainability, this study concerns sustainability at lowland level, not at plot level. In the Kumasi area, plot level sustainability of lowland rice cultivation is not an issue, since most farmers are practicing shifting rice cultivation with several years of fallow. The issue we are concerned with here is continuous use of lowlands for rice cultivation. This is more like economic sustainability because it depends on profitability of rice production. Based on this definition, sustainability of rice cultivation at lowland level is measured by (1) current use of lowland for rice cultivation, and (2) the number of years since rice

Table 6 Adoption of Water Control Technologies (% of number of lowland)

	Modern dam irrigation	Rainfed lowlands (without modern irrigation)				
		No water control technologies	Bunds	Supply canal	Drain canal	Bunds + both canals
Bouaké area All the lowlands	4.1	70.7	23.3	13.6	6.6	3.8
Bouaké area Lowlands under rice cultivation	10.1	43.4	45.0	27.9	11.6	7.0
Kumasi area	0	100	0	0	0	0

Total number of lowlands is 317 in the Bouaké area and 188 in the Kumasi area. Number of lowlands currently under rice cultivation is 129 in the Bouaké area. The percentages do not add up to 100% because of adoption of several technologies.

Table 7 Determinants of Adoption of Water Control Technologies in the Bouaké area[1]

Explanatory Variables	Bunds	Canals
Village Level Variables		
Village population as of 1988	0	0
Immigrant indicators		
Ratio of male to female population as of 1988	+ +	+ +
Dominant ethnic group in the village		
Akan	- - -	- - -
Tagbana	0	0
Origin of the village is outside	0	0
Ethnic minorities live in hamlets	0	+ + +
Existence of primary school as of 1980	+	0
Access to the village		
Distance to regional capital	0	- -
Distance to sub-prefectural capital	- - -	- - -
Lowland Level Variables		
Distance from village center to lowland	0	0
Acreage of lowland area	0	0
Water Source		
Permanent stream	+	0
Seasonal stream	+ + +	+ + +
Constant	0	0
Correlation in the residuals	+ +	
Pseudo R squared[3]	0.13	0.23
Number of lowlands ever utilized for rice cultivation	249[2]	249[2]
Number of lowlands with water control technologies	74	43
Fraction of correct predictions[3]	0.73	0.86

+ (-), + + (- -), and + + + (- - -) indicate that the coefficient is estimated to be positive (negative) at significance level 10%, 5%, and 1% respectively. 0 indicates the coefficient is not statistically significant at the 10% level.

[1] Dependent variable is binary dummy, whose value is unity if the lowland has adopted water control technologies (bunds and water supply canals), and zero otherwise. Bivariate Probit model is used to estimate the coefficients, but only signs of coefficients are presented in the table. Regression results are available from the author upon request.

[2] Thirteen lowlands irrigated by modern dam irrigation are excluded from the analyses.

[3] Based on single-equation Probit estimation.

was last cultivated in the lowland. For the first measure, a binary dummy variable is created with a value of 1 for lowlands currently under rice cultivation, and a value of 0 for lowlands where rice was grown at least once in the past but where rice cultivation was abandoned, i.e. where rice was not grown at the time of study. By the second measure, if rice was present at the time of study, the number of years is 0. If rice has been abandoned, the more years have passed since rice was cultivated last, the less sustainable cultivation will be. Hence, this measures rather "non-sustainability." Note that even if rice is not cultivated in a lowland at the time of study, it does not mean that the lowland was abandoned permanently. But it would be reasonable to assume that the longer the period of non-utilization since the last rice cultivation, the closer to permanent abandonment, although we cannot foresee when they will resume rice cultivation. Therefore, we will use the two kinds of indicator of sustainability.

We assume that when rice cultivation was attempted, the decision was rational and hence the rice cultivation was expected to be profitable at least in the short run. But after a while, rice cultivation was abandoned due to some changes in the economic environment that made rice production unprofitable. There could be two reasons for this: one is a lower rice price, and the other is a higher labor cost. The lower rice price might be due to lower import price reflecting the lower world price and/or lower price of local rice due to successful irrigation projects. The higher labor cost could be a result of stagnation of population growth in the village or migration. Hence, with respect to sustainability of lowland rice cultivation, we postulate the following hypotheses: **hypothesis 5** is that distance from the market has a negative effect on sustainability because high transportation costs make it impossible for local rainfed lowland rice to compete with cheap rice in the market; **hypothesis 6** is that immigrants have a positive effect on sustainability because they supply cheap labor force; and **hypothesis 7** is that lowlands with water control technologies are more sustainable because of higher efficiency.[5]

Table 8 presents the results of Probit regressions to explain the sustainability measured by the current use, and Table 9 presents the results of Tobit regressions to explain the "non-sustainability" measured by years since the last rice cultivation. First, the distance to the markets has no significant effect in the Kumasi area, but it has unexpected signs in the Bouaké area. Hence, hypothesis 5 is rejected. Second, in the Bouaké area village population increases the sustainability measured by current use as shown in Table 8, but the male to female ratio has no significant effect on sustainability as shown in Tables 8 and 9. On the other hand, in the Kumasi area, lowland rice cultivation in cocoa producing villages tends to be more sustainable in both measures. The results support hypothesis 6 for the Kumasi area, but the support is partial for the Bouaké area. Third, in the Bouaké area the adoption of bunds and canals increases the probability of sustainable rice cultivation in lowlands, which renders a support to hypothesis 7. As already shown in Table 7, the adoption is significantly influenced by access to the market and male population, but those variables do not appear to have significant effect in Tables 8 and 9. Therefore, market access and effective population pressure enhance the sustainability of rice cultivation, but their effects may not be direct, but rather through the investment in water control technologies. In sum, sustainability of lowland rice cultivation depends on water control technologies which are affected by male population and market access in the Bouaké area, while it depends on migrant population for cocoa plantation in Kumasi area which has no relationship with the distance to market.

4. Discussions

We found that in both Bouaké and Kumasi areas, rice cultivation was attempted in more than 80% of the total lowlands in the past. The expansion was induced by population pressure. But the sustainability of lowland rice cultivation differs in the two sites. In the Bouaké area some of the lowlands have adopted water control technologies, and rice cultivation in such lowlands tends to be more sustainable than those without water control. As a result, a number of lowlands that failed to adopt water control technologies have been abandoned. On the other hand, in the Kumasi area, no lowland has adopted water control technologies, and sustainability does not depend on the technologies. Surprisingly, however, more lowlands are under sustained utilization in the Kumasi area than in the Bouaké area. That is, while in the Kumasi area lowland rice cultivation is more extended and more sustainable, in the Bouaké area lowland rice cultivation is more concentrated to lowlands with water control technologies.

Table 8 Determinants of Sustainability of Rice Cultivation (current use of lowland)[1]

Explanatory Variables	Bouaké	Kumasi
Village Level Variables		
Village population as of 1998 / 2000	+ + +	0
Immigrant indicators		
Ratio of male to female population as of 1998	0	na
Cocoa producing village	na	+ +
Dominant ethnic group in the village		
Akan	+ + +	na
Tagbana	+ + +	na
Origin of the village is outside	0	- -
Ethnic minorities live in hamlets	0	0
Number of years since establishment of primary school	0	+ +
Access to the village		
Distance to regional capital	0	0
Distance to sub-prefectural capital	+	na
Village on highways	na	0
Lowland Level Variables		
Water control technologies in lowland		
Bunds	+ + +	na
Canals (for water supply)	+ + +	na
Distance from village center to lowland	0	0
Acreage of lowland area	+ +	na
Water source		
Permanent stream	0	na
Seasonal stream	0	na
Constant	- - -	- -
Pseudo R squared	0.35	0.10
Number of lowlands ever utilized for rice cultivation	249[2]	158
Number of lowlands currently being cultivated	103	97
Fraction of correct predictions	0.79	0.65

+ (-), + + (- -), and + + + (- - -) indicate that the coefficient is estimated to be positive (negative) at significance level 10%, 5%, and 1% respectively. 0 indicates the coefficient is not statistically significant at the 10% level.

[1] Dependent variable is a binary dummy, whose value is unity if the lowland is currently being utilized for rice cultivation (i.e. at the time of this study), and zero otherwise. Probit model is used to estimate the coefficients, but only signs of coefficients are presented in the table. Regression results are available from the author upon request.

[2] Thirteen lowlands irrigated by modern dam irrigation are excluded from the analyses.

Thus, the first question is why lowland rice cultivation in the Kumasi area is more sustainable than that in the Bouaké area. As Table 5 shows, lowland rice cultivation in the Kumasi area does not depend on the distance to Kumasi, the regional market. This does not mean that the rice production in the Kumasi area is only for self-consumption. Rather, most of their production is sold in the market. But most of the transaction takes place at the millers in local towns (Furuya and Sakurai (2005) and Sakurai, Furuya, and Futakuchi (2006)). Rice producers bring paddy to local millers and mill the paddy. Then, they sell the milled rice to rice traders who come to purchase milled rice. They resell it in the bigger market like Kumasi. The number of millers has increased in recent years according to our own survey on millers. It implies that milled rice transaction at local millers is profitable for producers, millers, and traders. On the other hand, in the Bouaké area, lowland rice production depends on the distance to the city market. This indicates that transportation cost is too high for rice producers in remote areas. Current output/input price ratio suggests that the price of rice might be so high in the Kumasi area that it gives a good incentive for producers. As mentioned above, the retail price of milled local rice in the Bouaké market is about 250 – 300 FCFA/kg, and that in the Kumasi market is about 2600 – 3200 cedis/kg. On the other hand, standard daily wage for agricultural labor is 1000 FCFA/day in the Bouaké area and 6000 cedis/day in the Kumasi area. Hence, 1 kg of milled rice costs 0.25 – 0.30 day work and 0.43 – 0.53 day work respectively. That

Table 9　Determinants of Non-Sustainability of Rice Cultivation (number of years of fallow)[1]

Explanatory Variables	Bouaké	Kumasi
Village Level Variables		
Village population as of 1998 / 2000	0	0
Immigrant indicators		
Ratio of male to female population as of 1998	0	na
Cocoa producing village	na	- -
Dominant ethnic group in the village		
Akan	- - -	na
Tagbana	- - -	na
Origin of the village is outside	0	0
Ethnic minorities live in hamlets	0	0
Number of years since establishment of primary school	0	0
Access to the village		
Distance to regional capital	- - -	0
Distance to sub-prefectural capital	0	na
Village on highways	na	0
Lowland Level Variables		
Water control technologies in lowland		
Bunds	- - -	na
Canals (for water supply)	- - -	na
Distance from village center to lowland	0	0
Acreage of lowland area	0	na
Water source		
Permanent stream	0	na
Seasonal stream	0	na
Constant	+ + +	0
Pseudo R squared	0.07	0.05
Number of lowlands ever utilized for rice cultivation	247[2]	145[3]
Number of lowlands currently NOT being cultivated	144	45

+ (-), + + (- -), and + + + (- - -) indicate that the coefficient is estimated to be positive (negative) at significance level 10%, 5%, and 1% respectively.　0 indicates the coefficient is not statistically significant at the 10% level.

[1] Dependent variable is number of years since last rice cultivation.　If a lowland is currently cultivated to rice, the number of years is zero, otherwise it is a positive number.　Tobit model is used to estimate the coefficients to take into account the significant number of cases of zero in the dependent variable.　Only signs of coefficients are presented in the table.　Regression results are available from the author upon request.

[2] Two lowlands are dropped from 249 lowlands due to missing information.　Thirteen lowlands irrigated by modern dam irrigation are excluded from the analysis.

[3] Thirteen lowlands are dropped from 158 lowlands due to missing information.

is, rice is more expensive in the Kumasi area. Because labor is the major input for rice production, this high price of rice can explain why lowland rice production in the Kumasi area is more sustainable at this moment.

As for intensification, even though the "non-intensive" system in the Kumasi area may be profitable enough, it does not explain why lowland rice cultivation in the Kumasi area has not been intensified at all.　Some intensification will bring a larger harvest, which is likely to result in a larger profit under higher price of rice.　We may have three explanations, which are not mutually exclusive, for "non-intensification" in the Kumasi area.[6]

First, intensification is, as already discussed, affected by the relative factor price.　Average rental cost of one hectare of lowland is 41,000 FCFA (standard deviation is 20,000) in the Bouaké area and 177,000 cedis (standard deviation is 144,000) in the Kumasi area according to our own survey. Although the standard deviations are very large, the ratio of rental cost to daily wage is 41 days/ha and 30 days/ha respectively.　This implies that the extensive land use continues in the Kumasi area because land is relatively cheap.　This is consistent with our casual observation in the Kumasi area where lowlands are so abundant that cultivators are still able to shift their plot every year.

The relative price can explain why the intensification is sustainable in the Bouaké area, but it does not explain why it was technically possible for them to adopt intensification technologies because water control technologies were not indigenous. Therefore, the second explanation concerns interventions that have taken place in the past. In fact, during the 1970s, massive interventions took place in Côte d'Ivoire through the creation of a state agency for rice development, i.e. SODERIZ (Société de Développement de la Riziculture), as well as foreign aid particularly from Taiwan (Le Roy, 1998; Wakatsuki, 2000). Out of 317 sample lowlands in the Bouaké area, 13 lowlands are irrigated by modern dam irrigation facilities, while in the Kumasi sample there is no dam irrigation site.7 Not only water control technologies such as bunds and canals, but also improved rice varieties and transplantation technology are considered to have been spilled-over from the irrigation project sites to rainfed lowlands.

Finally, the third explanation is from the viewpoint of land tenure systems. In the Kumasi area, tenancy contract is usually valid only for one year, and therefore tenant cultivators have to make a new contract every year. This encourages rice cultivators to shift their plots every year, and consequently discourages investment in land to use the same plot continuously. On the other hand, in the Bouaké area, tenancy contract is less strict and hence usually no duration is specified at the time of contract. In this case, investment in water control technologies is safer and could be more encouraged than in the Kumasi area. The difference in land tenure systems in the two sites may be caused by historical factors, particularly by the plantation of cash tree crops such as cocoa and palm in the Kumasi area. Because investment in land by tree planting enhances land ownership rights (Besley, 1995), migrants usually are not allowed to plant trees. Investment in water control technologies may be regarded on a similar footing as tree planting.

5. Conclusions

This paper explores the factors affecting the expansion, intensification, and sustainability of lowland rice production around two large inland markets in Côte d'Ivoire (Bouaké) and Ghana (Kumasi). The analyses reveal that immigrant population is the most significant determinant of the expansion and sustainability of lowland rice cultivation in the Kumasi area. But no water control technologies have been adopted there: rice cultivation is purely rainfed. On the other hand, in the Bouaké area, the expansion seems to have been driven by population pressure, but the sustainability depends on the adoption of water control technologies. That is, inefficient rice production does not last. Since bund and canal construction is influenced positively by the accessibility to the market and number of immigrants, lowlands located closer to Bouaké tend to have water control technologies.

Comparing the two study sites, we showed that the difference in rice cultivation methods could be attributed to: (1) higher relative price of land in the Bouaké area, (2) past governmental and/or foreign intervention in the Bouaké area, and (3) land tenure systems in the Kumasi area. Modern irrigation projects around Bouaké (which are excluded from our analyses) may have had spill-over effects of technologies. This suggests that, although the relatively high price of land is a necessary condition for intensification, intensification will not take place 'automatically', i.e. it needs a push, through the introduction and dissemination of technologies.

Footnote

[1] The five ecologies for rice cultivation are irrigated lowland, rainfed lowland, rainfed upland, mangrove, and deep-water (Dalton and Guei, 2003).

[2] The sampling rate for each stratum is summarized in the table at the end. The number of villages along the highways is much lower than that of villages off the highways. But because we assumed *a priori* that whether a village is located along or off the highways should be an important factor affecting market access and consequently lowland rice cultivation, we sampled the two types of villages equally so that we would be able to examine the effect of market access.

[3] As noted in the text, half of the 80 villages initially sampled have no accessible lowland. Therefore, assuming that half of the 60 sample villages have access to lowlands, the average number of lowlands is estimated as 188/(60+60).

[4] Lowland rice production is generally considered to be less profitable than upland cropping such as maize. But this needs to be formally verified. We are currently collecting plot level data of

lowland rice and upland maize production so that we will be able to compare their profitability.

[5] Sakurai (2006) showed that rice production in rainfed lowland is more profitable with partial water control technologies such as supply canals than without them. He used data collected from lowlands in the city of Bouaké where transportation costs to the market can be ignored.

[6] Because there is no lowland with water control technologies in the Kumasi area, the three explanations cannot be statistically tested, unfortunately.

[7] In the Kumasi area, we found only one dam-irrigated paddy field developed with Taiwanese aid, but it was not included in our sample.

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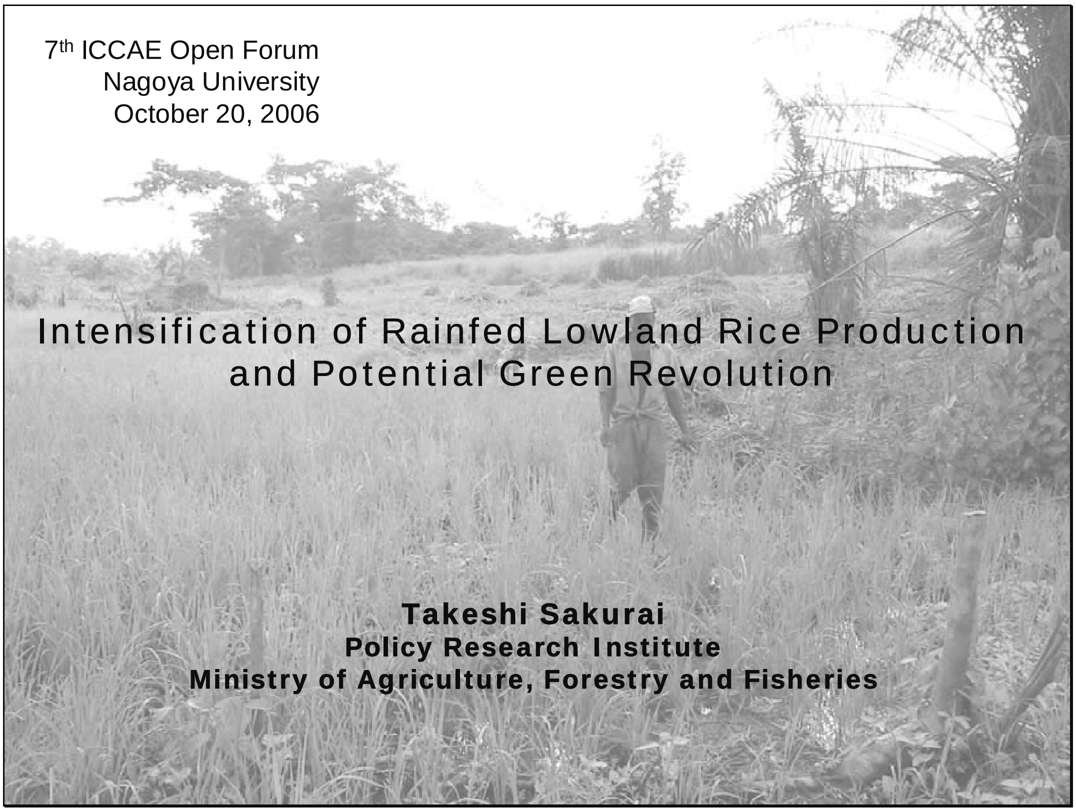
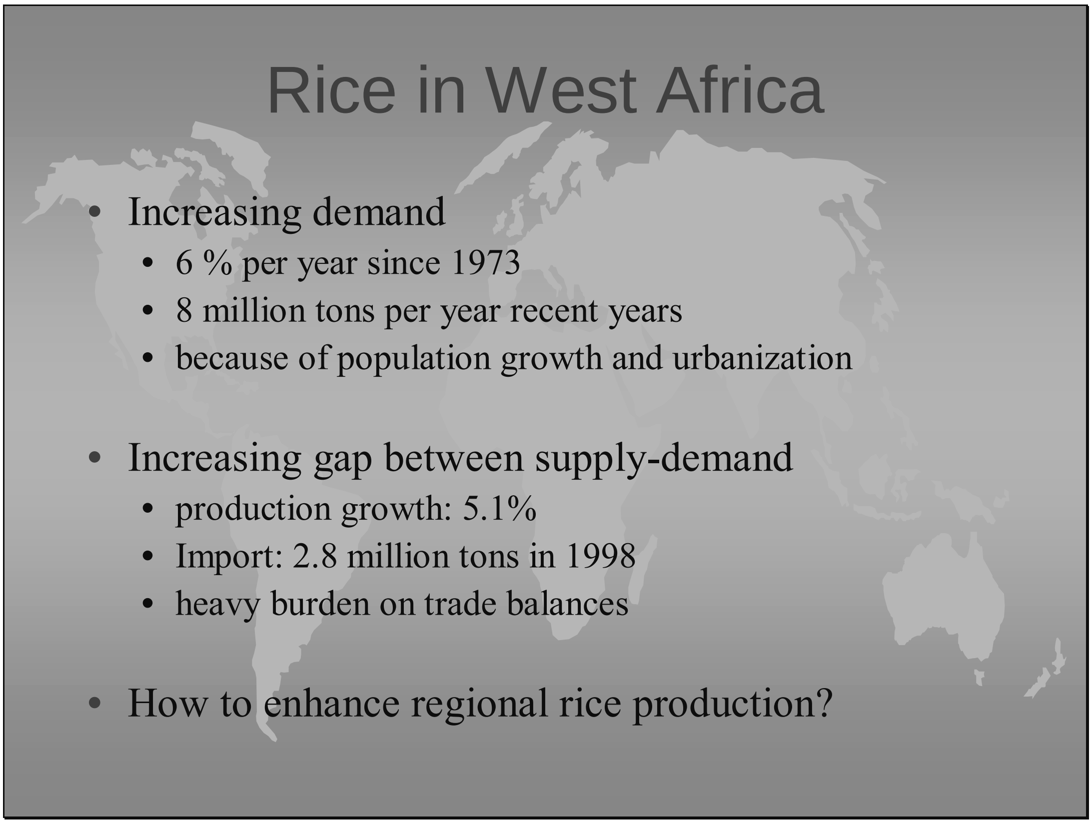
	Along the highways		Off the highways	
Stratum	Total number of villages	Number of sample villages	Total number of villages	Number of sample villages
10 – 20 km	35	6 (17.4%)	138	6 (4.3%)
20 – 40 km	114	12 (10.5%)	534	12 (2.2%)
40 – 60 km	106	12 (11.3%)	564	12 (2.1%)
Total	255	30 (11.8%)	1236	30 (2.4%)


7th ICCAE Open Forum
Nagoya University
October 20, 2006
Intensification of Rainfed Lowland Rice Production and Potential Green Revolution
Takeshi Sakurai
Policy Research Institute
Ministry of Agriculture, Forestry and Fisheries

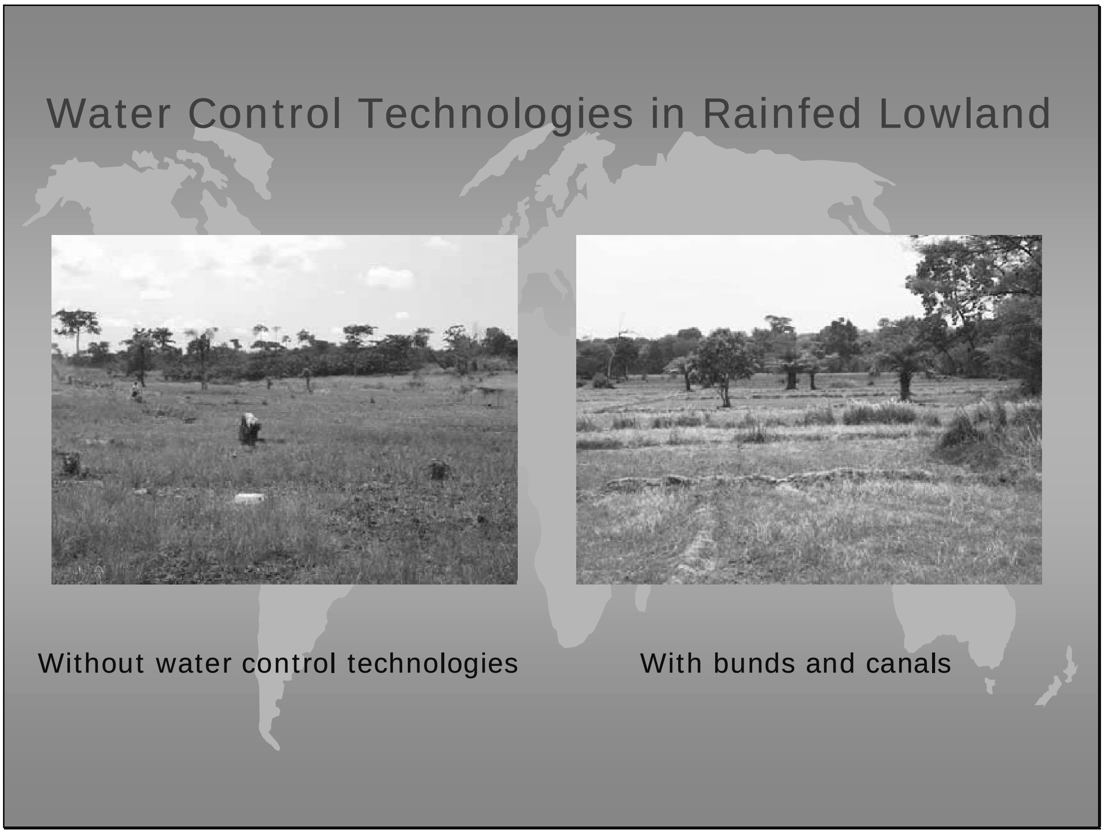

Rice in West Africa
• Increasing demand
• 6 % per year since 1973
• 8 million tons per year recent years
• because of population growth and urbanization
• Increasing gap between supply-demand
• production growth: 5.1%
• Import: 2.8 million tons in 1998
• heavy burden on trade balances
• How to enhance regional rice production?

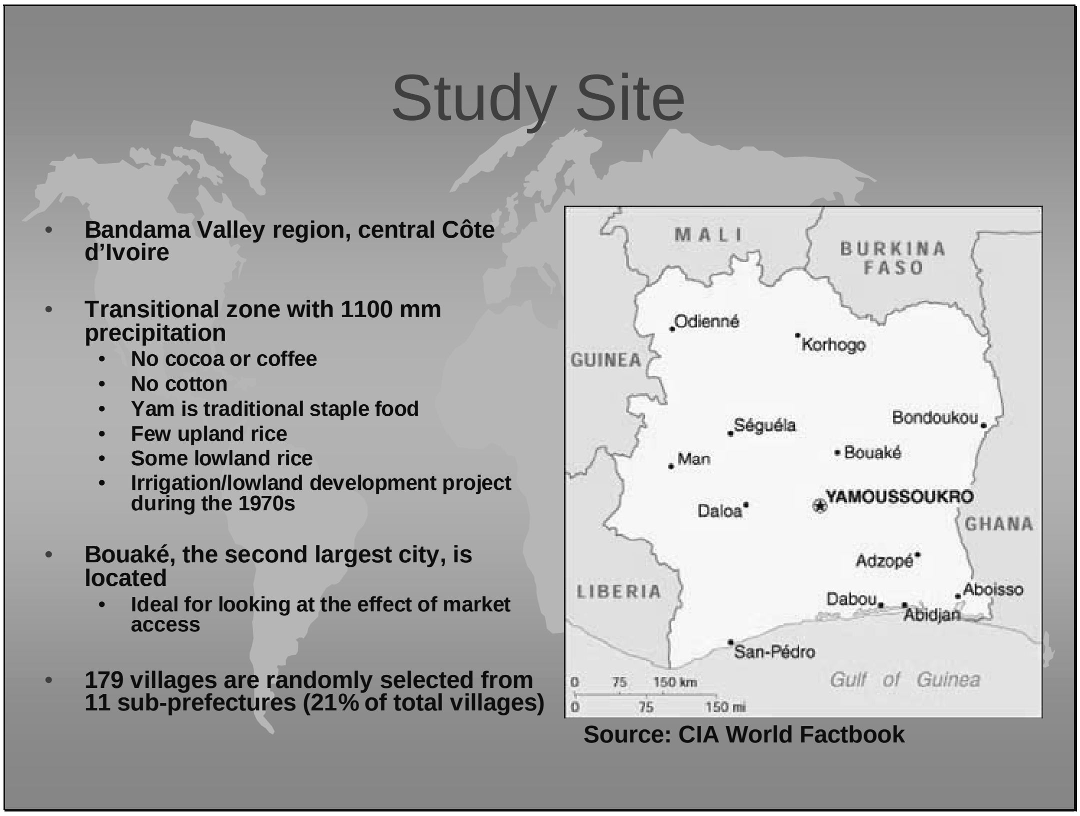
Enhancing Rice Production in West Africa

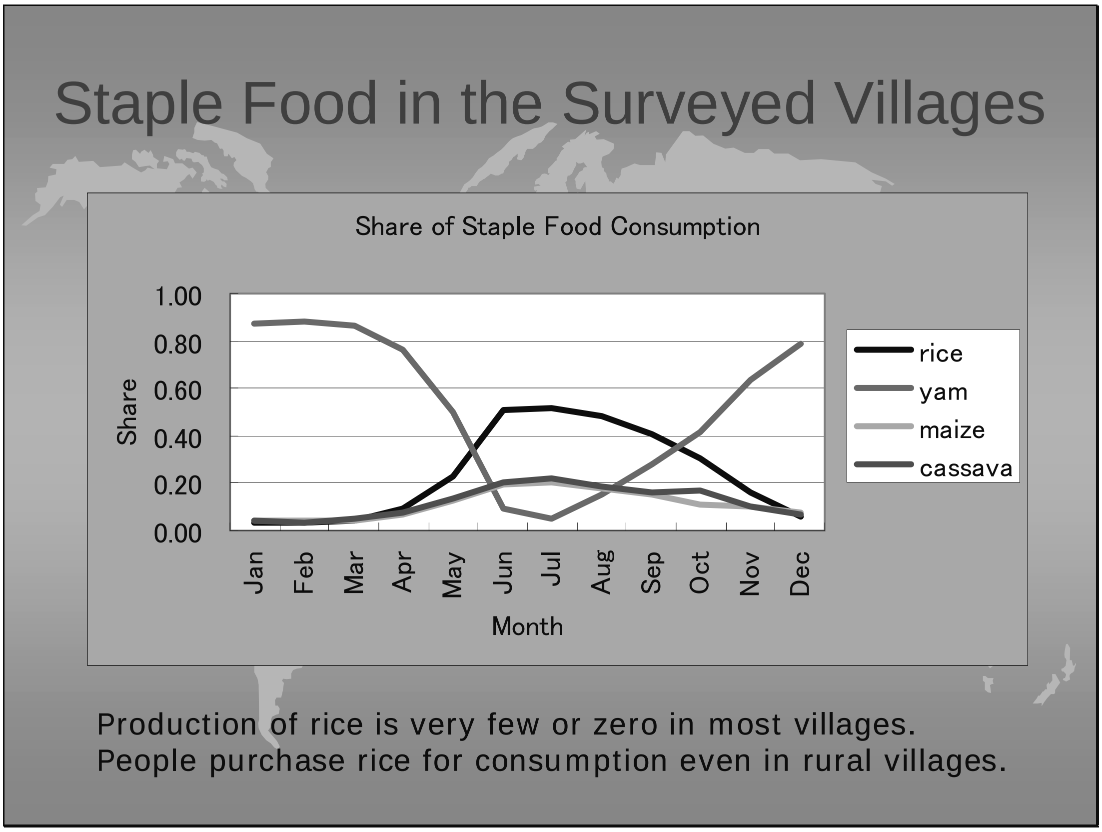
- Area expansion (extensification)
  - Upland is limited since fallow period is required
  - Vast lowland area remains uncultivated
    - 10 – 25% of total area is under cultivation
- Yield increase (intensification)
  - Modern irrigation facilities are too costly
  - Low potential of yield increase in upland ecology
  - There is a room for intensification in lowland ecology
    - Water control technology (canal and bund)
    - High yielding varieties are already available
    - Chemical fertilizer is more effective in lowland

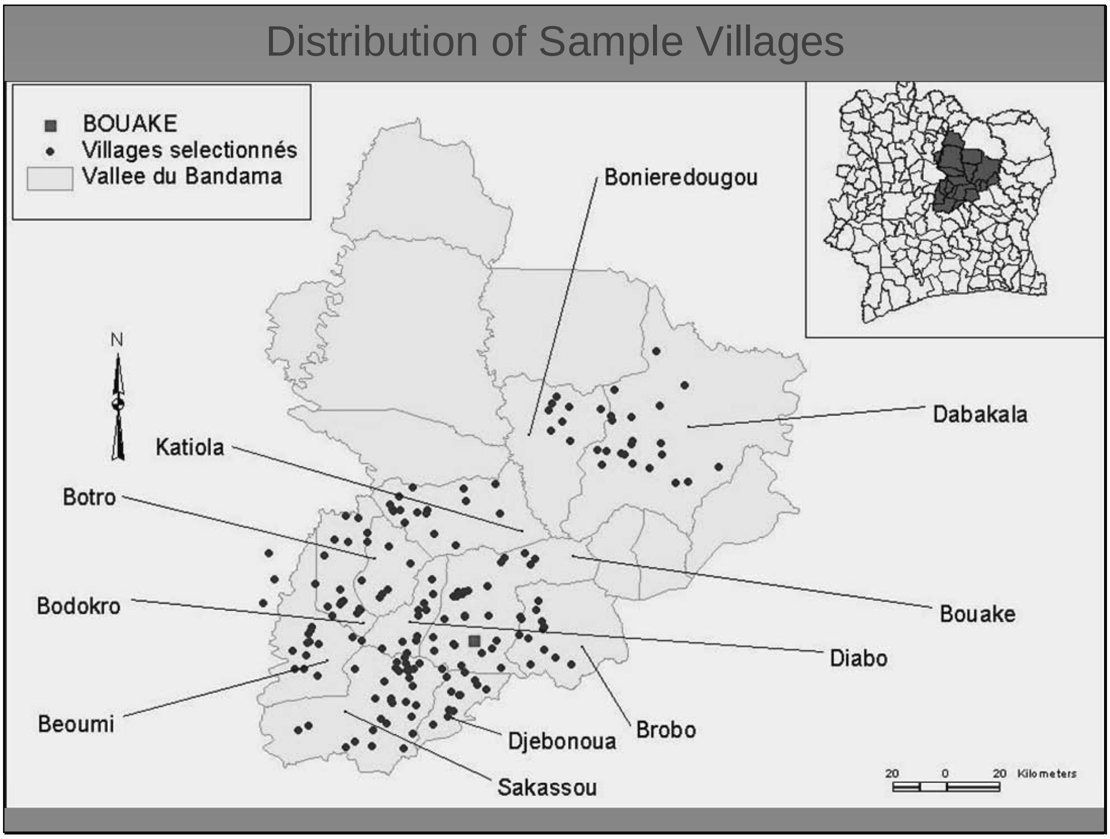
Questions

- What factors influence
  - Area expansion of lowland rice production
  - Intensification of lowland rice production
- Is there potential Green Revolution of rice in West Africa?
  - Water control technologies
  - Rice modern varieties
  - Their impact on rice yield


Water Control Technologies in Rainfed Lowland
Without water control technologies
With bunds and canals


Study Site
• Bandama Valley region, central Côte d'Ivoire
• Transitional zone with 1100 mm precipitation
• No cocoa or coffee
• No cotton
• Yam is traditional staple food
• Few upland rice
• Some lowland rice
• Irrigation/lowland development project during the 1970s
• Bouaké, the second largest city, is located
• Ideal for looking at the effect of market access
• 179 villages are randomly selected from 11 sub-prefectures (21% of total villages)
MALI
BURKINA FASO
GUINEA
Odienné
Korhogo
Séguéla
Bondoukou
Man
Bouaké
Daloa
YAMOUSSOUKRO
GHANA
Adzopé
LIBERIA
Dabou
Abidjan
Aboisso
San-Pédro
Gulf of Guinea
0 75 150 km
0 75 150 mi
Source: CIA World Factbook


Staple Food in the Surveyed Villages
Share of Staple Food Consumption
1.00
0.80
0.60
0.40
0.20
0.00
Share
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Month
rice
yam
maize
cassava
Production of rice is very few or zero in most villages.
People purchase rice for consumption even in rural villages.


Distribution of Sample Villages
BOUAKE
Villages selectionnés
Vallee du Bandama
N
Bonieredougou
Dabakala
Katiola
Botro
Bodokro
Bouake
Diabo
Beoumi
Brobo
Djebonoua
Sakassou
20
0
20
Kilometers

Current Situation

Source: Ministry of Foreign Affairs of Japan

Data Collection

- Village/Lowland survey
  - Randomly sampled 179 villages
  - All the accessible lowlands from the villages (317 lowlands were identified)

- Rice cultivator survey
  - 64 cultivators in the city of Bouaké
  - No difference in terms of market access
  - All the corresponding land owners

Market Access and Prices

	In Bouaké	Average of 179 villages
Distance from Bouaké	0 km	46 km
Sale Price of Paddy	128 F/kg	79 F/kg
Purchase Price of Chemical Fertilizer	240 F/kg	289 F/kg
Paddy/Fertilizer Price Ratio	0.53	0.27

Village/Lowland Survey

- Total number of lowlands: 317
  - With irrigation facilities 13 (excluded)
  - Without irrigation facilities 304

TABLE 1

Current Lowland Use at Lowland Level

(% of number of lowland plots)

	No Use	Rice	Vegetables	Maize	Tree Plantation	Rice + Vegetables	Rice + Maize	Rice + Tree Plantation
Rainy season	59.3	36.6	13.3	0.6	1.9	9.8	0.3	0.3
Dry season	88.6	4.1	7.3	0.9	1.9	0.0	0.3	0.0

Notes: 1. Total number of lowland plots is 317.
2. The percentages do not add up to 100% for each season because of multiple use.

- Out of 304 lowlands without irrigation
  - Rice was cultivated at least once 249
  - Determinants of rice cultivation are identified by Probit regression

Determinants of Utilization of Lowland for Rice Production

Explanatory Variables[2]	
Village Level Variables	
Village Population	
Population density	0.01 (0.00)***
Population growth rate	-0.01 (0.08)
Immigrant indicators	
Percentage of immigrants in total population	0.01 (0.02)
Percentage of male in female population	-0.02 (0.01)***
Dominant ethnic group in the village	
Baoulé	-1.98 (0.42)***
Tagbana	-1.20 (0.54)**
Primary school	0.00 (0.01)
Market access	
Price ratio of paddy and fertilizer	2.86 (1.27)**
Distance to sub-prefectural capital	-0.03 (0.01)**
Lowland Level Variables	
Distance from village center	0.05 (0.04)
Acreage of lowland area	0.00 (0.00)
Water Source	
Permanent stream	0.48 (0.38)
Seasonal stream	0.12 (0.29)
Constant	3.45 (0.81)***
Total number of sample lowlands	304[3]
Number of lowlands ever utilized for rice cultivation	249
Fraction of correct predictions	0.84

Population Density	+
Paddy/Fert. Price	+
Access to city	+

Table 2

Determinants of Lowland Rice Expansion

- Higher population density leads the use of lowland area for rice cultivation
  (due to the scarcity of upland area)
- It is not immigrants but population pressure that induces the use of lowland area
- Closeness to city is a positive factor for lowland rice cultivation
  - technology is disseminated from the city
  - favorable output price due to transportation cost

Village/Lowland Survey: Water Control

TABLE 3

Water Control Technologies at Lowland Level

(% of number of lowland plots)

	Modern Dam Irrigation	Rainfed Lowlands (Without Modern Irrigation)				
		No Water Control Technologies	Bunds	Supply Canal	Drain Canal	Bunds + Both Canals
All the lowlands	4.1	70.7	23.3	13.6	6.6	3.8
Lowlands under rice cultivation	10.1	43.4	45.0	27.9	11.6	7.0

Notes: 1. Total number of lowland plots is 317. Number of plots currently under rice cultivation is 129.
2. The percentages do not add up to 100% because of adoption of several technologies.

- Lowlands ever utilized for rice cultivation: 249
  - With bunds: 74 (29.7%)
  - With irrigation canals: 43 (17.3%)
- Determinants of the adoption of water control are identified by Probit regression

Determinants of Adoption of Water Control Technologies

Explanatory Variables	Bunds	Canals
Village Level Variables		
Village Population		
Population density	-0.00 (0.00)	-0.00 (0.00)
Population growth rate	0.01 (0.08)	0.02 (0.12)
Immigrant indicators		
Percentage of immigrants in total population	0.05 (0.04)	0.10 (0.04)**
Percentage of male to female population	0.02 (0.01)***	0.01 (0.01)**
Dominant ethnic group in the village		
Baoulé	-1.09 (0.34)***	-0.69 (0.38)*
Tagbana	-0.31 (0.56)	0.12 (0.78)
Primary school	0.01 (0.01)	0.02 (0.01)*
Market access		
Price ratio of paddy and fertilizer	3.07 (1.17)***	4.50 (1.30)***
Distance to sub-prefectural capital	-0.04 (0.02)***	-0.04 (0.02)*
Lowland Level Variables		
Distance from village center	-0.05 (0.04)	0.02 (0.04)
Acreage of lowland area	0.00 (0.00)	0.01 (0.00)
Water Source		
Permanent stream	0.61 (0.38)	-0.09 (0.55)
Seasonal stream	1.22 (0.36)***	1.90 (0.07)***
Constant	-2.58 (0.78)***	-4.46 (1.03)***
Number of lowlands ever utilized for rice cultivation	249[3]	249[3]
Number of lowlands with water control technologies	74	43
Fraction of correct predictions	0.76	0.87

Male Population	+
Paddy/Fert. Price	+
Access to city	+

Table 4

Determinants of Water Control Technologies

- Immigrants promote water control technologies
  - Effective population pressure
  - Technology is brought by immigrants
- Population density and population growth have no effect on the technology adoption
  - Lowland is not a scarce resource
- Closeness to the city is again a positive factor of the technology adoption

Rice Cultivator Survey in Bouaké: Water Control

- Total number of sample cultivators 64
  - Bunds 62 cultivators
  - Irrigation canals 42 cultivators
    - Much higher adoption rates than in rural areas

TABLE 5

Adoption of Water Control Technologies in Bouaké at Cultivator Level

(%)

Modern Dam Irrigation	Rainfed Lowlands (Without Modern Irrigation)				
	No Water Control Technologies	Bunds	Supply Canal	Drain Canal	Bunds + Both Canals
0	3.1	96.9	65.6	59.4	42.2

Notes: 1. Total number of cultivators is 64.
2. The percentages do not add up to 100% because of adoption of several technologies.

Rice Cultivator Survey in Bouaké: Land Ownership and Cultivator's Status

Combinations of Rice Cultivator and Land Owner in Bouaké[1)]

Type of Land Owners / Status of Rice Cultivators	Indigene (inherited from father)	Indigene (inherited from other than father)[2)]	Immigrant	Owner/Cultivator			Public or institutional owner[4)]
				Indigene (inherited from father)	Indigene (inherited from other than father)[3)]	Immigrant	
Immigrants (total 54)	13	19	11	NA	NA	1	10
Indigenes (total 9)	1	4	0	1	2	NA	1

[1)] Numbers in the table are the number of rice cultivators that fall in each combination. The number of rice cultivators interviewed is 64, but one has been dropped due to missing information.
[2)] Out of 23 cases, 15 are the case of inheritance from an uncle on the mother's side.
[3)] The two are the case of inheritance form an uncle on the mother's side.
[4)] This includes land owned by city government, land inside a military camp, and land owned by public/private companies.

Rice Cultivator Survey in Bouaké: Land Tenure

- Determinants of the adoption of irrigation canals are identified by Probit regression
  - Market access and population pressure are assumed to be equal in the sample
  - Effect of land tenure security is focused
    - Proxied by
      - Cultivator's status: immigrants or indigenes
      - Type of land ownership in the case of immigrant cultivator
        - Indigenous communal land (inherited from relatives)
        - Indigenous individualized land (inherited from father)
        - Institutional land (public or private firms)
        - Immigrants
    - Immigrants cultivator's land tenure security is low at the beginning
    - If investment enhances the security, the cultivator is willing to invest in land relative to otherwise
      - In the case of communal land and immigrant's land

Determinants of Adoption of Water Control Technologies

Determinants of Water Supply Canals and Modern Varieties at Cultivator Level

Explanatory Variables	Dummy for Cultivators with Water Supply Canals Probit Model
Cultivator's status (dummy variable):	
Immigrants cultivators	2.78 (1.29)**
Type of landownership (dummy variables):	
Immigrants*Indigenous communal	0.41 (0.80))
Immigrants*Indigenous individualized	–3.12 (1.14)***
Immigrants*Public/Institutional	–3.25 (1.13)***
Cultivator's characteristics:	
Age (10^{-2})	0.44 (2.56)
Sex (1 = male, 0 = female)	0.43 (1.00)
Years of schooling	–0.02 (0.07)
Living in own house (= 1, otherwise 0)	–0.64 (0.58)
Years of rice cultivation experience	–0.11 (0.05)**
Plot characteristics:	
Water source is permanent stream	0.50 (0.99)
Water source is seasonal stream	1.47 (0.71)**
Water source is pond	–0.94 (0.98)
Distance from water source (1,000 m)	–0.06 (0.24)
Walking time from the residence (100 min)	–0.02 (0.01)**
Acreage of the plot (ha)	2.36 (1.87)
Constant	0.65 (1.78)
Fraction of correct prediction	0.84
No. of positive observations	42
No. of observations†	63

- Use rights are weak relative to the case of indigenes
- Less secure

- Ownership is strong relative to other cases
- Fewer room to enhance the use rights

Table 6

Rice Cultivator Survey in Bouaké: Rice Varieties

TABLE 7

Adoption of Modern Rice Varieties (MV) in Bouaké at Cultivator Level

(%)

Traditional Local Varieties	Unknown Varieties (Early MV)	MV				
		Recent MV		Early MV		
		Bouaké 189	WARDA Varieties	Jaya	IR5	Others
0	10.9	68.8	12.5	3.1	1.6	4.7

Notes: 1. Total number of cultivators is 64.
2. The percentages do not add up to 100% because of adoption of several technologies.

- Unknown varieties are classified as early modern varieties (MV) as they were adopted many years ago and have been continuously cultivated without renewal
- Determinants of the adoption of recent modern varieties (MV) are identified by Probit regression

Determinants of Adoption of Rice Modern Varieties

Determinants of Water Supply Canals and Modern Varieties at Cultivator Level

Explanatory Variables	Dummy for Cultivators with "Recent MV" Probit Model
Cultivator's status (dummy variable):	
Immigrants cultivators	2.38 (1.47)
Type of landownership (dummy variables):	
Immigrants*Indigenous communal	–1.99 (1.37)
Immigrants*Indigenous individualized	–1.12 (1.30)
Immigrants*Public/Institutional	–0.72 (1.19)
Cultivator's characteristics:	
Age (10^{-2})	–1.52 (2.89)
Sex (1 = male, 0 = female)	3.35 (1.59)**
Years of schooling	–0.18 (0.11)
Living in own house (= 1, otherwise 0)	2.02 (0.97)**
Years of rice cultivation experience	–0.08 (0.06)
Plot characteristics:	
Water source is permanent stream	0.03 (1.13)
Water source is seasonal stream	–0.80 (1.00)
Water source is pond	–5.33 (2.21)**
Distance from water source (1,000 m)	3.16 (1.82)*
Walking time from the residence (100 min)	0.99 (0.77)
Acreage of the plot (ha)	4.43 (2.57)*
Constant	–2.30 (1.88)
Fraction of correct prediction	0.86
No. of positive observations	50
No. of observations†	63

Land tenure has no effect

Male cultivator +

House owner (wealth) +

Table 6

Factor Payments by Water Control and Rice Varieties

	With Water Supply Canal		Without Water Supply Canal	
	Recent MV	Early MV	Recent MV	Early MV
Plot Size (ha)	0.35 (0.24)	0.26 (0.15)	0.32 (0.18)	0.30 (0.05)
Yield of Paddy (kg/ha)	3633 (2112)	2896 (1310)	2770 (1340)	2454 (2080)
Variable Input Costs (10^3 FCFA/ha)				
Seed	17.4 (11.9)	15.0 (6.3)	14.3 (8.5)	12.6 (4.8)
NPK	7.4 (16.6)	0.6 (1.7)	11.5 (18.3)	1.3 (2.5)
Urea	11.5 (18.7)	3.4 (7.9)	10.3 (12.1)	5.0 (10.0)
Herbicide	9.0 (10.5)	1.1 (3.0)	17.8 (16.1)	9.4 (12.0)
Insecticide	2.4 (5.3)	0.4 (1.2)	1.2 (3.6)	1.6 (3.1)
Family Labor	299 (215)	307 (159)	291 (241)	128 (83.3)
Hired Labor	104 (90.9)	86.5 (111)	132 (166)	124 (111)
Total Variable Costs (10^3 FCFA/ha)	451 (244)	414 (144)	479 (276)	281 (104)
Value of Output (10^3 FCFA/ha)	454 (264)	362 (164)	346 (168)	307 (260)
Residual (10^3 FCFA/ha)	3.5 (235)	-52 (124)	-133 (302)	25.2 (218)
Unit Costs (FCFA/kg of paddy)	144 (84.0)	153 (51.2)	220 (188)	123 (70.9)
Number of Cultivators	32	8	17	4

The yields do not differ significantly.
The uses of chemical fertilizer differ significantly: higher in the case of recent MV
The residuals are not significantly different from zero.

Table 8

Rice Cultivator Survey in Bouaké: Fertilizer Use and Yield

- 33 out of 64 cultivators use no chemical fertilizer
  - Average use (urea + NPK) for 31 cultivators: 146 kg/ha (SD=138)
  - Average use (urea + NPK) for all cultivators: 69kg/ha (SD=118)
- According to WARDA's on-farm trial under partial water control
  - 100 kg urea per ha is recommended
  - Yield: 2.6 t/ha (SD=1.4) without fertilizer
  - Yield: 3.9 t/ha (SD=0.9) with recommended fertilizer
  - This much fertilizer makes more profit, given the current prices
  - This yield level is quite similar to the results of the Bouaké survey

Effect of Irrigation and Modern Varieties on Fertilizer Use

Effects of Technology Adoption on Fertilizer Use and Yield at Cultivator Level

Explanatory Variables	2SLS Model Chem Fertilizer Use (kg/ha)
Water supply canals (endogenous)	16.1 (53.0)
Use of recent MVs (endogenous)	53.8 (38.5)
Cultivator's characteristics:	
Age	–2.88 (0.83)***
Sex (1 = male, 0 = female)	48.7 (48.9) *
Years of schooling	–5.04 (2.73)*
Living in own house (= 1, otherwise 0)	116 (39.8)***
Years of rice cultivation experience	1.54 (1.36)
Plot characteristics:	
Water source is permanent stream	–119 (62.5)*)
Water source is seasonal stream	–116 (61.1)*
Water source is pond	–179 (79.2)**
Distance from water source (100 m)	–0.30 (0.78)
Acreage of the plot (ha)	–16.6 (49.8)
Constant	166 (64.7)**
R^2	0.41
No. of observations[†]	63

Neither irrigation nor modern variety influences the amount of chemical fertilizer use

House owner (wealth) has a positive effect

Table 9

Effect of Irrigation and Modern Varieties on Yield

Effects of Technology Adoption on Fertilizer Use and Yield at Cultivator Level

Explanatory Variables	2SLS Model Yield (kg/ha)
Water supply canals (endogenous)	1340 (730)*
Use of recent MVs (endogenous)	201 (1030)
Cultivator's characteristics:	
Age	–15.3 (21.9)
Sex (1 = male, 0 = female)	1200 (640)*
Years of schooling	4.71 (63.1)
Living in own house (= 1, otherwise 0)	–139 (510)
Years of rice cultivation experience	51.5 (32.4)
Plot characteristics:	
Water source is permanent stream	–241 (803)
Water source is seasonal stream	–1110 (634)*
Water source is pond	–1330 (941)
Distance from water source (100 m)	10.9 (17.1)
Acreage of the plot (ha)	–3550 (1120)***
Constant	2900 (1060)***
R^2	0.34
No. of observations[†]	63

Canal increases yield

Modern varieties have no significant effect on yield

Table 9

Summary of Findings

- Rice cultivation in lowland tends to be induced by
  - Population pressure
  - Market access
- Water control technologies are adopted due to
  - Immigrant population
  - Market access
  - Tenure security as well as potential enhancement of security
- Adoption of rice modern varieties is affected by several factors, among which:
  - Relatively wealthy cultivators seem to have adopted them through purchase
- Half of the sample cultivators put no chemical fertilizer
  - If they use, the amount is good enough
  - Relatively wealthy cultivators tend to use chemical fertilizer
- Water control technologies enhance rice yield, while new modern varieties have no effect on rice yield
- Rice production in lowlands is not so profitable even in the city of Bouaké
  - Modern varieties without water control is less profitable than with water control due to lower yield
  - In rural areas it may be less profitable due to lower paddy/fertilizer price ratio

Conclusions

- Despite of potential land tenure problem and liquidity/credit constraints, the average yield in the city of Bouaké is comparable with Asian countries like the Philippines.
- For realizing a Green Revolution, investment in water control technologies in rainfed lowland and further improvement of modern varieties are necessary.
- Although there are vast areas of lowlands in rural area where potential of a Green Revolution exists, poor infrastructure makes rice production less profitable and limits area expansion and intensification.

質疑応答
Question and Answer Session

西アフリカにおける低湿地稲作の集約化と緑の革命の可能性
Intensification of Rainfed Lowland Rice Production and Potential Green Revolution

櫻井　武司　 Takeshi Sakurai
農林水産省 農林水産政策研究所 主任研究官*
Senior Economist, Policy Research Institute, Ministry of Agriculture, Forestry and Fisheries, Japan*

司会：　杉本　充邦　 Chair person: Mitsukuni Sugimoto
名古屋大学農学国際教育協力研究センター　准教授
Associate Professor, ICCAE, Nagoya University

杉本（司会）:

Thank you very much for your presentation. Dr. Sakurai has mentioned about the land tenure problems and how the African people can accelerate the adoption of NERICA varieties. Are there any questions?

小山： 細かい質問で恐縮ですが、移民の役割、移民という要件がかなり技術導入に効いているということでしたが、移民とはどのような定義をされているのでしょうか。移民はいつまで経っても移民なのか、それとも何代か経てば移民ではなくなるのでしょうか、そういう transitional なことを分析されているのではないかという気がするのですが、その辺はいかがでしょうか？

櫻井： 今ブアケ周辺に住んでいる Baoulé の人々は 2～300 年ぐらい前にガーナから来たので移民ですが、彼ら自身はもう地元の人間だと強く意識していて、自分たちの土地であるといって権利を主張しています。それに対して誰もクレームする人はいませんから、それはそうなのでしょう。そうするとその土地は Baoulé の土地であるということになっていて、Baoulé がコントロールしているわけです。Baoulé に属さない民族の移民はフランス植民地時代に始まったことでしょうから、せいぜい数世代しか経っていません。民族の定義から言えば、Baoulé でなければいつまで経っても移民は移民です。結婚とか、長く住んでいて Baoulé の言葉がしゃべれるようになるなどして、いつの間にか地元民化する人もいるかもしれません。しかし、いくら長く住んでいても移民の子孫であれば、その土地に対する生得的な権利は生じませんから、そういう意味では移民か移民でないかということは彼ら自身の認識の中でクリアに分かれていると思います。それが一時的なものなのか、それとも未来永劫に続く

* 2006 年 10 月講演当時。2010 年 2 月現在は一橋大学経済研究所教授。
At the time of presentation in October 2006. The present title is Professor, Institute of Economic Research, Hitotsubashi University.

かどうかはわかりませんが、現状の分析をするにあたってはそのような形で十分だと思います。

浅沼: government がやっきになっても、まわりの農家がやっきになっても、なかなか広がらないというのが最後の結論のようですが、何が農民にとってインセンティブなのか、櫻井さんの研究のなかから分かることはあるでしょうか？

櫻井 明らかにマーケットに近いところでは技術は普及し、採用されていますし、稲作地も広がっているわけです。本日は稲作の話だけをしましたが、野菜作りなども市場に近い所では非常に拡大しています。これは government が普及しているわけではなく自分達でやっているのですから経済的インセンティブは非常に大きいということです。

一方で、技術的な情報が何もなく、低湿地で稲作をすることに関して何もアイデアを持っていない人達を放っておいても勝手に稲作を始めるかというと、やはりそういったことはないわけです。そこに経験のある移民が来るとか、今日はあまり強調しませんでしたが government の普及員が来るといったきっかけが必要です。コートジボワールでは、government がかつて低湿地での稲作を普及させた時代があります。今日の話はそういう活動が 90 年代初めに全部終わってしまって 10 年以上経った状態でどうなっているかという話です。今は 300 いくつかの低湿地のうち 100 いくつしか稲作をしていませんが、かつては 200 か所以上で稲作をしていた時期がありました。なぜかというと government が価格を管理していて米の価格が非常に高かったためです。そのころは稲作の普及も政府が行っていました。その後、構造調整政策のため、価格への介入を止めてしまい、普及もあまりやらなくなったため、低湿地での稲作がだんだん縮小してしまいました。そうすると government がやったことは普及にとって全然意味がなかったわけではないけれども、普及させた技術に持続性があるかどうかというところでは経済的な問題が一番大きいのではないかと思います。

飯嶋: 名古屋大学の飯嶋です。細かいことで恐縮ですが、肥料を投入した場合と投入しない場合の収量が非常に違っているのに興味を持ちまして、先ほどのスライドの中で肥料を投入した場合 3.9 トン、投入しない場合 2.6 トンの平均収量が得られるとありましたが、これはおよそ 1.5 倍くらいの収量が出ていることになります。肥料を投入している時は水を与えたりいろいろなことをやっていますので、トータルの利益としてはどれぐらいアップしているとみてよろしいでしょうか？

櫻井: これは私がやった試験ではなくて、WARDA の研究者が on farm で行った試験です。同じ partial water control の低湿地でやっていますので、水に関しては条件が

同じで、肥料の違いのみでこれだけ収量の違いが出ているということだと思います。稲作の利潤も計算していまして、私は数字は覚えていませんが、肥料として 100 キロの尿素を入れてこれだけの収量になったときに、当時の肥料と米の価格に基づいて計算するならば利益は十分高いということになっていました。肥料を入れる労力はたいしたことありませんので、労働時間に関してはほとんど同じで、肥料のコストの違いだけでしょうから、単純にいえば、収量の増えた分を金額に換算して、そこから肥料のコストを引いただけ利益が増えているといえます。

飯嶋:　そうしますと、肥料を投入して奨励品種を栽培することで、十分余分の利益はあがると考えてよろしいでしょうか。

櫻井:　はい。ただし、これは 1 年だけの試験です。partial water control がどれくらい有効かわかりませんが、降水量の毎年の変動がありますので、肥料を入れても雨が少ない年には駄目になるというリスクもあります。単純に毎年これだけの違いがあるかどうかはわからないと思います。それともう一つには、私が行った別の研究に示しましたけれども、肥料を買うに際してクレジットなどはありませんので、キャッシュがある人は買えるが無い人は買えません。降水量が多いことが判っていたとしても皆が肥料を買うかというと、今の市場経済のメカニズムではなかなかそうはいきません。もちろん、だからといって私は肥料に補助金を出せという議論はあまりしないのですが、補助金ではなくクレジットを供与するにしても、借金をしても旱魃になると返せないというリスクがあるので農家も簡単には飛びつきません。

飯嶋:　どうもありがとうございました。

杉本(司会):

ありがとうございました。

Profile

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1985 年東京大学理学系研究科動物学専攻修士課程修了。同年 4 月より、日経 BP 社（入社時社名、日経マグロウヒル社）に記者として勤務。1989 年 9 月より、休職し、米国ミシガン州立大学大学院に留学、農業経済学を学ぶ。1995 年 8 月、同大学より Ph.D.授与、同年 10 月、農業総合研究所（農林水産政策研究所の前身）に主任研究官として採用される。1999 年 1 月より国際農林水産業研究センターに出向し、同センターの「アフリカ稲作プロジェクト」に参画した。その一環としてコートジボワールにある西アフリカ稲作開発協会（WARDA - The Africa Rice Center）にエコノミストとして 2003 年 7 月まで勤務。2004 年 4 月に農林水産政策研究所に復帰し、国際政策部主任研究官。和光大学経済経営学部教授を経て、現在は一橋大学経済研究所教授。専門は、サブサハラ・アフリカと南アジアの農業技術、天然資源管理、貧困削減にかかわる経済分析。

Academic career

Professor Takeshi Sakurai received his Master degree in Zoology from Graduate School of Science, the University of Tokyo in 1985, and Ph.D. in agricultural economics in August 1995 from Michigan State University, USA.

Professional career

Professor Takeshi Sakurai started his professional career as a staff writer for Nikkei Business Publications, Inc.　After obtaining Ph.D., he joined the National Research Institute of Agricultural Economics (the predecessor of PRIMAFF) in October 1995 as a senior economist.　In January 1999, he transferred to Japan International Research Center for Agricultural Sciences (JIRCAS) to work for the Africa Rice Project, and worked as an economist at West Africa Rice Development Association (WARDA) in Côte d'Ivoire until July 2003.　From April, he returned to PRIMAFF and served as a senior economist for Policy Research Institute until March 2008.　Professor of economics and business management, Wako University from April 2008 to March 2009, and he has been a professor of Institute of Economic Research, Hitotsubashi University.　His study covers economic analyses on agricultural technologies, natural resource management, and poverty alleviation in sub-Saharan Africa and South Asia.

第3章　わが国の取り組み

Chapter 3　Japan’s Activities

アフリカ向けイネ品種の改良を目指したJIRCASでの研究開発
JIRCAS's Research Activities Targeting at Improvement of Rice Varieties for Africa

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要　約

独立行政法人国際農林水産業研究センター (JIRCAS)は、世界、とりわけ発展途上地域の安定的な食糧生産に農業研究を通じて貢献することをミッションに掲げている。発展途上地域では干ばつ等により農業生産が脅かされる機会が増加しており、干ばつなどの環境ストレス耐性を重要な目標として研究を推進している。JIRCASは日本政府と国連開発計画による「アフリカ・アジア共同研究：アフリカ・アジア稲の品種交配研究プロジェクト」に1998年から参画し、西アフリカ稲開発協会(WARDA)に研究者を派遣してきた。ここでは、アフリカのイネ品種の改良に関連してJIRCASで進行中の研究課題について紹介する。

WARDAで開発されたNERICAは現在アフリカ各地への普及が図られている段階であるが、普及には、純正な種子が大量に準備されていることが前提となる。NERICAの種子増殖体系をアフリカで構築するためにJIRCAS所属のJICA専門家である池田氏がBeninのWARDAで育種家種子から原々種の生産方法の体系化に取り組んでいる。育種家種子の評価中にいくつかのNERICAでは種子の均一性が担保されていないことが明らかとなり、種子増殖体系確立とともに育種家種子からの純系選抜をも併行して進めている。

乾燥、冠水はアフリカのイネ栽培では大きな制限要因であり、これらに耐性を示すイネ遺伝資源の選抜を行うためにJIRCASは2人の研究者をWARDAおよびIRAG (ギニア)に派遣している。この研究の目的は耐性を示す遺伝資源の選定と、耐性に関連するDNAマーカーの獲得であり、両者は、耐性品種を育成する際の有力なツールとなる。

環境ストレス耐性の分子的機構の解明に関する研究により、種々の環境ストレスに対して耐性を示す遺伝子を単離した。現在、この遺伝子を国際農業研究機関と共同で各種作物に導入中であるが、このたび、JIRCAS独自の研究課題としてこの遺伝子をNERICAに導入するプロジェクトを開始した。

これらの研究活動を通じて、すでに育成されたNERICA、あるいは将来開発される環境ストレス耐性品種がアフリカ各地で栽培され、食糧の安定化に繋がることを期待している。

JIRCAS's Research Activities Targeting at Improvement of Rice Varieties for Africa

Takashi Kumashiro
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Abstract

Holding its mission to contribute to global agriculture, especially in developing regions, through research in agricultural sciences, JIRCAS has been conducting many research activities in various areas of agriculture. Among traits needed for such regions, JIRCAS has been placing its top priority in abiotic stress tolerance in a number of crops.

Since 1998, JIRCAS has dispatched its scientists to Africa Rice Center (WARDA), as a member of Collaborative Projects of Africa/Asia Joint Research on Interspecific Hybridization between African and Asian Rice Species supported by Japanese Government and UNDP. In this article, our on-going research activities dealing with improvement of rice varieties in Africa will be introduced.

NERICA (New Rice for Africa) developed by WARDA is now in the phase of dissemination to various cultivation regions in Africa. One of the pre-requisites for dissemination of new varieties is availability of ample amount of certified seeds. Dr. Ikeda who is a specialist of JICA and a member of JIRCAS has been establishing a seed propagation system for NERICA in WARDA at Benin. During a course of evaluation of each variety, some of NERICA varieties have been found to be not always homogeneous in the breeder seeds, which will cause serious problems in practical cultivation. Therefore, along with developing the seed propagation system, selection for pure lines has to be pursued.

Two scientists of JIRCAS have been conducting collaborative research on drought tolerance and submergence tolerance of rice with WARDA (Nigeria) and Institut de Recherche Agronomique de Guinee (IRAG). Wide ranges of rice germplasm including Oryza glaberrima have been subjected to evaluation for tolerance of drought or submergence. As one of the indicators of drought tolerance, rooting depth is used. Goals of these projects are 1) identification of germplasm with the tolerance, and 2) acquisition of DNA markers linked to such tolerance, both of which can be a powerful tool in breeding programs targeting for drought and submergence tolerance of rice varieties in Africa.

As results of extensive molecular work on stress tolerance, JIRCAS has identified DREB (dehydration responsive element binding protein) genes which confer tolerance to abiotic stresses including drought, high salinity and low temperature. JIRCAS is collaborating with a number of International Agriculture Research Institutes to develop abiotic stress tolerant varieties. Recently, JIRCAS has initiated its internal project to develop drought tolerant NERICA by introducing these genes.

Through these research activities, both conventional and biotechnological, JIRCAS is hoping that the existing NERICA as well as new stress tolerant varieties to be developed would contribute towards increased rice acreage in Africa.

Introduction

Under the mission to contribute to global agriculture, especially in developing regions, through research in agricultural sciences, JIRCAS has been conducting many research activities in various areas of agriculture. Among traits needed for such regions, JIRCAS has been placing its top priority in abiotic stress tolerance in a number of crops.

Since 1998, JIRCAS has dispatched its scientists to Africa Rice Center (WARDA), as a member of Collaborative Projects of Africa/Asia Joint Research on Interspecific Hybridization between African and

Asian Rice Species supported by Japanese Government and UNDP. In this article, our on-going research activities dealing with improvement of rice varieties in Africa will be described.

Research activities targeting genetic improvement of rice adapted for African ecosystems can be classified into the following 3 phases. The first phase is targeting dissemination of the already developed NERICA varieties. In the first phase, higher priority should be placed in establishment of seed propagation system as well as in accumulation of data on agronomic performance of each variety. The second and the third phase are aiming at improvement of drought tolerance of rice in Africa, because among many stresses, drought has been considered to be major constraints for rice production in Africa. In the second phase, conventional approach is taken and in the third phase molecular approach is employed to attain the targeted goal.

Phase 1 Research on the existing NERICA varieties

NERICA (New Rice for Africa), developed by WARDA by hybridization between *Oryza sativa* and *O. glaberrima* and backcrossed with *O. sativa,* is now in the phase of dissemination to various cultivation regions in Africa. One of the pre-requisites for dissemination of new varieties is availability of ample amount of certified seeds.

Generally, seeds for farmers for a new variety will be produced in the following steps; 1) breeders' seed, 2) foundation seeds, 3) registered seeds, and 4) certified seeds from which seeds for farmers will be finally propagated. Dr. R. Ikeda who is a specialist of JICA and a member of JIRCAS has been establishing a seed propagation system for NERICA in WARDA at Benin. For establishment of an overall seed propagation system for NERICA, WARDA and ARI (African Rice Initiative) are taking a role to establish a system for breeders' seeds and foundation seeds. During a course of evaluation of breeders' seed of each variety, some of NERICA varieties have been found to be not always homogeneous (Ikeda 2006), which will cause serious problems in practical cultivation. Typical off-types observed during the evaluation in the field include, dwarf, abnormal panicle, sterility and albino (Table 1). It is not certain at this moment whether these off-types are resulted from segregation or simple mixture with other variety. Since the breeders' seed must be homogeneous in all aspects, the first step for establishment of seed propagation system for NERICA is to select a genetically homogeneous line within a variety.

Another important point for dissemination of a new variety is to accumulate data on overall agronomic performance of each variety. Since such date is limited for NERICA, systematic survey will be definitely necessary involving field evaluations at multiple sites.

Phase 2 Improvement of drought tolerance by conventional approach

According to FAOSTAT, total acreage of rice field in Sub-Saharan Africa is about 5 million ha. About 80% of the rice field is so-called rain-fed field (Table 2). Among many constraints to rice production, drought has been regarded to be most serious one. In order to improve the productivity in these regions as well as to expand rice cultivation area, it is essential to develop rice varieties with higher tolerance to drought.

Drought tolerance is a very complex trait. The expression of drought tolerance depends on interaction of different morphological (earliness, reduced leaf area, leaf rolling, wax content, rooting system, and reduced tillering), physiological (reduced transpiration, high water use efficiency, stomatal closure and osmotic adjustment) and biochemical (accumulation of compatible solutes, increased nitrate reductase activity and increased storage of carbohydrates) characters (Mitra 2001). Tobita et al. (2001) found that xylem exudation rate can be used as a criterion to discriminate drought resistant and susceptible rice varieties. With regard to rooting system, the importance of a deep root system has been repeatedly emphasized in rainfed rice (Nguyen et al. 1997, Ito et al. 1999). Among the traits related to drought tolerance, we have selected rooting depth as an indicator of drought tolerance.

Wide range of rice germplasm consisting of the core collection of IRRI, the core collection of National Institute of Agrobiological Sciences (NIAS) in Japan, upland rice varieties provided by Ibaraki Agricultural Center, and 86 lines of *O. glaberrima* from WARDA was first evaluated in Bouake, Cote d'Ivoire, for drought tolerance at seedling stage using the standard evaluation system (IRRI 1996). The varieties classified as drought tolerant were subjected to measurement of root depth in the field. Six drought tolerant varieties such as Azucena, Black Gora showed deeper roots compared with drought sensitive varieties, indicating positive correlation between drought tolerance and rooting depth. Under this evaluation, NERICA 1 - 4 and its parental lines were not regarded to have deeper roots in the experimental field at WARDA (Sakagami and Tsunematsu 2003).

Furthermore, root depth at the reproductive stage was evaluated for approximately 600 rice germplasm including *O. glaberrima*. Based on the deepest root length at the stage of 2 weeks after heading, top 100 germplasm has been selected. Second and third rounds of the evaluation are now on-going at WARDA Nigeria Station. After identifying germplasm with deeper root, correlation with drought tolerance at the reproductive stage will be further examined. Also, hybridization between germplasm with deep root and with shallow root will be made for development of the segregating population which will be used for QTL analysis for rooting depth.

Phase 3 Molecular approach to improve drought tolerance

JIRCAS molecular group has been conducting research to elucidate molecular mechanisms of abiotic stress tolerance of plant. The group has revealed the complex regulatory network of gene expression in response to drought, high salinity and cold stresses using a model plant, *Arabidopsis*. The *Arabidopsis* RD29A gene encoding a LEA (late embryogenesis abundant)-like protein responds to dry, high salinity and cold stresses strongly. Through the yeast one hybrid method, a transcription factors that bind to DRE *cis*-acting element on RD29A promoter was isolated from *Arabidopsis* and named DREB (Dehydration Responsive Element Binding protein).

Gene constructs consisting of constitutive promoter 35S or stress inducible promoter RD29A from *Arabidopsis* linked to DREB1A were introduced into *Arabidopsis*. The resultant transformants showed increased level of tolerance to freezing, drought and high salt concentration. In the case of 35S promoter, transformants showed retarded growth. However, the use of stress inducible promoter, RD29 from *Arabidopsis*, minimized the negative effect on the growth retardation. DREB1 can activate more than 40 target stress-inducible genes under stress condition. Over-expression of DREB1 activated strong expression of the target genes which, in tern, resulted in an increased tolerance of freezing and drought stresses. (For review; Nakashima and Yamaguchi-Shinozaki 2005, Umezawa et al. 2006)

Orthologs for DREB1 were found in rice genome and termed OsDREB. Over-expression of OsDREB1A in *Arabidopsis* resulted in higher tolerance to high salinity and freezing stress (Dubouzet et al., 2003). Furthermore, when OsDREB1A under control of a constitutive promoter was introduced into rice, the resultant transgenic rice showed improved tolerance to drought (dehydration for 9 days), high salinity (250mM NaCl for 3 days) and low temperature (2℃ for 93 hr) stresses (Ito et al. 2006).

Results from the evaluation of transformed *Arabidopsis* and rice at greenhouse-level indicate that transcription factor genes, DREB1, has great potential to generate crops which show tolerance to abiotic stresses, such as drought, high salinity and freezing, at practical field level. To investigate to what extent transformants carrying DREB genes exhibit tolerance to abiotic stresses at field level, JIRCAS has been carrying out collaborative research with a number of international research institutes including International Rice Research Institute (IRRI), International Center for Tropical Agriculture (CIAT), International Maize and Wheat Improvement Center (CIMMYT), International Crops Research Institute for the Semi-Arid Tropics (ICRISAT), and International Center for Agricultural Research in the Dry Areas (ICARDA), covering many different economically important crops such as rice, wheat, soybean, lentil, groundnut, and chickpea.

Since an ultimate goal of the collaborative research is placed in generation of transformants carrying a single and an intact copy of a transgene, a transformation protocol should enable to generate large number of independent primary transformants. The reason why a large number of independent transformants are necessary derives from the fact that any available transformation systems currently available are not a perfect system in the sense that the following parameter cannot be controlled; 1) intactness of transgene (without modification or fragmentation of transgene), 2) copy number of transgene (somehow related to number of locus for transgene), 3) location of insertion of transgene in host genome (resulting in positional effect), and 4) suppression of somaclonal variation during dedifferentiation phase (if tissue culture phase involved).

Although examples of large-scale transformation are very limited, one example can be found in a paper by Hu et al. (2003). In their attempt to generate elite transformants of herbicide tolerant wheat, they found the frequency of such elite line as 0.8% and 0.2 % of primary transformants, by *Agrobacterium* and biolistic transformation method, respectively. Therefore, a high-throughput transformation system is certainly one of important pre-requisites for obtainment of elite transformants.

JIRCAS has recently started its internal transformation work aiming at improvement of drought tolerance of rice in Africa, including NERICA. Since there has been no prior work on transformation system of NERICA which is an interspecific hybrid between *O. sativa* and *O. glaberrima*, we are now working on establishment of transformation system which would fulfill the requirements listed above.

Conclusion

Through these research activities, both conventional and biotechnological, JIRCAS is hoping that the existing NERICA as well as new stress tolerant varieties to be developed would contribute to not only stable production of rice but also expansion of rice cultivation areas in Africa.

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Table 1 Off-types found in NERICA varieties.

NERICA Variety	Frequency of Off-type (%)	Example of Off-type
1	0.25	Drarf, Abnormal panicle
2	7.39	Early maturity, Dwarf, Semi-sterility
3	0.99	Early maturity, Dwarf, Abnormal tillering, Semi-sterility
4	--	Mixture
5	4.83	Broad leaf, Narrow leaf, Semi-sterility, Abnormal tillering
6	6.33	Dwarf, Early maturity, Semi-sterility, Abnormal tillering
7	0.36	Dwarf, Plant elongation, Narrow leaf, Abnormal tillering, Semi-sterility

Source: Ikeda (2006)

Table 2 Cropping System of Rice in Sub-Saharan Africa

Cropping System	Area (%)*	Major Constraints
Rainfed Lowland	42.6	Iron toxicity, Floods, Insects, Diseases, Drought
Upland	37.1	Drought, Weeds, Disease (Blast), Pests, Low inputs
Irrigated	13.9	Diseases, Insects, Pests, Weeds, Nutrient deficiency, Toxicity
Deepwater	4.8	
Mangrove	1.6	

* After Nguyen and Tran (2002)

質疑応答
Question and Answer Session

アフリカ向けイネ品種の改良を目指したJIRCASでの研究開発
JIRCAS's Research Activities Targeting at Improvement of Rice Varieties for Africa

神代 隆 Takashi Kumashiro
独立行政法人 国際農林水産業研究センター（JIRCAS） 生物資源領域長
Director, Biological Resources Division
Japan International Research Center for Agricultural Sciences (JIRCAS)

司会： 松本 哲男 Chair person: Tetsuo Matsumoto
名古屋大学農学国際教育協力研究センター 教授
Professor, ICCAE, Nagoya University

松本（司会）:

私のほうから質問させてもらってもいいですか。先ほどローカルのものと比較して乾燥のストレスに対する抵抗性の問題ですが、NERICAは一般的に弱いと考えていいのでしょうか？

それから、そこに入ってくる今度新しく出る乾燥遺伝子のdrought toleranceは、先ほどの説明ですと、塩とかまた、温度との関係でストレス耐性が高まるという効果があると思うのですが、それもやはり同じ遺伝子がtolerance関係のものをすべてコントロールしていると考えていいのでしょうか、あるいは生理的な仕組みがそうなっていると考えてよろしいのでしょうか？

神代： まず一番目の質問ですが、WARDAのパンフレットにdroughtについて書いてありますが、乾燥抵抗性はいろいろ複雑なメカニズムもあり、drought escapeであることは確かです。生育期間が短い、つまり成熟まで100日以内でやるということで、乾燥が来る前に全部収穫し終えるので、乾燥にあわずに収穫できるということが、ここでは正しいと思います。しかし、根が長いということなのか、あるいは本当に水の無い、水の少ないところでどうなるかということに関しては、我々のデータ、それから他にもいくつか知っているのですが、必ずしもそれほど強くないと私は思っています。

それからdroughtの話ですが、これは確かにdrought遺伝子を交鎖させると 乾燥、塩、低温、この三つに効きます。これはmoist levelと同じです。この三つに共通していることがありまして、これは非常に細胞の浸透圧が高くなります。というのは水が抜けるからです。そういうことで大丈夫だということで、そこのメカニズムでは確かに効果があります。しかしこの遺伝子を入れたから根が深くなるとか、あるいは気孔の開化温度が変わるかというと、そういったことまでは期待できないと思います。だから、そこは色々な他の性質を組み合わせて総合的に抵抗性を上げていかなければならないと思います。

先ず我々がやらなければいけないことは、遺伝子のデータモードが必要な時に、どのあたりのレンジで耐性を示すのかということをちゃんと記録しなくてはいけないと思っています。

松本（司会）：

他にご質問はありますか？

飯嶋：NERICA が他の品種等と混ざっているものがある可能性を最初のほうのスライドで言及されていましたが、特に NERICA の 4 番が他のものと比べて非常に根も大きいし、乾燥する度合いも高いというのが、私自身も栽培していてそう感じているのですが、これがどうも、他のものと混ざっているというデータが出ていまして。

神代：これはじつは、育種家種子にふたつあったのです。ある人が持っていて名前は忘れたのですが、それが混ざっていたということです。専門家の話によりますと、分けてあればあんなにひどい結果は出ていなかった、もう少しまともだったということです。どちらが良いかはわかりませんが。

飯嶋：そうしますと、他の NERICA に近いようなものが NERICA 4 だったということですね。あの、NERICA 4 はとても非常に何か、ちょっと変わっているなという印象を受けましたので。

神代：どれかと言われると私もよくわからないのですが…。

飯嶋：はい、どうもありがとうございました。

浅沼：Submergence tolerance というのは特殊な条件でそういう問題があるのでしょうか、あるいは、何か環境問題などがあると思うのですが、どういうところでそこに注目されたのですか。

神代：必ずしも特殊な例ではないです。いわゆる lowland rainfed の場合は最初はいやというほど水があって、それから急になくなって最後は乾燥になるということです。要するに水はあるのだけれどその配分がコントロールできないから色々な問題が起きてくるわけです。だから、最初は submergence でやられることもあるわけで、そこに対してもある程度耐性がないと、特に lowland には適さないということで始めたわけです。

浅沼：それは幼苗期の話しということですか？

神代：そうですね、生育初期ですね。

松本（司会）：

神代先生、ありがとうございました。

Profile

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1974年に京都大学大学院農学研究科（育種学専攻）を修了し、民間企業において植物バイオテクノロジー分野を担当し、葯培養による半数体育種法の確立、非対称細胞融合を用いた核—細胞質置換による雄性不稔性品種の開発、および単子葉植物の形質転換法の開発など研究開発に従事した。研究開発管理部門を経て、2004年7月にJIRCASの現職に就いた。

Academic career

Mr. Takashi Kumashiro graduated from Graduate School of Kyoto University in 1974 with a major in Plant Breeding.

Professional career

After graduation, Mr. Kumashiro immediately joined a private company where he conducted and was involved in biotechnology-related research projects, including haploid breeding using anther culture, asymmetric protoplast fusion, and development of Agrobacterium-mediated transformation for monocots. With his wealthy experience in management of research and development, Takashi Kumashiro joined Japan International Research Center for Agricultural Sciences (JIRCAS) in 2004 and is currently the Director of the Biological Resources Division.

JICA のアフリカにおけるネリカ普及支援
JICA's NERICA Dissemination in Africa

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Japan International Cooperation Agency (JICA)

要　約

JICA のネリカ普及支援は、2002 年 8 月の WSSD および 2003 年 10 月の TICAD3 において、わが国がアフリカ農業開発支援の具体的な貢献策としてネリカの普及促進を打ち出したことを受け、2003 年より開始された。

JICA は、70 年代より大規模灌漑稲作によるアフリカへの稲作協力を実施しており、90 年代からは農民参加型の小規模灌漑稲作協力を開始し、稲作に対する協力を行っていた。水稲栽培は気候や地形により普及が制限されることもあり、ネリカ支援が加わったことで、JICA の稲作協力は水稲と陸稲に拡大されることとなった。

ネリカ普及に対する JICA の協力は、農業・農村開発分野における主要なアフリカ支援策として位置づけられ、2003 年の基礎調査団の派遣以降、各国へ派遣中の農業専門家を通じての協力を開始した。また、2004 年にはネリカ事業に専従する専門家をウガンダへ1名派遣すると共に、2005 年にはベナンの WARDA へ2名のネリカ専門家を派遣した。現在までに、これらのネリカ専門家ならびに各国の農業専門家によりネリカ普及支援が進められており、協力を実施した国は15カ国（ベナン、エチオピア、ガンビア、ガーナ、ギニア、ケニア、マダガスカル、マラウィ、マリ、モザンビーク、ナイジェリア、セネガル、タンザニア、ウガンダ及びジンバブエ）に上る。

当面のネリカ普及支援は、ウガンダ及び WARDA へのネリカ専門家派遣を中心に、これらの専門家による周辺国への巡回指導、並びに各国派遣の農村開発専門家の協力を得ながら、各国試験研究所の研究員、普及員、指導的農家等の人造り協力を中心として支援していく方針である。

ネリカの開発・普及のためには、4つのステージ（育種～試験研究・実証～種子増殖～普及）が必要であると言われている。ARI(African Rice Initiative)が掲げる目標である栽培面積の拡大に寄与するため、JICA としては「試験研究・実証」及び「種子増殖」を中心に協力を行っていく計画である。

これらの取り組みにあたっては、各国の状況に合わせた対応が必要である。すなわち、既に品種試験を実施している国については、試験結果の分析及び奨励品種候補の選定について協力を目指し、一方、これから品種試験を開始する国については、周辺国の経験を踏まえた試験計画の標準化及び品種比較試験の導入を目指していくことが必要と考えている。

ネリカ普及支援にあたっては、内外の諸機関との連携強化が重要であり、これを推進させると同時に、JICA 内部においても他の事業スキームとの連携を進めるべく体制整備を進めている状況となっている。

JICA's NERICA Dissemination in Africa

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Abstract

JICA started NERICA dissemination in 2003 which was inline with the government policy to support NERICA for agricultural development in Africa as declared in WSSD and TICAD III held in 2002 and 2003 respectively.

JICA's cooperation in rice cultivation commenced in the 1970s by means of paddy rice cultivation with equipped irrigation schemes in large scale, then it turned over to small-scaled irrigated rice cultivation with farmers' participation in the 1990s. The target crop of these interventions was paddy rice which needs much water for its harvest, therefore, possible extension area depended on climate and geographic condition. Since 2003, JICA's cooperation in rice cultivation extends to both paddy and NERICA rice.

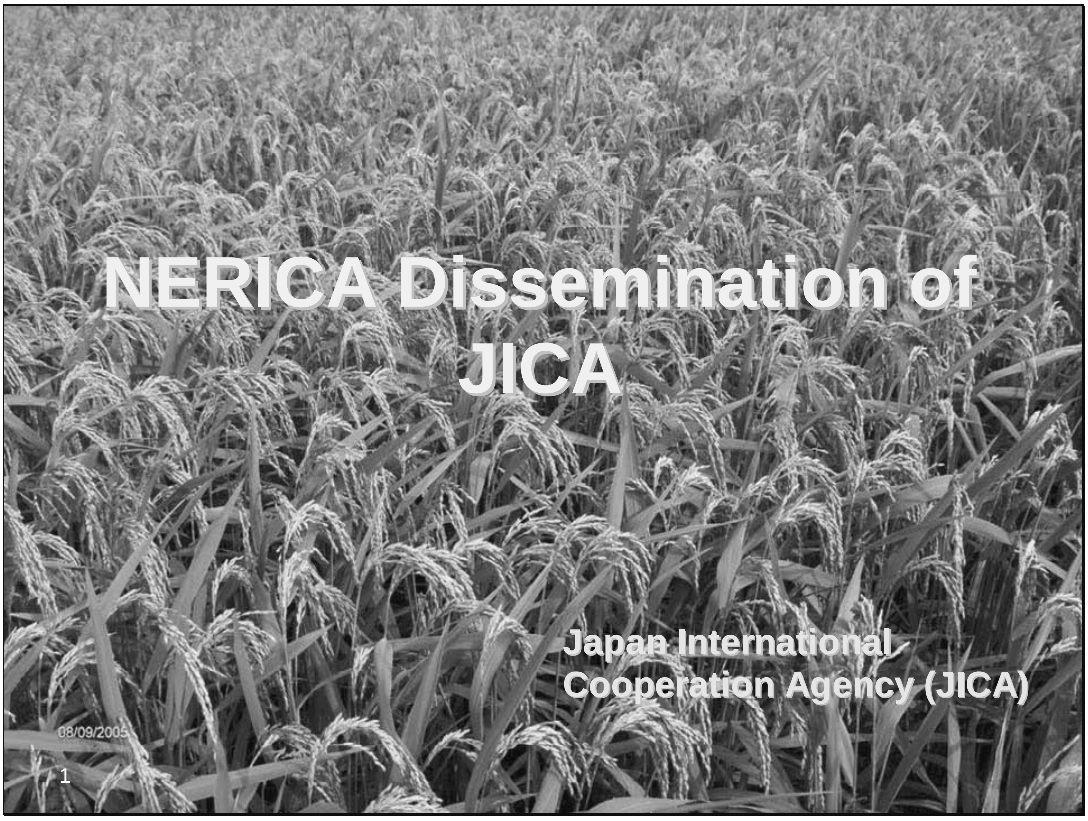
JICA commenced its NERICA cooperation by trial cultivations through the participation of the existing agricultural projects of JICA as well as sending of preliminary study teams to survey possible areas for dispatch of NERICA experts. Then, JICA dispatched one expert to Uganda in 2004 and two experts to WARDA in Benin in 2005. Strengthening of NERICA dissemination has been implemented through NERICA experts and other existing agricultural projects of JICA in over 15 countries such as in Benin, Ethiopia, Gambia, Ghana, Guinea, Kenya, Madagascar, Malawi, Mali, Mozambique, Nigeria, Senegal, Tanzania, Uganda and Zimbabwe.

JICA aims to expand its cooperation through visits of the NERICA experts based in Uganda and Benin to the surrounding countries and strengthening of collaboration between the NERICA experts and the existing agricultural projects to support researchers conducting varietal trails, extension workers and model farmers.

NEIRCA dissemination would be classified by four phases such as breeding, varietal trial, seed multiplication and extension to the farmers. To contribute to the progress of WARDA/ARI (African Rice Initiative), JICA will concentrate on varietal trial and seed multiplication which will sustain future expansion of NERICA in Africa.

It is necessary to consider how to participate in the progress of NERICA dissemination of the country to adopt our intervention to the country's situation. JICA will concentrate more on improvement of data analysis and selection of recommended varieties in the countries where the varietal trials are already in progress, meanwhile introduction and standardization of experimental method are given priorities in countries where varietal trials are about to be commenced.

NERICA dissemination should be conducted in association among research institutes, pilot projects and extension organizations. Therefore, JICA plans to extend collaboration with other institutions as well as collaboration with JICA's other cooperation schemes.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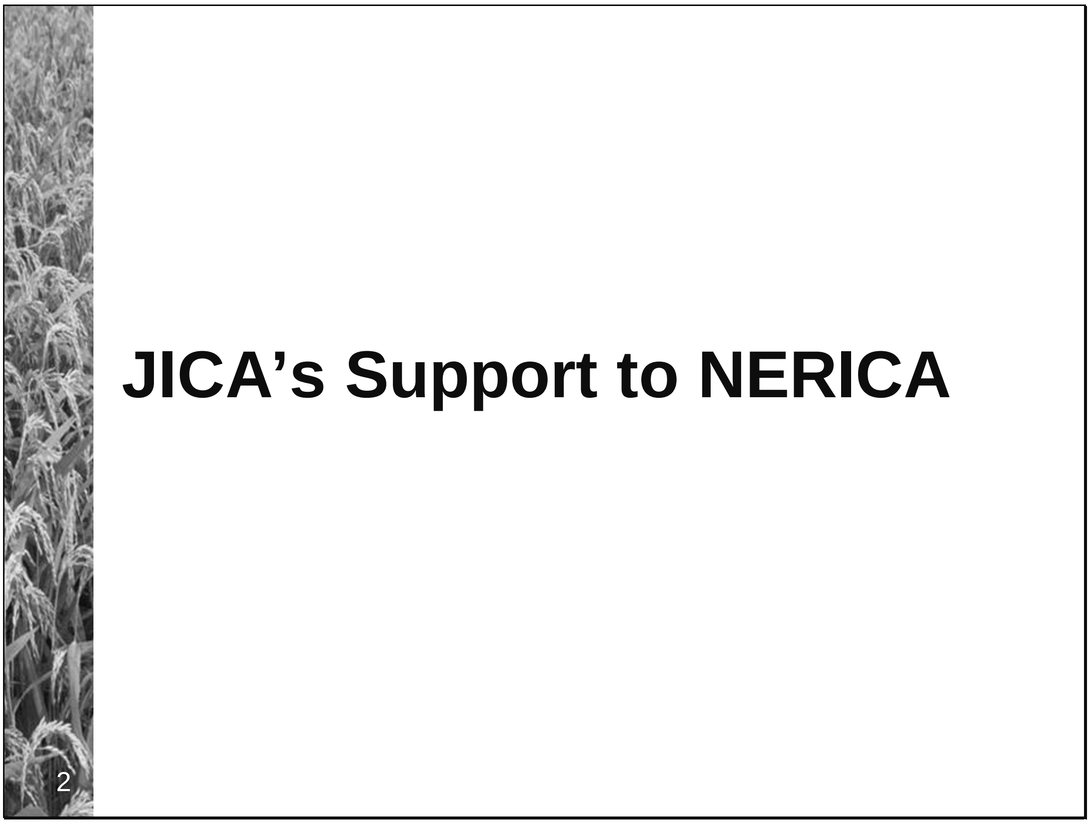

JICA's Support to NERICA
2

Trade of Major Crops

- Trade ratio of rice is much lower than other major crops.

	Production (million t)	Trade (million t)	Trade Ratio (%)
Rice	**40**	**2.7**	**6.7**
Wheat	55	10.7	18.5
Corn	60	7.8	12.8

Rice is a crop mostly consumed in domestic markets

3

Crop Production in Sub-Saharan Africa

- Rice is no longer miner crop in Sub-Saharan Africa.

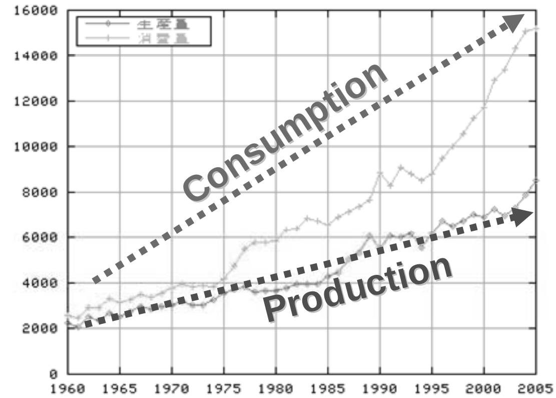
	1970	1990	1998
Rice (mil. t)	**2.44**	**5.80**	**7.32**
Corn (mil. t)	4.99	7.94	9.16
Sorghum (mil. t)	6.63	7.79	9.18
Millet (mil. t)	6.51	8.12	9.76

Lunch served in a local restaurant in Uganda

4

Food Security in Sub-Saharan Africa

- Demand for rice is increasing
  - Rice is becoming popular recently
- Local production does not meet its demand
  - Lack of paddy field
  - Low yield
  - Lack of materials
  - Pest & diseases
  - Lack of tech.



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JICA's assistance in rice production

- 70's – 90's
  - Irrigated rice in large scale (paddy rice)
- 90's
  - Irrigated rice in small scale with PRA （Participatory Rural Appraisal）

paddy

<<Gov. assistance to NERICA dissemination>>
2002 : Stated in WSSD
2003 : Stated in TICAD III

upland

- 2003
  - Commencement of NERICA activities of JICA

6

Japan’s contribution to Agric. Dev.

Manifestation in TICAD III.

1 Assistance in the formulation of agricultural policies
2 Improving food productivity
3 **NERICA Initiative**
4 Sustainable rural development through independent efforts of African people
5 Emergency measures to combat famine
6 Fight against desertification
7 Nurturing small enterprises and vitalization of the informal sector through ODA

7

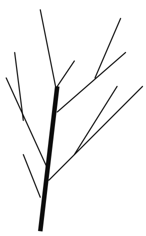
What is “NERICA” ?

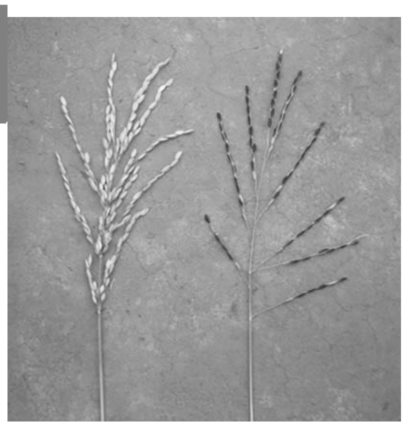
Asian Rice (*O. glaberrima*)

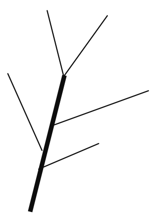
African Rice (*O. sativa*)

Yield: high
Tolerance: low

Yield: low
Tolerance: hifh







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NERICA = New Rice for Africa

8

Japan's Support to NERICA

WARDA

- 1971: Established
- 1991: IHP Research
- 1994: Birth of NERICA

Japan

1978- : Collaboration in Univ. & Research Institute level

1997: Budget assistance of the Gov. of Japan for NERICA development through UNDP

Release of NERICA 1 to 7

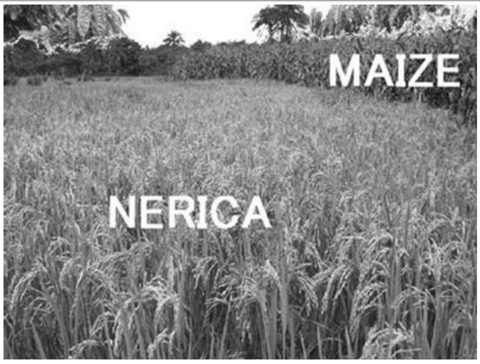
9

JICA's intervention for NERICA

1. Experts to WARDA
2. Expert to Uganda
3. Experimentations conducted by the existing agric. projects
4. Technical seminars held in AICAD of Kenya.

10

NERICA around JICA expert in Uganda

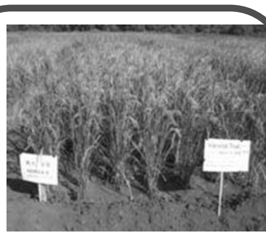


Capable to increase local rice production in various upland condition.

11

Priority in NERICA dissemination

breeding



Experimental trials

dissemination

Seed multiplication

JICA's priority

1. **Capacity development of rice researchers and extension workers**
2. **Improvement of seed distribution system**
3. **Cooperation with other organizations**
4. **Data collection/analys is/distribution**

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Role of Japanese Institutions

- **JICA**
  - ➢**Trial Cultivation (Expert, Seminar, Training in Japan)**
  - ➢**Seed Multiplication (Expert)**
- JIRCAS
  - ➢Breeding
- JAICAF
  - ➢Trial Cultivation
- SG2000
  - ➢Trial Cultivation
  - ➢Household Improvement
  - ➢Exploitation of Farming Materials

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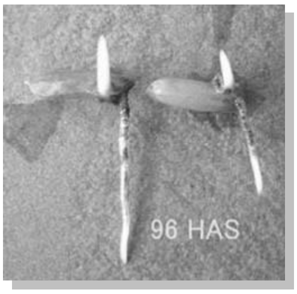
Tasks to be Taken



- Accumulation of basic data and transfer of cultivation technology are important in NERICA dissemination in each recipient countries, since each recipient country has deferent climate.

- Cultivation trials
- Soil moisture content
- Temperature / Altitude
- Fertilizer Application
- Disease prevention

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VARIETAL TRIAL

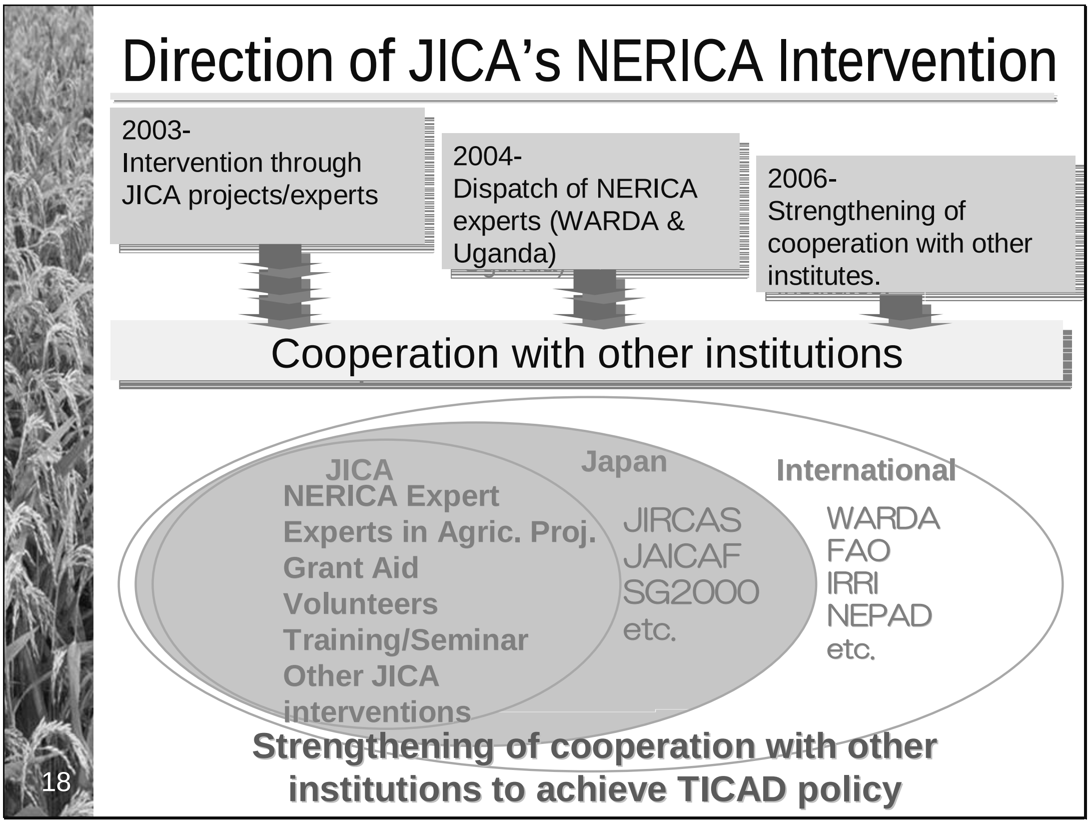
NAMULONGE, UGANDA

15

Long Term Fertility Trial

16


Weed control trial
R-1 Control
W-1 No weeding
17


Direction of JICA's NERICA Intervention
2003-
Intervention through
JICA projects/experts
2004-
Dispatch of NERICA experts (WARDA & Uganda)
2006-
Strengthening of cooperation with other institutes.
Cooperation with other institutions
JICA
NERICA Expert
Experts in Agric. Proj.
Grant Aid
Volunteers
Training/Seminar
Other JICA interventions
Japan
JIRCAS
JAICAF
SG2000
etc.
International
WARDA
FAO
IRRI
NEPAD
etc.
Strengthening of cooperation with other institutions to achieve TICAD policy
18

Activities by countries

<Uganda, Guinea>
Interventions in research, vulgarization & seed multiplication to increase existing NERICA farming field.

<Kenya, Ethiopia, Mali, Gambia>
Interventions to extend variety trials from research institutions to farmers' fields.

<other counties>
Interventions to strengthen the structure for NERICA promotion and to promote cultivation trials at national level.

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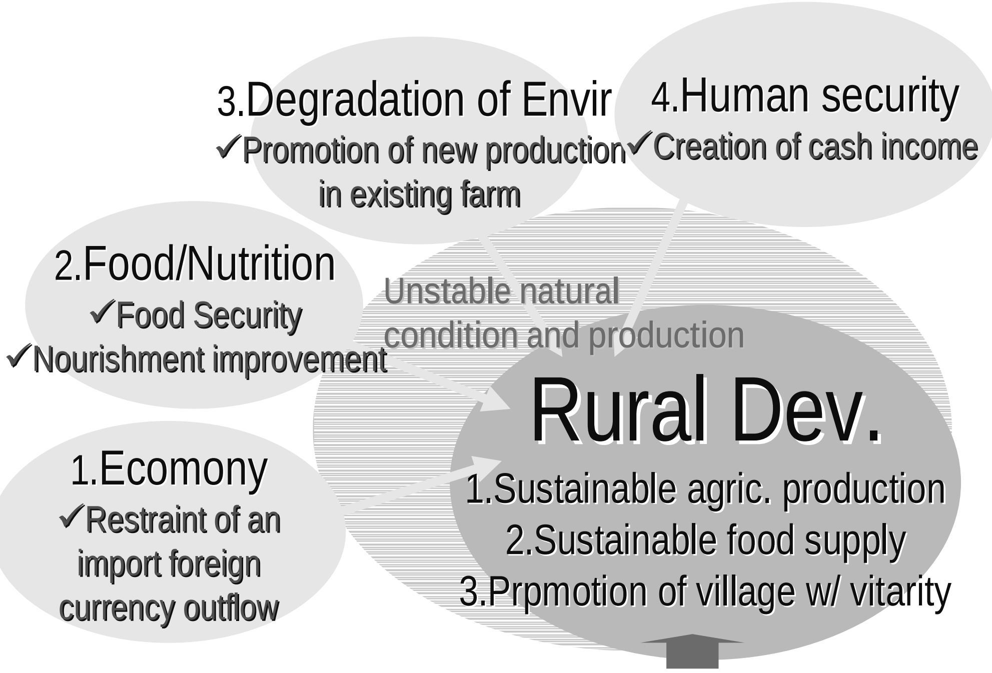
Role of NERICA in Rural Dev.



NERICA dissemination contribute to rural dev.

20

Contribution of NERICA to farmers

Rural development through NERICA dissemination

Profit

- **Cash income**
  good market price than other crops
- **Stabilization of production**
  Shorter cultivation period to avoid natural disaster

Other crops

- Maize:
  Market price is unstable
- Tubers:
  low market price
- Sorghum , millet
  mainly self-consumption

Example

<Uganda>
Area:0.4 ha, Ave. yield:3.5 t/ha, price:500/kg

✓Harvest:3500kg/ha x 0.4ha =1400kg
✓Self-comsumption:200kg
✓Income:1200kgx500=600,000
✓Cost:200,000
→**Profit:400,000≒220USD**

GDP per capita:300USD

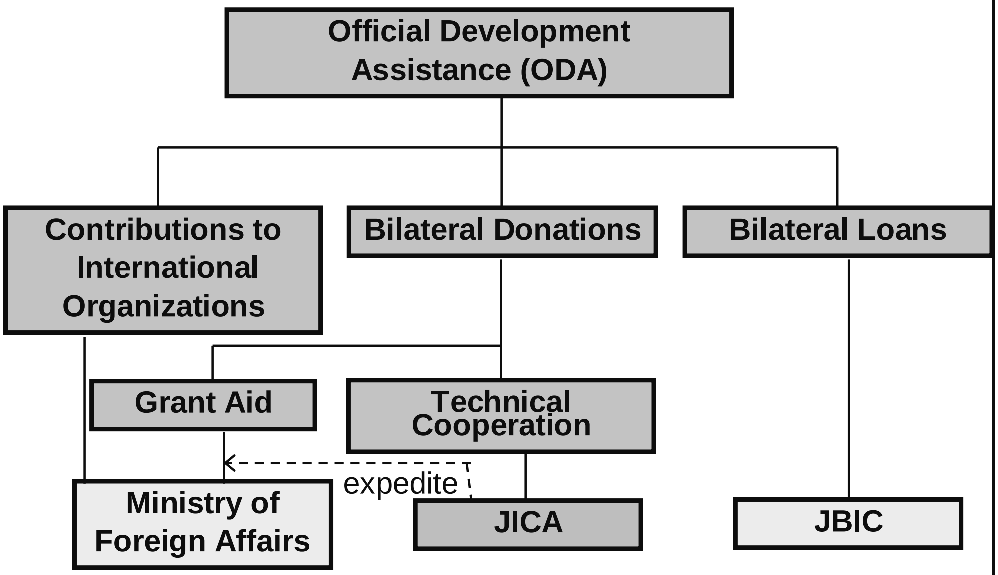
INCOME from NERICA: 220USD

21

JICA's Role in General

22

Categories of Japanese ODA



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JICA's Role

- JICA is responsible for the technical cooperation aspect of Japan's ODA programs.
  - Technical cooperation is aimed at the transfer of technology and knowledge that can serve the socioeconomic development of the developing countries.

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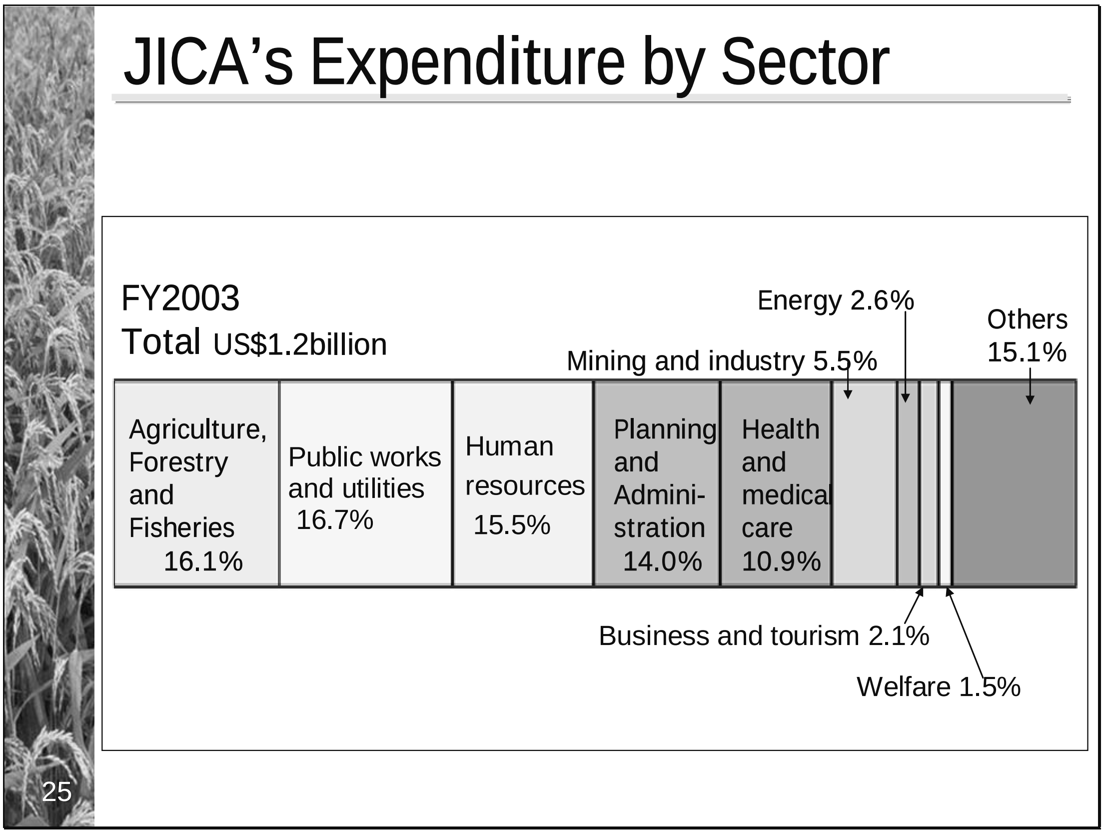
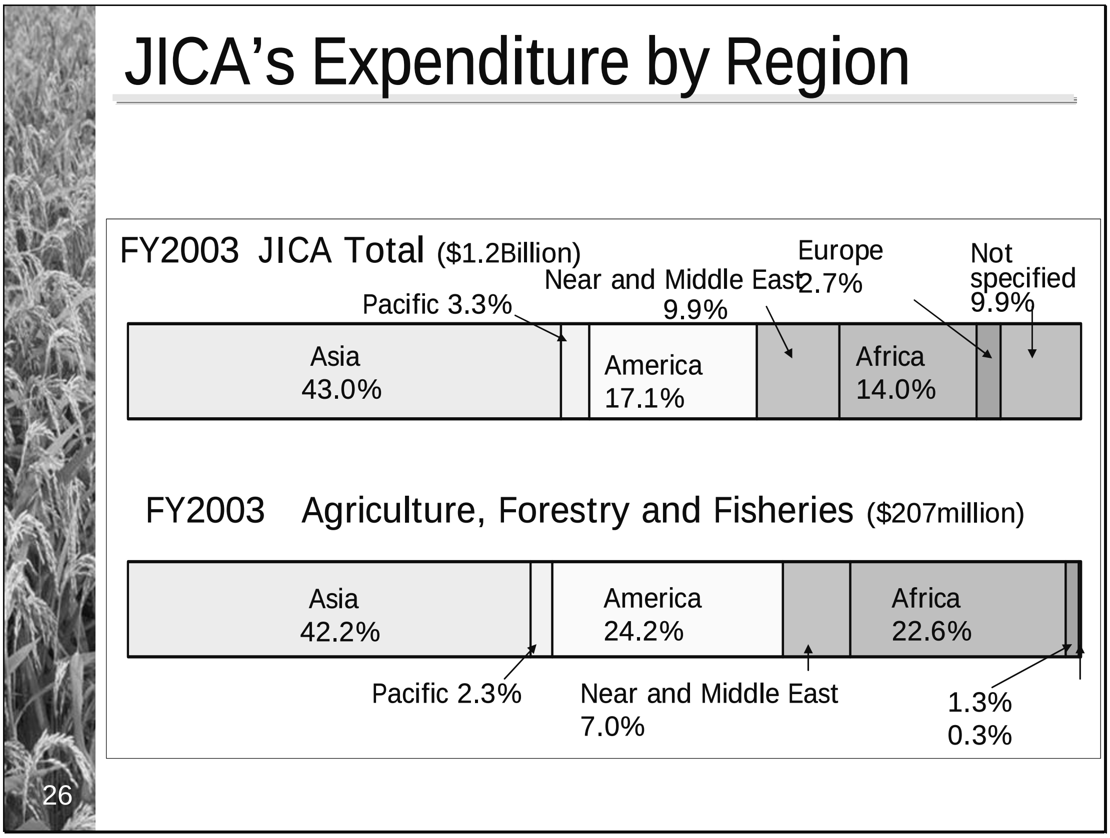

JICA's Expenditure by Sector
FY2003
Total US$1.2billion
Energy 2.6%
Others 15.1%
Mining and industry 5.5%
Agriculture, Forestry and Fisheries 16.1%
Public works and utilities 16.7%
Human resources 15.5%
Planning and Admini-stration 14.0%
Health and medical care 10.9%
Business and tourism 2.1%
Welfare 1.5%
25


JICA's Expenditure by Region
FY2003 JICA Total ($1.2Billion)
Europe 2.7%
Not specified 9.9%
Near and Middle East 9.9%
Pacific 3.3%
Asia 43.0%
America 17.1%
Africa 14.0%
FY2003 Agriculture, Forestry and Fisheries ($207million)
Asia 42.2%
America 24.2%
Africa 22.6%
Pacific 2.3%
Near and Middle East 7.0%
1.3%
0.3%
26

質疑応答
Question and Answer Session

JICA のアフリカにおけるネリカ普及支援
JICA's NERICA Dissemination in Africa

内島 光孝 Mitsutaka Uchijima
独立行政法人国際協力機構（JICA）
Japan International Cooperation Agency (JICA)

司会： 松本 哲男 Chair person: Tetsuo Matsumoto
名古屋大学農学国際教育協力研究センター
Professor, ICCAE, Nagoya University

松本（司会）：
ご質問があるかたはお願いします。

飯嶋： JICA が NERICA に対して非常に力をいれていることがよくわかりました。そこで、NERICA がまだ普及していないということですが、いつ頃普及するというふうに見積もりをされているのでしょうか。そのあたりもしあればお願いします。と申しますのは、2000 年に既にコートジボアールとギニアでリリースされていて、それに比べると少し遅い気がしていまして、そのあたりどうでしょうか。

内島： 非常に難しいところで、コートジボアールは内戦の影響を非常に受けていまして、そこに WARDA も元々はありましたので避難することになって、それでまた、影響を受けている部分があることは確かなのですが、かたや、それぞれの国でいつまでに何が達成できるかまだわからないのか、ということはあるかもしれませんが、手探りの段階にあります。当初は稲作の研究者、あるいは稲作の技術、upland ですね。NERICA の栽培技術のほとんどない状態から始まったなかで、だんだんと手応えというか、この国にはこういうところでこれが足りなくて、あるいはこういうすすめ方をすると、表現は悪いのですが農家が飛びついてくれるというところが分かってきつつありますので、多少これまでの助走からは少し速度を速めていけるかと思います。最終的には農家がどれぐらい興味を持ってくれるかに尽きると思います。栽培技術に限らず、いろいろな流通の問題や精米の問題があると思うのですが、今はまだそこまで手をつけていないのですが、いずれは必ずそこにも範囲を広げながら取り組んで行きたいと思っています。そうすることで、これまでよりはスピードを多少はあげることが出来るかと思います。なかなか大きな課題ですので、いつまでにというのはいまのところ申し上げづらいと思います。

飯嶋： どうもありがとうございました。

若月： 今回の第 1 回のアフリカ会議がタンザニアのダラエスサラームでありまして、テーマは“Beyond the NERICA”でした。それは WARDA がつけました。もちろん JICA としては政府の国際公約がありますのでやらなければならないのですが、やはりいまアフリカではNERICAは品種というよりも稲作そのものとして農家は捉えていると思います。そのあたりを考えると、考え方として品種としての NERICA と稲作振興のシンボルとしての NERICA とがあって、稲作振興の方にもう少し枠組みを広げてもいいのではないかということで、そういう意味で “Beyond the NERICA”というようなことを考えておられますか？

内島： タンザニアも含めて、“beyond”に至るまでの基盤があるのかというところは、ちょっと個人的には疑問がある部分もあるのですが、ただ現時点で言うと陸稲品種の中において NERICA の品種が持っているポテンシャルというのは決してひけをとっていないというか、むしろずいぶん高いということは間違いなく言えると思っています。他にいいものが出てくれば当然、そちらに移っていくのでしょうが、今のところは NERICA を起爆剤というか、それを中心としてやるのが一番取り組みとして的を得ているのではないかと思っています。

松本（司会）：

内島先生、ありがとうございました。

Profile

内島　光孝　Mitsutaka Uchijima

独立行政法人国際協力機構（JICA）
農村開発部第3グループ第2チーム（中・西部アフリカ地域）　主査
Project Management Officer
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1993 年北海道大学大学院農学研究科修士課程修了。1993 年 4 月から JICA 筑波国際農業センターにて海外農業分野研修員の受入に従事。1995 年より仏国にて 1 年間の語学留学を経て、1996 年より無償資金協力業務部に異動し、アフリカの基礎生活改善事業の実施管理を担当したのち、1999 年にセネガル事務所へ異動し、セネガル及び周辺国の技術協力事業を担当。2002 年に帰国し、総務部総務課にて JICA の独立行政法人化に携わる。2005 年 4 月より、農村開発部第 3 グループにて、サブサハラ・アフリカ地域の農業・農村開発案件を担当し、グループ内のネリカ普及事業を総括、現在に至る。

Academic career

Mr. Uchijima graduated from Graduate School of Hokkaido University in 1993.

Professional career

After the graduation, Mr. Uchijima started his professional career as a training officer in Tsukuba International Agricultural Training Center of JICA, Japan International Cooperation Agency, to provide training in agricultural fields for trainees from the other countries. Mr. Uchijima had studied in France for one year from 1995 to master the language, and transferred to the grant aid project management department in 1996 and started to work as a project management officer for implementing grant aid projects providing basic human needs in Africa. In 1999 , Mr. Uchijima moved to the Senegal office of JICA and served as an assistant to the resident representative and managed cooperation projects in Senegal and neighbouring countries for three years. He moved back to Japan in 2002 and participated in JICA's structural reform scheme. Since 2005, Mr. Uchijima has been serving as a project management officer in the rural development department of JICA, being in charge of NERICA dissemination projects and other rural development projects.

ギニアとウガンダにおけるネリカ稲普及活動：笹川グローバル 2000 の経験から
NERICA Dissemination Activities in Guinea and Uganda The Experience of Sasakawa-Global 2000

伊藤　道夫　Michio Ito
笹川アフリカ協会（SAA）東京事務局
Sasakawa Africa Association (SAA), Tokyo Headquarters, Japan

要　約

SAA は、サブサハラ・アフリカ諸国の、主に天水農業を営む小規模農民の食糧穀物の生産性の向上を支援するために活動する国際 NGO である。プロジェクト対象国の公共の研究・普及機関を通じて、SAA は、優良な穀物生産性向上のための技術があれば、小規模農民は現状の農産技術と比べて、食糧穀物の収量を 2～3 倍に増やすことが可能であることを示してきた。ここでは、当会がギニアとウガンダで行ってきた NERICA の普及活動の経験を検証し、学んだ教訓を将来に活かすこととしたい。

ギニア

NERICA との関わりは、1998 年から WARDA の「農民参加型品種選択法」(PVS)への支援をすることから始まった。プロジェクト参加農民への実際の技術移転活動は 2000 年からで、2004 年までに、0.25～0.5ha の広さの NERICA 技術移転の圃場を 1 万箇以上実施し、適量の施肥と近代的農法を応用することによって、陸地条件で平均 3.0t/ha の収量を得てきた。

農業省によれば、1996 年には 30 万トンの米の輸入量があったが、2004 年には 5 万トンにまで減少したとのことである。

SG 2000 としての活動は 2004 年末で終了したが、NERICA を中心とした稲の普及活動への部分的支援は農業省内のリエゾン・オフィスを通じて現在も続いており、UNDP やアフリカ開発銀行の援助を受けて、ギニア政府は NERICA の技術普及を全国で続けている。

ウガンダ

ウガンダは長年に渡り、全人口を養うに十分な多彩な食糧を生産してきた。しかし最近までは、低収量と高い労働コストのため、稲作は盛んでなく、公的な関心もこの国では低かった。

SAA は 2001～2002 年に、ギニアから入手した数品種の NERICA の栽培試験を行った。その後、稲作は栽培環境が適した小規模農家の間に急速に広まった。NERICA はこの国では NARIC 3 および SUPARICA 2 の名で流通しており、SAA の参加農民は水成土壌条件下で平均 4.5t/ha の収量を得ている。

多くの農民が子供の教育費や生活必需品の購入のための換金作物として、稲を栽培しているのがこの国での特徴である。国の農業近代化計画（PMA）では、NERICA を食糧保障と同時に、零細農業から市場志向の科学農業へと変換させる所得創出のための戦略穀物として精力的に推奨している。

その他の国々

SAA はエチオピアとマリにおいても NERICA を含む稲の研究・普及活動を実施しており、陸稲、灌漑稲共に有望な成果が見えている。

教　訓

ギニア、ウガンダの農民はそれぞれ独自の違った理由で NERICA を選択している。NERICA には貧困削減の可能性がある。しかしサブサハラ・アフリカ全体の食糧保障を達成するには、トウモロコシ、ミレット、ソルガム、小麦、根菜などの全ての穀物を改良する努力が必要である。NERICA と米だけではアフリカ大陸を食べさせることはできないのだ。

NERICA Dissemination Activities in Guinea and Uganda: The Experience of Sasakawa-Global 2000

Michio Ito
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Abstract

SAA is an international NGO that assists small-scale farmers in sub-Saharan countries to increase their staple food crop production mainly under rain-fed conditions. Working with and through public research and extension organisations, SAA proves that, given access to improved crop production enhancing technology, small-scale farmers are able to double or triple their staple food crop yields compared to conventional farming practices. Today, our experience in NERICA technology demonstration in Guinea and Uganda will be elaborated and lessons learnt for the future will be discussed here.

Guinea: SAA involvement started from 1998 through support of Participatory Varietal Selection (PVS) in association with WARDA. Actual technology transfer demonstration with participating farmers started from the year 2000 and up to the cropping season of 2004, SAA conducted more than 10,000 NERICA technology demonstration packages (0.25-0.5ha) and obtained average yield of 3.0t/ha with upland condition, applying adequate fertilizers and modern agronomic practice.

According to the national ministry, rice import was down from 300,000MT in 1996 to less than 50,000MT in 2004.

Although the project activities of SG 2000 officially came to a conclusion at the end of 2004, minor support to NERICA related activities are still continuing through the liaison office at the ministry of agriculture and such international organizations such as UNDP and AFDB assist the effort of Guinean government to disseminate NERICA technology throughout the country.

Uganda: Uganda has been producing a wide selection of food enough to feed its populace for many years. But up to recently, due to low yields and high labour cost, rice farming was not popular and public involvement was least in this country. During 2000-2001 cropping season, SAA tested a number of NERICA varieties imported from Guinea. Since then, rice farming has rapidly spread among small-scale farmers where agro-ecological environments were suitable for rice cultivation. NERICA varieties here are traded in the name of NARIC 3 and SUPARICA 2, and SAA participating farmers gain average yield of 4.5t/ha under hydromorphic condition.

One notable characteristic of this country is that most farmers grow rice as a cash crop to generate additional income to pay school fees, purchase household essentials, etc. The country's Plan for Modernization of Agriculture (PMA) vigorously promotes NERICA as a strategic crop for food security as well as for income generation to transform subsistence one to a market-oriented science based agriculture.

Other countries: SAA is conducting research and extension activities of various rice varieties including NERICA especially in Ethiopia and Mali. In both upland and irrigated conditions, the positive result has been visible.

Lessons learnt: Farmers in Guinea and Uganda select NERICA for their own different reasons. NERICA has potential to alleviate poverty, but to achieve overall food security in Sub-Saharan Africa, efforts should be made to improve all other major crops such as maize, millet, sorghum, wheat, and tubers. NERICA and rice alone cannot feed the African continent.

Introduction

Sasakawa Africa Association (SAA) is an international NGO for assisting small-scale farmers in sub-Saharan African countries to increase their staple food crop production mainly under rain-fed conditions. The project is titled as Sasakawa Global 2000 (SG 2000). SAA/SG 2000 work with and through public research and extension organisations under the ministry of agriculture in the host countries. The main objective is to demonstrate and prove that, given access to improved crop production enhancing technology available in sub-Saharan African countries, small-scale farmers are able to double or triple their staple food crop yields by applying adequate inputs such as improved seed and organic as well as inorganic fertilizer associated with appropriate farm management practices, compared to conventional farming methods. Farmers who participate in the project must purchase those necessary inputs either by credit or by cash basis before planting. Technology demonstration is always conducted in the farmer's own field assisted by public extension workers. Therefore, practicing the technology with their own hands in their own fields, farmers are able to recognize the advantages of modern farming technology and to gain significant economic return by increasing their yields.

First SG 2000 projects were started in 1986 in Ghana and Sudan. Up to the year 2006, 15 countries have benefited from the advanced technology enhancing project.

Recently, as demand and consumption of rice has been growing in a number of sub-Saharan African countries, SAA/SG 2000 has been trying to assist those countries who need to boost rice production in order to meet increasing national demands.

Guinea

Rice is the main staple cereal in this country. Its consumption of 90-100 kg/person/year is the highest in West Africa. According to FAO statistics, Guinea is producing over 700,000~800,000 MT of paddy rice a year. However, it is not enough at all. The country is importing 200,000~300,000 MT annually in order to meet domestic demand. 65% of rice has been grown under upland, rain-fed conditions with very limited use of modern inputs. Traditional method of "slash and burn" farming has contributed to soil degradation rapidly as population increases and land for agriculture becomes less available. Eventually, national average yield obtained is 1.5 t/ha at best.

SG 2000 Guinea started its activities in 1996. Its involvement in NERICA has started from 1998 cropping season by assisting Participatory Varietal Selection (PVS) in association with WARDA. Through PVS, farmers are able to select varieties they want to plant, and NERICA 1, 2, 3, 4 and 6 were chosen by Guinean farmers. SG 2000 also helped multiplying NERICA seeds available to farmers through assisting WARDA's Community-Based Seed Production System (CBSS). Actual technology demonstration programme toward rice growing small-scale farmers has started from 2000 in collaboration with Service National de la Promotion Rurale et de la Vulgarisation (SNPRV), Guinean national extension organisation. Standard NERICA technology component recommended by SG 2000 Guinea through SNPRV extension workers are as follows:

(1) Plot size: 0.25~0.5 ha.
(2) Seed rate: 60 kg/ha for drill sowing and 70 kg/ha for broadcasting.
(3) Fertilizer rate (kg/ha): N=40, P2O5=17, K2O=17.
(4) Land preparation: By hand and hand hoe.
(5) Weeding: By hand or if available by herbicide (5lt of thiobencarb+propanil/ha).

Tables 1 to 4 show the results of NERICA technology demonstration plots from the year 2000 to 2003. SG 2000 conduced more than 1,000 NERICA technology demonstration packages and participating farmers were able to obtain average yield of 2.0~3.0 t/ha with upland condition, applying adequate amount of fertilizers and modern agronomic practice. According to the national ministry of agriculture, Guinea imported 300,000 MT of rice in 1996, but the figure went down to less than 50,000 MT in 2004.

In the early 2000s, NERICA seed multiplied in Guinea was exported to other African countries for on-station and on-farm experiments and made a significant contribution to speed up NERICA diffusion in African continent. SG 2000 Guinea alone exported 14.8 ton of NERICA seed to seven countries up to 2004.

The project activities of SG 2000 Guinea has officially come to a conclusion at the end of 2004. But minor support to NERICA related activities are still continuing through the liaison office at the ministry of agriculture, and international organisations such as UNDP and African Development Bank strongly assist the effort of Guinean government to disseminate NERICA technology throughout the country.

However, some bottlenecks which prevents the country from boosting NERICA production should be mentioned. First of all, soil fertility depletion in upland area is serious due to “slash and burn” farming practice. Although the soil nutrient recovery is essential to improve productivity, fertilizer use in Guinea is still too low and the price is too expensive and not affordable to small-scale farmers. SG 2000 recommended rotation with such legumes as cowpea, soybean and Mucuna (green manure) for soil fertility restoration. Another problem is that there is no sufficient and updated statistics without which it is hard to design effective programme planning. For example, in the year 2000, the government claimed that about 20,000 farm families planted NERICA in 8,000 ha of rice farming areas of the country. But there was no supporting evidence of this figure. National statistics are usually unreliable and not readily available. Government policy is quite often inconsistent and overambitious. In 2002, the government announced that by the year 2005, 300,000 ha of rice farming area which consists of about one half of rice cultivating area of the country shall be covered by NERICAs. Obviously, it has not been achieved. In spite of being endowed with rich mining, in particular, bauxite, marine and forest resources, Guinea still depends too much on external financial assistances. Such dependence does not help to construct effective coordination and linkage among all stakeholders because many objectives are not realized simply due to lack of external financing.

From 1998 to the end of 2004, SG 2000 has demonstrated that Guinean small-scale farmers can easily double or triple their NERICA yields, given access to available inputs. What a single NGO can do is limited and the further effort of dissemination and expansion of NERICA technology shall be led by the Guinean government with international and national partners. Guinea has a great potential, and it must be fully exploited.

Uganda

Rice is not staple and has long been not important in Uganda. The country has been producing a wide selection of food enough to feed its populace for through many years. Uganda has two crop seasons, a major season from March to July/August, and a minor one from September to January/February. Subsequently, farmers can grow anything they want almost all the year round. There was no immediate need or incentive to expand rice farming. However, urbanization and changing food consumption habits has been increasing rice import at a pace of 45,000~50,000 MT a year, the urgent need to boost domestic rice production arouse. But local rice production was characterized as low yield and high labour cost, because little research attention was paid over a long term of years. For that reason, rice farming was not attractive and profitable to small growers up to recent years.

SG 2000 Uganda’s involvement in NERICA has started in 2000 when NERICAs and other upland rice varieties developed by WARDA were brought from SG 2000 Guinea. In the same cropping season, on-station seed multiplication in a 1 ha of land was carried out. In the following season (first cropping season of 2001), 4,000 kg of seed was distributed to 100 farmers in three districts, Iganga, Tororo, and Jinja, and planted in 16 ha of farmers fields. Through on-farm trials, NERICA 4 and WABC 165 demonstrated their potential over local checks and the further farmer-to-farmer seed multiplication practice was encouraged. In the second cropping season of 2001, 105 farmers planted two selected WARDA varieties in 48 ha of plots. As shown in Table 5, average yield of NERICA 4 was a significant 4.9 t/ha, much higher than the yields in Guinea.

In 2002, two different institutes, one National Agricultural Research Organisation (NARO) and another NASECO, a private seed company, released new upland rice varieties under two different names - NARO released NARIC 3 and NASECO SUPARICA 2. Names were different, but NARIC 3 and SUPARICA 2 are the same NERICA 4, which created some confusion among all parties involved in rice promotion in the country. There could be many reasons why this confusion happened, most probable cause attributed to the result of mixing up of the original breeder seed at the initial stage when nobody clearly knew the characteristic of NERICA seed. And both public and private sectors were too impatient and too eager for the hasty release. However, one should admit that enthusiasm of both public and private sectors made the rapid expansion of NERICA possible in Uganda.

Table 6 presents the yield result as well as technical details of SG 2000 NERICA demonstration plots conducted in the first cropping season in 2003. Within a short period of time, NERICA 4 has become very popular among the small-scale farmers in agro-ecological environments suitable for the rice cultivation.

One notable characteristic of rice farming in this country is that most farmers grow NERICA and other rice varieties as a cash crop to generate additional cash income to pay school fees for their children, to purchase household items and essentials, etc. rather than to use for their own consumption. Rice is a marketable commodity which creates income generating opportunity for farmers.

The national government's Plan for Modernisation of Agriculture (PMA) vigorously promotes NERICA as a strategic crop for household food security as well as for income generation to transform subsistence agriculture to a market-oriented science based one.

Other Countries

SAA/SG 2000 is conducting research and extension activities of various rice varieties including NERICA especially in Ethiopia and Mali. Ethiopia did not have a rice growing culture and it is still not popular. It is only recently that its potential to reduce chronic food shortage has been recognized and rice has been placed as number four - after wheat, maize and teff - food security crop for the next five years, by the government of Ethiopia. Rice can be prepared as local bread (Injera, Dabo, etc.) mixed with teff and wheat which will create tremendous market opportunity if well coordinated. Water management is the key for potential rice area expansion because the country is blessed with the wide variety of water resources such as lakes and rivers which maintain water most of the year. In collaboration with national research institutes, SG 2000 has been carrying out a multi-location trial of NERICA and other rice varieties.

In Mali, first generation of two irrigated NERICA from WARDA Sahel station in St. Luis, Senegal performed above average. WAS 161-B-9-2 with 5708 kg/ha and WAS-197-B-6-3-11 with 5689 kg/ha could do well in the Office du Niger irrigation system after one or two cycles of selection. SG 2000 Mali will grow both irrigated and lowland NERICAs and continue the field dissemination activities.

Way Forward

In many countries of sub-Saharan Africa, rice is not consumed as a main staple, but traded as a marketable commodity. Many countries are eager to reduce the import quantity by increasing domestic rice production. To reduce rice import, securing quantity is the first priority, but at the same time, quality of the product must be drastically improved. Market would not appreciate the final product if it is always contaminated with stones , dusts and other unidentified objects. Access to the wide market opportunity will be guaranteed only if the post harvest treatment of all stages involving threshing, cleaning, drying, milling, and storage is paid much attention. Centuries-old processing technologies should be replaced by much improved ones at each farming community level.

Importance of rice is rapidly growing in Africa. But we should not forget the fact that rice is still new to the majority of African population. NERICA and rice in general can certainly make a great contribution for poverty alleviation, but rice alone cannot solve overall food problems in the continent. Effort should be made to increase and improve productivity as well as quality of all other major food crops such as maize, millet, sorghum, wheat, and tubers. Continuous and concerted effort to improve all major food crops production technology is very crucial to the poverty alleviation and food self-sufficiency in sub-Saharan Africa.

Table 1 Guinea: NERICA technology demonstration result 2000

Location	Number of Plots	Area Total (ha)	Average Yield (t/ha)	Yield Range	Traditional Yield
Kindia	103	25.75	1.94	1.58-2.10	1.53
Mamou	46	11.50	1.36	1.20-1.88	0.95
Labe	170	42.50	1.64	1.32-1.97	1.16
Faranah	118	29.50	2.09	1.52-2.67	1.13
Kankan	70	17.50	1.89	1.45-2.24	0.95
Boke	126	31.50	2.19	1.66-2.72	1.19
Macenta	168	42.00	2.55	1.92-3.18	1.96
N'zerekore	165	41.25	2.80	1.99-3.50	2.20
Total	**966**	**241.5**	**2.06**		**1.38**

Table 2 Guinea: NERICA technology demonstration result 2001

Location	Number of Plots	Area Total (ha)	Average Yield (t/ha)	Yield Range	Traditional Yield
Kindia	27	6.66	2.70	1.90-3.50	NA
Labe	55	13.75	2.50	1.50-4.50	NA
Faranah	116	29.00	2.40	1.70-4.80	0.93
Macenta	116	29.00	2.30	2.07-2.54	2.54
N'zerekore	105	26.25	2.46	2.34-2.58	1.08
Total	**419**	**104.66**	**2.47**		

Table 3 Guinea: NERICA technology demonstration result 2002

Location	Number of Plots	Area Total (ha)	Average Yield (t/ha)	Yield Range	National Average
Kindia	82	20.5	2.7	1.9-3.6	
Labe	145	36.3	2.0	37,258	
Faranah	105	26.3	2.4	1.3-2.8	
Macenta	86	21.5	2.2	35,832	
Total	**418**	**104.5**	**2.3**		**1.61**

Note National Average of all rice produced.

Table 4 Guinea: NERICA technology demonstration result 2003

Location	Number of Plots	Area Total (ha)	Average Yield (t/ha)	Yield Range	National Average
N'Zerekore	30	35	2.5	1.5-3.5	
Mamou	30	25	2.2	35,552	
Labe	50	60	2.7	35,464	
Kindia	30	43	3.2	35,553	
Faranah	60	70	2.5	35,553	
Total	**200**	**233**	**2.6**		**1.71**

Note National Average of all rice produced.

Table 5　Uganda: The result of on-farm trial in the 2001 first cropping season

Location & (Condition)	Variety and Yield (t/ha)		
	NERICA 4	WABC 165	Local Check
Busemebatia (lowland)	6.50	4.60	2.50
Busemebatia (upland)	4.26	5.00	1.50
Bonkonte (upland)	3.49	5.00	1.00
Bonkonte (hydromorphic)	4.70	4.80	1.20
Bosolwe (hydromorphic)	5.02	-	-
Namadope (hydromorphic)	6.00	3.80	2.00
Namadope (upland)	4.60	3.50	1.80
Namadope (lowland)	5.45	4.00	2.20
Nagongera (lowland)	4.70	4.20	1.95
Paragang (upland)	4.30	3.80	1.00
Average Yield	4.90	4.30	1.68

Table 6　Uganda: NERICA technology demonstration result: 2003 first cropping season

Location	Number of Plots	Area Total (ha)	Average Yield (t/ha)	Traditional Yield (t/ha)
Kamuli	13	1.3	2.50	0.70
Luwero	18	1.8	5.22	1.09
Pallisa	34	3.4	4.50	1.92
	65	**6.5**	**4.07**	**1.24**

<u>Technology component</u>
Plot size: 0.1ha
Seed rate: 25kg with 30cm x 30cm x 2 (drilling)
Fertilizer rate: Urea 40kg, SSP 26kg, MOP 12kg
Weeding: Hand and/or thiobencarb+propanil (Satunil) 0.5lt/ha

NERICA 1 demonstration plot in Guinea, 2004

JICA expert and SAA rice director examine NERICA field in Uganda

Multi location trial at Ethiopian research station

Irrigated NERICA experiment in Mali

Rice drying in Guinean village. Vehicles run on the products.

NERICA Dissemination Activities in Guinea and Uganda:
The Experience of Sasakawa-Global 2000

Michio Ito, 20 October, 2006

Sasakawa Africa Association

Brief Introduction: What is SAA?

- Staple food crop production enhancing technology transfer through public extension.
- On-farm demonstration with inputs (seed, fertilizer) on credit and/or cash basis.
- Demonstration of proven technology available in sub-Saharan Africa which can dramatically increase the yields of staple food crops.
- From 1986 up to present, 15 countries have benefited.
- **Project is called "Sasakawa-Global 2000 (SG 2000).**

Rice in Guinea: Basic Facts and Figures

- Rice is the main staple food.
- Consumption 90-100 KG/person/year = Highest in West Africa.
- Producing over 700,000~800,000 MT/year of paddy rice.
- Average yield 1.5 t/ha. 65% produced under rain-fed upland conditions.
- Importing 200,000~300,000 MT annually.

SAA/SG 2000 in Guinea: NERICA activities from 1998 up to the present

- Participatory Varietal Selection (PVS) with WARDA from 1998 cropping season.
- NERICA 1, 2, 3, 4 & 6 selected in Guinea.
- Seed multiplication with SNPRV (public extension organization) from 2000.
- SG 2000 NERICA technology dissemination among participating farmers from 2000.
- **Collaboration between research and extension.**

Standard NERICA technology component recommended by SG 2000 Guinea

1. Plot size: 0.25~0.5ha
2. Seed rate: 60kg for drill sowing, 70kg for broadcasting
3. Fertilizer rate (kg/ha): N=17, P_2O_5=17, K_2O=17
4. Land preparation done by hand and hand hoe
5. Weeding done by hand or by herbicide (5l of thiobencarb+propanil/ha)

SG 2000 NERICA technology demonstration Crop year 2000 result

Location	Number of Plots	Area Total (ha)	Average Yield (t/ha)	Yield Range	Traditional Yield
Kindia	103	25.75	1.94	1.58-2.10	1.53
Mamou	46	11.50	1.36	1.20-1.88	0.95
Labe	170	42.50	1.64	1.32-1.97	1.16
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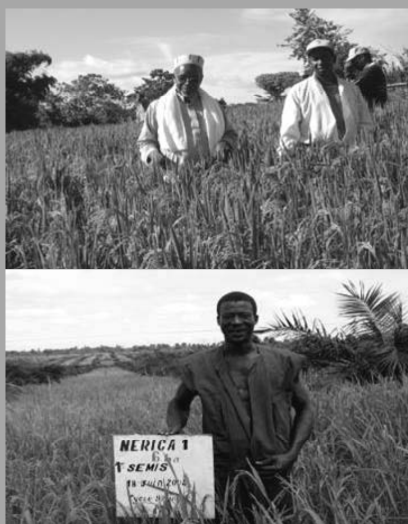
Faranah	105	26.25	2.4	1.3-2.8	
Macenta	86	21.5	2.2	2-2.7	
Total	**418**	**104.5**	**2.3**		**1.25**

SG 2000 NERICA technology demonstration Crop year 2003 result

Location	Number of Plots	Area Total (ha)	Average Yield (t/ha)	Yield Range
N'Zerekore	30	35	2.5	1.5-3.5
Mamou	30	25	2.2	1.5-3
Labe	50	60	2.74	1.2-4
Kindia	30	43	3.2	1.5-4
Faranah	60	70	2.5	1.5-4
Total	**200**	**233**	**2.6**	

Major Achievements in Guinea

- Rice import down from 300,000 MT in 1996 to less than 50,000 MT in 2004.
- SG 2000 Guinea exported 14.8 tons of NERICA seed to 7 countries for on-station and on-farm experiments.
- SG 2000 and SNPRV attracted UNDP and AfDB support to continue NERICA diffusion.



Major Bottlenecks in Guinea

- Soil fertility depletion in upland area: Rotation with legume-cowpea, soybean and mucuna recommended.
- National statistics = unreliable and unavailable.
- Lack of political coordination = weak linkage among all stakeholders.
- Great potential, but not exploited enough.

Rice in Uganda: Basic Facts and Figures

- Rice is not the main staple.
- Little research attention.
- However, urbanization and changing food consumption habits increases rice import, 50,000/year.
- Local production characterizes as low yield and high labour costs = not attractive to grow.

SAA/SG 2000 in Uganda: NERICA involvement from 2000 to the present

- Brought NERICA and other upland rice varieties from SG 2000 Guinea in 2000 cropping season.
- On-farm trial in the same season selected NERICA 4 and WABC 165 as promising in upland, lowland and hydromorphic soils conditions. NERICA 4 gained 4.5 t/ha average yields with adequate fertilizer application and agronomy practice (drill sowing, weeding, etc.)
- Farmer to farmer seed multiplication spread through the country.

SG 2000 NERICA technology demonstration Crop year 2003

NERICA 4

Location	Number of Plots	Area Total (ha)	Average Yield (kg/ha)	Traditional Yield (kg/ha)
Kamuli	13	1.3	2,498	700
Luwero	18	1.8	5,220	1,093
Pallisa	34	3.4	4,500	1,920
Total	**65**	**6.5**	**4,073**	**1,238**

Technology for 0.1ha plot

Seed 25 kg with 30cm x 30cm x 2 (drilling)

Urea 40kg, SSP 26kg, MOP 12kg

Hand weeding and/or Satunil (thiobencarb+propanil) 0.5lt

Rice as a marketable commodity in Uganda

- Favorable environment-two crop season/year.
- Farmers grow NERICA (rice) as a cash crop to gain additional income-school fees, house repairs, etc.
- GOU promotes NERICA to transform subsistence agriculture to a market oriented science based one.
- **Plan for Modernisation of Agriculture (PMA)**

Activities in other countries

Lessons Learnt and the Future

- To access market opportunity, improvement of post harvest treatment is essential
- Quantity as well as Quality should be secured.


Lessons Learnt and the Future

- For food self-sufficiency and security in sub-Saharan Africa, all major food crops – maize, millet, sorghum, wheat, tubers, etc., should be improved.
- NERICA alone cannot feed African continent.


THANK YOU!!

質疑応答
Question and Answer Session

ギニアとウガンダにおけるネリカ稲普及活動
NERICA Dissemination Activities in Guinea and Uganda: the Experience of Sasakawa Global 2000

伊藤　道夫　　Michio Ito
笹川アフリカ協会（SAA）東京事務局
Sasakawa Africa Association (SAA), Tokyo Office, Japan

司会：　松本　哲男　Chair person: Tetsuo Matsumoto
名古屋大学農学国際教育協力研究センター
Professor, ICCAE, Nagoya University

Matsumoto, Chair:

Do you have any questions or comments?

Asanuma:

In Guinea, you had trials of crop rotation using rice and cowpea.　How was the result?　Did you get the results?

Ito:

Since I myself am not an agricultural scientist, I completely depend upon what our Guinea office supplies to me.　So far as I understand, I don’t have any statistical data on that, however, NERICA with Mucuna, that is green manure, showed impressing results improving soil fertility.　Farmers grow rice and cowpea to sell cowpea for getting cash flow.　And, farmers grow rice and soybean because their families eat soybean.　That is consumption for nutritional reasons.　That’s how I understand.

Matsumoto, Chair:

Any others?

Yamauchi:

NERICA に関する様々な試験を色々な国で行われていますが、一番問題になっていること、例えば栽培上のことでも何でも結構なのですが、問題点は何だとお考えでしょうか？

Ito:

我々は実際に普及や実験で upland rice の NERICA の1～7までを、我々のプロジェクト対象国で色々試しています。例えばエチオピアではとても標高の高い所が多いので、NERICA の一番の特性である early maturity といいますか、90 日間で収穫できるというような特性が現れずに、110 日とか 120 日かかるということがあります。そういった特性が現れる場合、他の米や稲と比べても特に高い収量は得られないということがあります。どこの国でも NERICA が干ばつ耐性であるとか、早期に収穫できるというような特性が現れるわけではな

いので、すべての国でNERICAだけを勧めるのではなく、それぞれの国に合った稲の品種を勧めるのがいいのではないか、ということが挙げられると思います。

Yamauchi:

どうもありがとうございました。

Tokida:

Do you have any view about using urea rather than ammonium sulfate as a fertilizer?

Ito:

That completely depends on the availability of fertilizers, and in most of the South African countries where we are in operation, they don't depend on any fertilizers. Maybe they are grown without fertilizers. The availability of fertilizers is the factor we want to recommend.

Participant:

Thank you very much for your presentation on your NERICA dissemination activities. I have a question about perception of farmers in Uganda. You mentioned the local production characteristics, low yield and high developing cost for farmers growing rice. What makes such costs high? How is the perception of the farmers?

Ito:

I think that is comparison. In Ghana or Uganda, in their major states, I think people prefer plantain, banana, and maize. I think, in my limited knowledge, maize and plantain are very easy to grow. But rice, even upland rice, you have to pay much attention to it, and you have to care for the weeding and so on. You have to take much care of rice compared to other crops such as maize and plantain.

Matsumoto, Chair:

Nothing else? Thank you very much, Mr. Ito.

Profile

伊藤　道夫　Michio Ito

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1985 年、関西学院大学文学部英文学科卒業。同年より 1987 年まで、（社）アジア協会・アジア友の会に勤務。主としてブルキナファソの農村での飲料水用井戸建設の調整事業に従事。

1989 年、英国マンチェスター大学大学院開発学（経済）修士課程修了。1991 年より笹川アフリカ協会東京事務局員。現在に至る。笹川グローバル 2000 農業開発プロジェクトの管理・運営業務を担当。これまでブルキナファソ、コートジボアール、セネガル、マリ、ギニア、ガーナ、トーゴ、ベナン、ナイジェリア、南アフリカ、モザンビーク、マラウィ、エチオピア、ケニア、タンザニア、ウガンダにてプロジェクト関連業務に従事する。2005 年より東京農業大学非常勤講師（国際活動実践論）を兼任。

Academic career

Mr. Michio Ito received his Bachelor's degree in English literature from Kwansei Gakuin University, Japan, in 1985, and his Master's degree in development studies (M.A. Econ) from the University of Manchester, UK.

Professional career

After obtaining his first degree, Mr. Michio Ito joined Japan-Asian Friendship Society, Japan, and mainly engaged in a project for constructing drinking water wells in Burkina Faso. Since 1991, Mr. Ito has been working for Sasakawa Africa Association in its Tokyo Headquarters and responsible for management and coordination of Sasakawa Global 2000, an agricultural development project. Mr. Ito has often visited many African countries, for project related works, such as Burkina Faso, Cote d'Ivoire, Senegal, Mali, Guinea, Ghana, Togo, Benin, Nigeria, South Africa, Mozambique, Malawi, Ethiopia, Kenya, Tanzania, and Uganda. Mr. Ito also has been working as a part-time lecturer for Tokyo University of Agriculture since 2005 to teach practical analysis of international activities.

Mr. Michio Ito is currently an administrative and program officer for Sasakawa Africa Association (SAA), Tokyo Headquarters.

―今後の進め方―

Chapter 4　General Discussion

総合論議
―今後の進め方―

General Discussion

司会: 浅沼 修一
名古屋大学農学国際教育協力研究センター教授
Chair person: Shuichi Asanuma
Professor, ICCAE, Nagoya University

Asanuma, Chair:

We have to finish this place by five o'clock and Professor Takeya has another seminar after this forum. I'm sorry but I have to hold this general discussion much shorter than the original schedule. Probably, we can just talk about only one issue. I would like to choose an issue everybody has mentioned and many participants are considering.

This slide shows the consumption of paddy rice in African countries. Nigeria consumes the most because of their high population, 127 million people. Then Madagascar, Cote d'Ivoire, Senegal, Guinea, Tanzania and Mali. People in those countries consume rice a lot when converted to the per-capita consumption. It is something like this. 37.8 kilograms per year in Nigeria, 139 in Madagascar, 90 in Cote d'Ivoire, 107 in Senegal, and so on. Then, look at the production. The production is not compatible to the consumption. This is an example, in Japan. You can see here that the rice consumption is decreasing from 1961. This slide was prepared by Dr. Adachi, a post-doctoral fellow of our center. He used FAOSTAT to make this graph.

This is the rice production in sub-Sahara African countries. The increase of the consumption is much higher than that of the production. These countries are from the list of sub-Saharan Africa listed in FAOSTAT: 7 countries in Central Africa, 16 countries in Western Africa, 10 countries in Eastern Africa, and 12 countries in Southern Africa. In total, people in 45 countries eat rice. This is the gap between the production and consumption in Western Africa, Eastern Africa, Central Africa and Southern Africa. In all the regions, the consumptions are increasing, but the production is not reaching to that consumption level. For instance, in Nigeria, Ghana, Cote d'Ivoire and Kenya, there are these gaps. Of cause, if you see these lines, you can see the difference among the countries. Going back to Nigeria, the level in the vertical line is five to four thousand which is about ten times higher than the other countries. But anyway, the gap between production and consumption is increasing in most of the countries.

Now, I have given you some background information, to know why we have this open forum today, and to discuss how we can, I mean, how Japan can help African people to reduce these gaps.

In the first session, Professor Onyango, Professor Yamauchi, and the other presenters have presented their researches on rice, particularly on its drought tolerance, and the other three presenters have talked about their research and experiments. And now we are going to talk about "roles of Japan". Mr. Uchijima from JICA has summarized the role of Japan or what Japanese government is doing to help rice promotion in Africa. Today, we have a participant from Ministry of Foreign Affairs of Japan, Mr. Noguchi. And first of all, I would like to ask him for some comments about rice promotion in Africa by Ministry of Foreign Affairs of Japan.

Noguchi:

Thank you, Professor Asanuma. I would like to give a brief comment on today's session. Agriculture is a core strategy for poverty reduction through economic growth in Africa. Japan's approach to agriculture and their development had four pillars.

The first one is improvement of agriculture for activity. The second is enhancement of linkage between agriculture and its markets. The third is capacity development. The fourth is sustainable development.

Regarding improvement of productivity, NERICA surely has high potential, but the data collection and statistics on NERICA are not efficient. So, I think Japanese scientists or experts can play a role in supporting this area through research cooperation.

The second point, the linkage to market is definitely important. The income generation is important unless the products are not sold and the farmers can not generate income. So, improving infrastructure for post harvest and marketing is important for income generation.

The third point, capacity development, is an urgent problem. We should support training for African scientists, government staff, and extension staff, and we should promote technology cross-works and build up human resources in African countries.

Regarding sustainable development, we should invest in profitability of NERICA and in profitable upland/lowland or other crops in each area in African countries. We should support policy making on promotion of agriculture in each country. Regarding this, I think it is important to promote rice cultivation and agriculture and the other crop, NERICA. Finally, I think it is important to make a success story of NERICA dissemination, so we should consider developing collaborations with international institutions, African regional stations, NEPAD, and each African country's government. Thank you.

Asanuma, Chair:

Thank you very much. Mr. Noguchi has talked about how we should increase the agricultural productivity; researches are required to overcome the problem. Then, the importance of linkage between agriculture and markets needed for increasing the farmers' income. The third point, capacity development, is important, I think. There are several levels of capacity development for: researchers, extension workers, government officials and stakeholders, who are involved in agriculture. The fourth point, sustainable development of agriculture related to the profitability in rice cultivation. Mr. Noguchi also said that we need a success story to show, maybe Japanese contribution, to the world. Considering the TICAD which is scheduled for 2008 in Japan, the success story would be urgently needed.

In today's forum, we could share information about Japan's contribution in many aspects of rice promotion in Africa, not only research aspects but also dissemination activities by JICA until 2008. It is rather difficult for me, because of the diversity, to summarize all the presentations given today. Therefore, I would like to just focus on "what kind of research should be focused or privatized to promote the rice production". Before proceeding the discussion, I think that the concept of Sawah and upland rice given by Dr. Wakatsuki could be the main issue. However, Professor Wakatsuki has mentioned in his presentation that if Sawah could be developed in a place, it is better to develop Sawah system there. However in other places, he is not opposed to work on upland rice. So, please let me exclude the issue of Sawah and upland from today's main issue.

Professor Onyango, who knows best on these issues, has talked about several aspects of research on rice promotion; you can see them in Dr. Onyango's abstract. Professor Onyango has suggested many aspects such as drought tolerance, efficient and effective control of nutrient usage, and many other aspects and problems. I would like to ask Dr. Onyango what we should overcome or study at first and second, because human resources we have in Japan, who can work on rice in Africa, is very limited. So, I think it is better to prioritize the problems to be solved; what is more important, or what should be urgently tackled?

Onyango:

Thank you, chair person. That is a very difficult task but anyway at the end of my abstract, I had given some of my ideas on what we should tackle first, so as to make us realize the outcome of this venture. I know the Japanese Government made a very strong promise to the

African governments; this was at the World Summit on sustainable development in Johannesburg, South Africa in the year 2002 that was followed by NEPAD and the involvement in the NERICA production. I understand that the third TICAD is coming in two years time and we would like to learn about the success story on the Japanese government contribution in NERICA production in Africa. From the contributions presented in this Open Forum it is clear that there are several aspects of NERICA production, in Africa and all of them are geared towards sorting out food shortage in Africa. I think it is only the last presentation by Sasakawa 2000 which mentioned that in case of Uganda, NERICA is actually not being produced to sort out the food problem, it is being produced as a cash crop, and if that is a case it is still a contribution because that will be alleviating the foreign currency balance from the Uganda government, therefore, we are still in the right direction.

In my prioritization brief, we are talking of the upland conditions of rice production. If all of us listened to Professor Yamauchi's presentation then one might have realized that, when we talk of upland situation, it is soil moisture which keeps fluctuating and we need to arrest it. Most of us plant scientists are very quick at looking at what is happening above ground which everyone can observe. But what happens below ground which is being expressed by the above ground characters we don't know, this is where precipitation or water requirement under upland conditions comes in handy and we need to look at that. As he suggested, I would not like to go GMO direction, I would like to go through the conventional breeding if at all we can identify the markers which code for less water usage and that will definitely be tied to water use efficiency among the various NERICA. If we can identify this we will have made more or less 50 % contribution towards promotion of NERICA production in Africa, given the fact that agro-ecological situation is very fragile. That is my first line, looking at the water requirement and that will entail looking at below and above ground structures of NERICA varieties. One advantage we have is that there are several NERICA varieties and it seems that the regions in Africa have already identified which lines they want to use and therefore those lines should be investigated for desirable traits. The other aspect which came out very clearly is the question of availability of certified seed. The contribution of double naming of NERICAs' seeds in Uganda is real. There is a variety which is NERICA 4 which one commercial seed firm calls it Suparica 2 while National Agricultural Research Organization (NARO) also in Uganda calls it Naric 3. This creates confusion to farmers. They are growing same variety but depending on where they sourced the seed they think the varieties are different. Therefore we need to look at the seed aspect and harmonize it. This would ensure seed purity which is very fundamental in genotype research. From those two main points, I would like to complement the Sawah strategy. However, there should be some socio-economic activities which prepare farmers at the farm level to receive some of the NERICA technology which can complement lack of greenhouses. Otherwise all my presentation strategies remain as presented on the main presentation or summarized in the abstract. Thank you so much.

Asanuma, Chair:

Thank you very much, Dr. Onyango. Soil moisture problems are very important, and so seed availability is, for preparedness of the people to receive Sawah system. I would like you to ask for some opinions from the floor, but please let me give priority to opinions on research aspect.

Yamauchi:

I would like to just give a few comments. I think we need to give priority to the technical aspects rather than to the social-scientific aspects. We need to clearly identify the characteristics of the ecosystem and we should know how we can control the constraints. Most people are talking about problems of drought and water scarcity. But the scarcity of water is, in almost all cases, coupled with nutrient deficiency and problem soil. To be honest, this is my first time to learn that there is a lowland NERICA. I think I've just learned that from Dr. Kumashiro's presentation. We are talking about the different definitions of lowland, upland, paddy and so on; that is from the scientific aspect. So, we really need to identify what the real constraints are to achieve the goals. I think that's from technical aspects and that is the priority of the research. Sometimes I've talked about something like "drought is related to deep root", but it is not always the case. Maybe deep rooted plant is working well but that is possible under only a very specific environment. But in most areas, we need to identify other traits than deep root for the production of the plant. That is my comment.

Asanuma, Chair:

Thank you very much Professor Yamauchi; we need to clarify or understand the ecosystem and the constraints on the rice promotion. However to do that, I think Japanese scientists need to go to Africa to work with and help them conducting the experiments, in cooperation with African counterparts, of course, otherwise it's difficult to learn from the literature of them. Maybe rather difficult, but better to go to work and stay on the fields. It is now the time to go to work on the fields.

I can take one more comment from the floor.

Iijima:

I also agree with Professor Yamauchi's comment. I am working on NERICA for several years and I think its drought resistance and some other reasons are very important. However, I went to Guinea this year and met Dr. Sakagami. And I visited a farm where NERICA was grown last year. I asked some of the farmers, "Why don't you cultivate NERICA this year?" The farmers told me that NERICA is nice but very difficult to thresh. I was shocked to hear that. The farmers thought NERICA is nice but not so good for its characteristics when threshed. We should look at other characteristics like threshing capability and some like that.

Asanuma, Chair:

Thank you very much. Since we are discussing not only promotion of NERICA but also other rice promotion, we should consider your comment. However, we have to close this general discussion now. I apologize we don't have enough time to discuss more about rice promotion in Africa. We hold a mixing party from 5:30, and I hope many participants join it and continue the discussion. Thank you very much for your cooperation. I have to close the general discussion now. Professor Takeya, Director of ICCAE, will give us closing remarks. Professor Takeya, please.

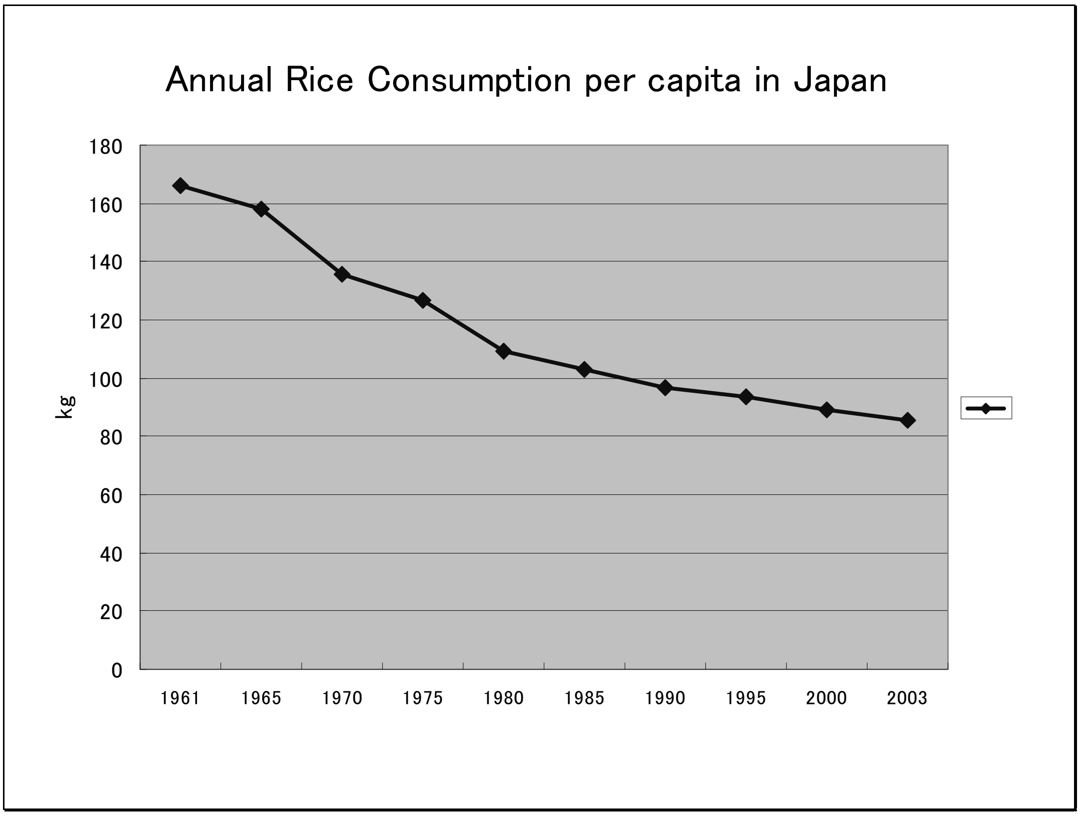
General Discussion

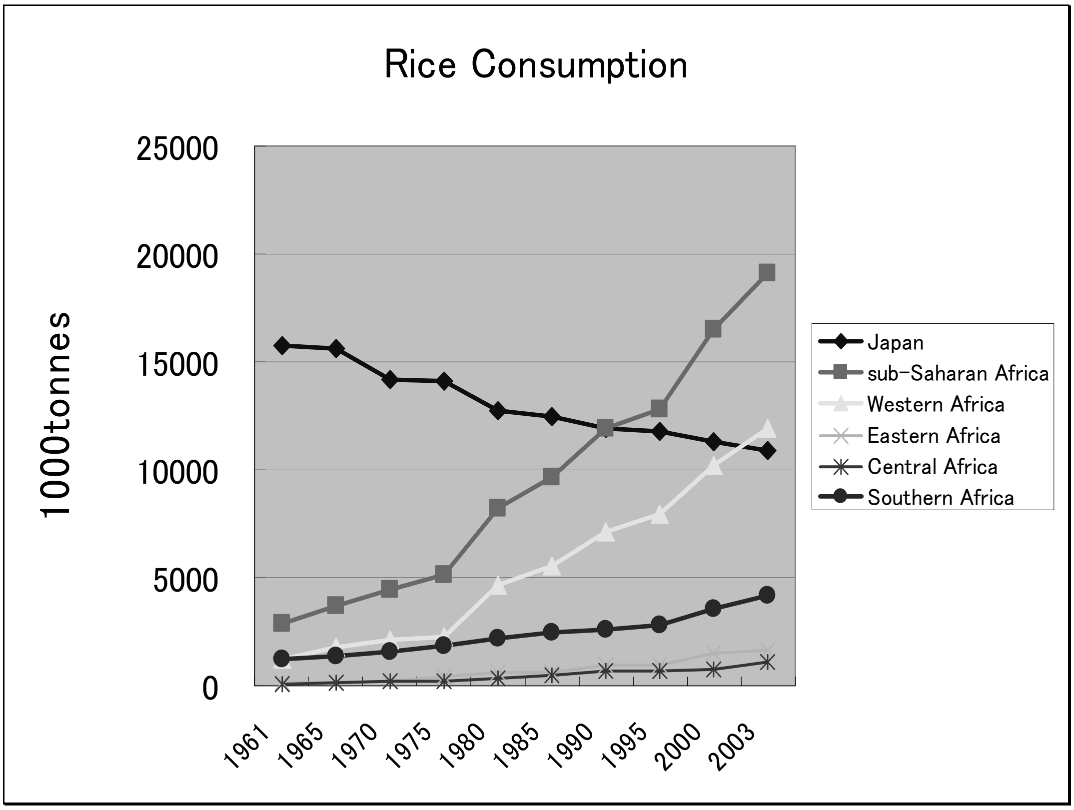
Recent Progress in Rice Promotion in Africa and Role of Japan

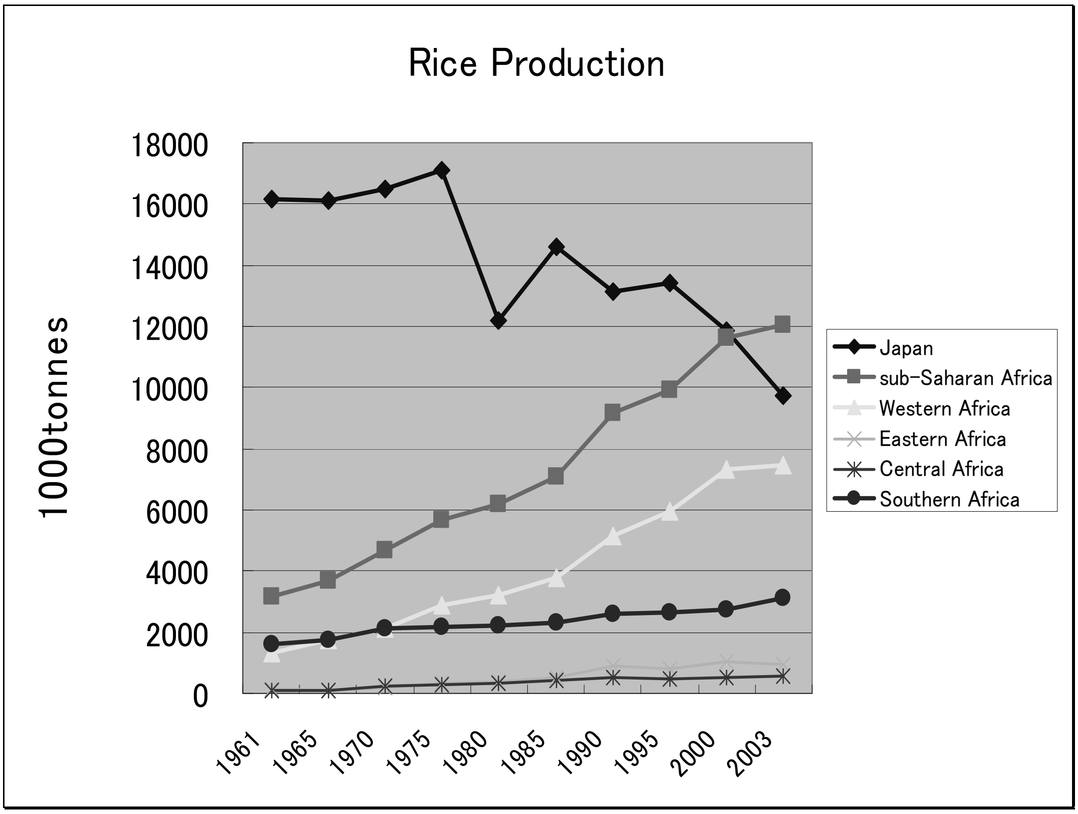
1. Trends of rice production and consumption
2. Research
3. Dissemination
4. Role of Japan

Annual Rice Consumption and Production in African Countries(2004)

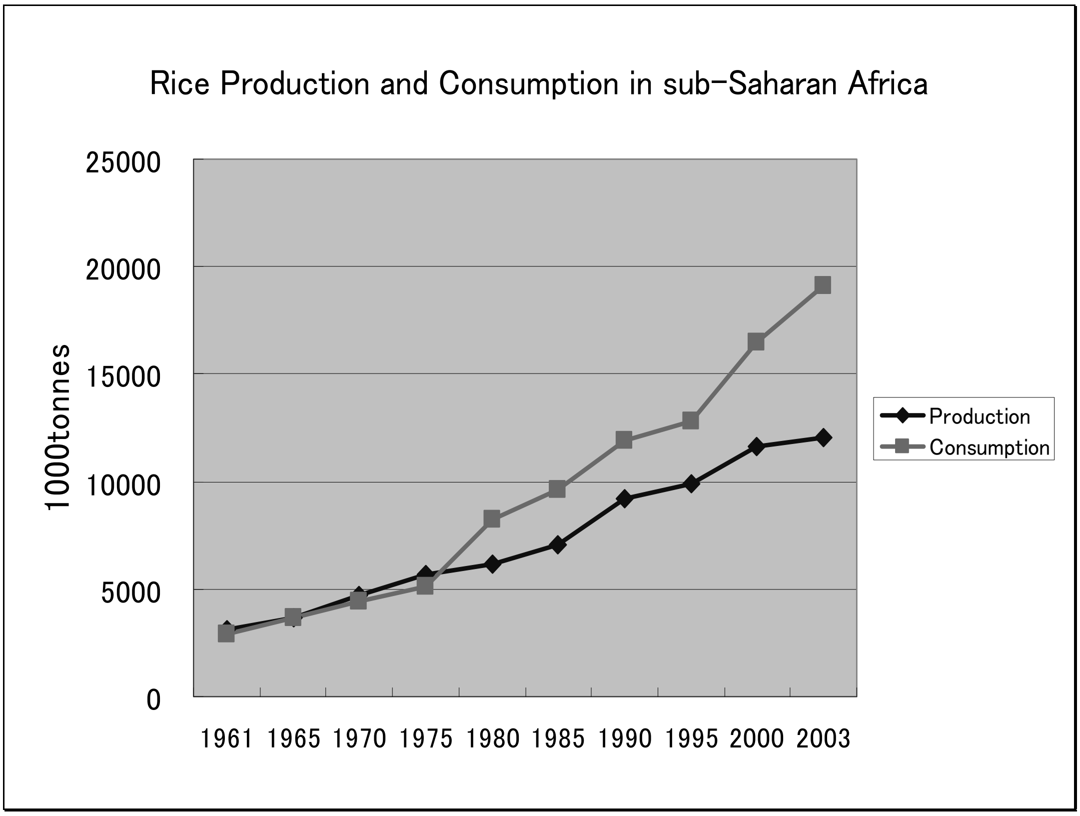
	Production	Consumption		Population
	(tons/year)	(tons/year)	per capita (kg/year)	(millions)
Nigeria	3,542,000	4,803,660	37.8	127.1
Madagascar	3,030,000	2,488,970	139.0	17.9
Cote d'Ivoire	1,150,000	1,522,620	90.1	16.9
Senegal	201,740	1,106,050	107.0	10.3
Guinea	900,000	868,510	100.8	8.6
Tanzania	680,000	772,640	20.5	37.7
Mali	718,090	762,120	56.8	13.4
Ghana	241,810	716,300	33.5	21.4
Cameroon	49,960	480,800	29.5	16.3
Kenya	49,300	322,510	9.9	32.4
Burkina Faso	74,500	298,380	22.3	13.4
Uganda	140,000	167,840	6.3	26.7
Malawi	49,720	53,240	4.3	12.3
Zambia	11,700	42,930	3.9	10.9

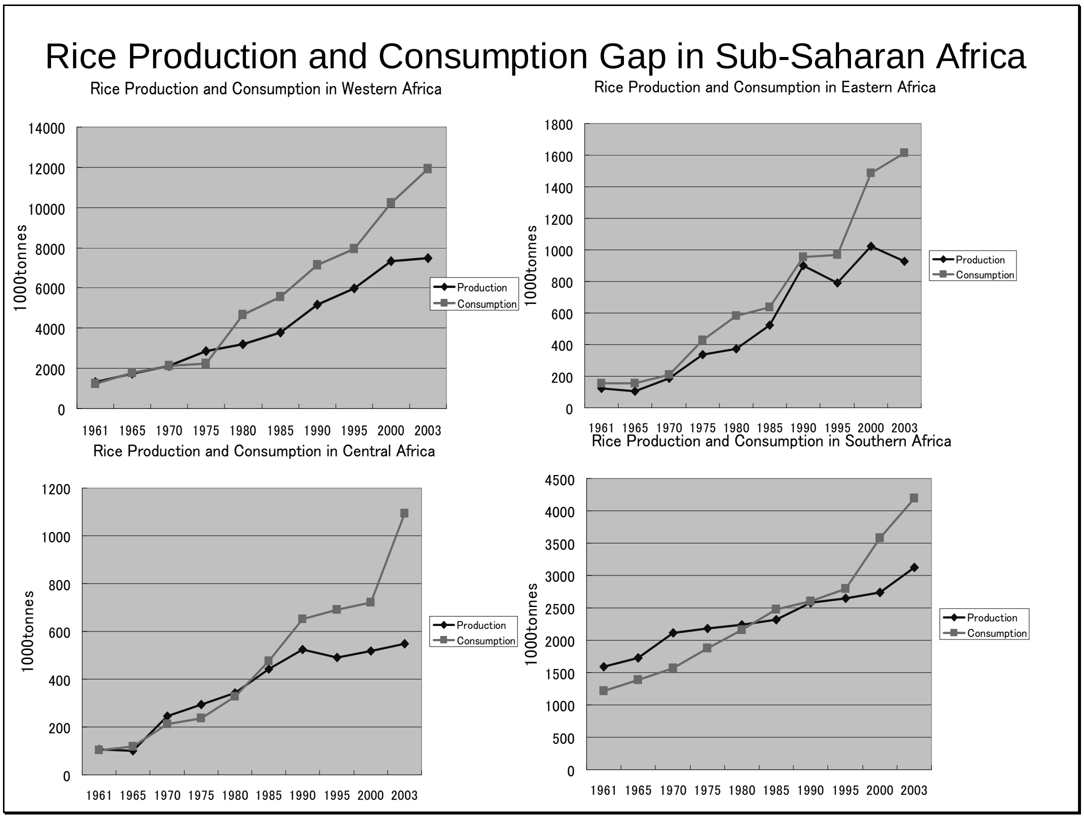

Annual Rice Consumption per capita in Japan
kg
180
160
140
120
100
80
60
40
20
0
1961
1965
1970
1975
1980
1985
1990
1995
2000
2003

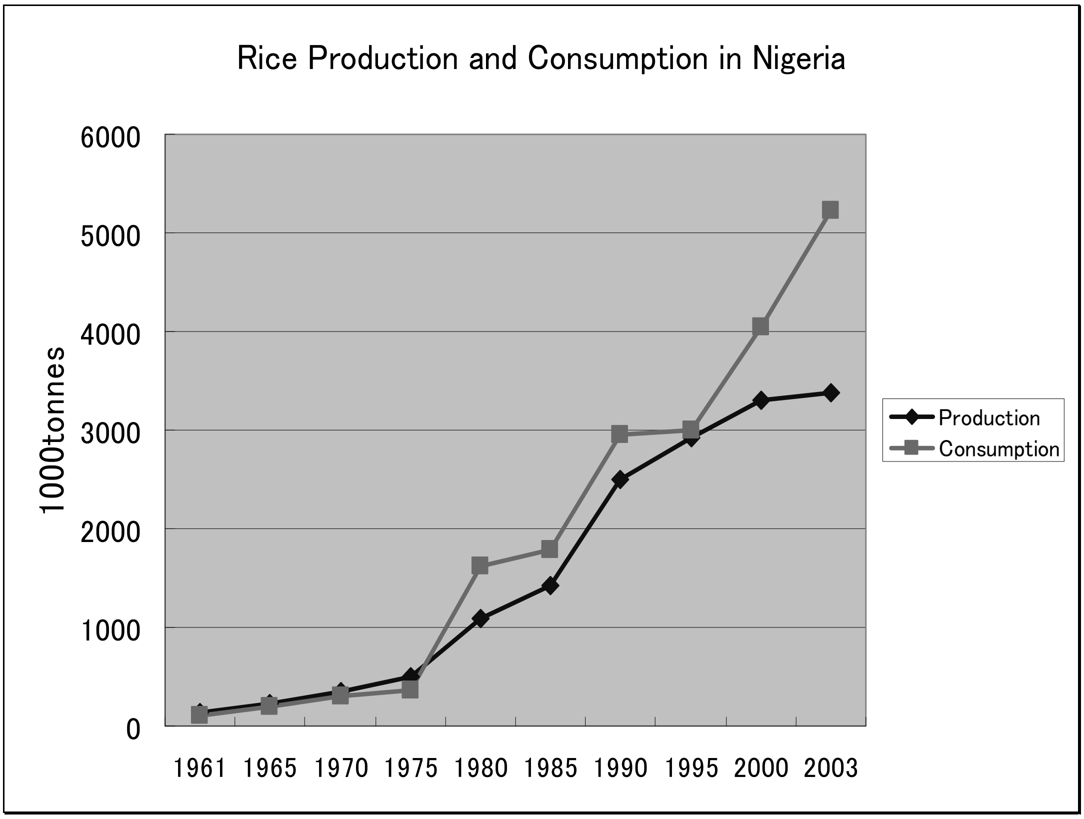

Rice Consumption
1000tonnes
25000
20000
15000
10000
5000
0
1961
1965
1970
1975
1980
1985
1990
1995
2000
2003
Japan
sub-Saharan Africa
Western Africa
Eastern Africa
Central Africa
Southern Africa

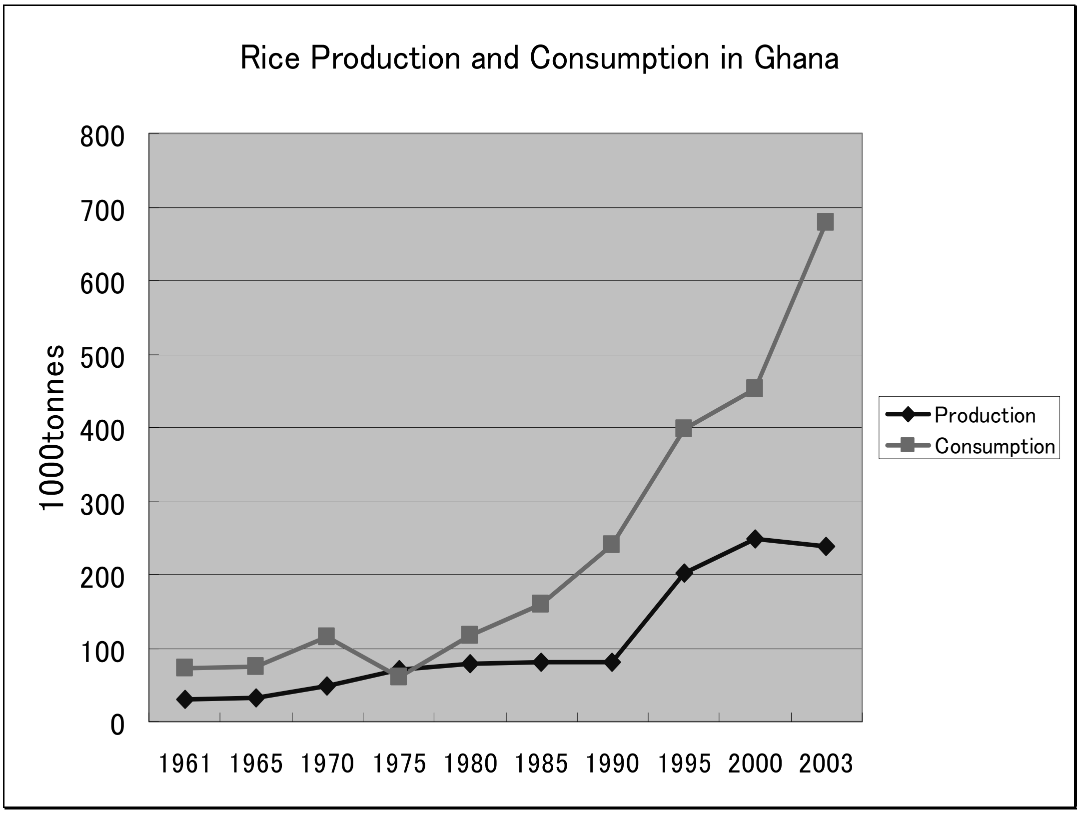


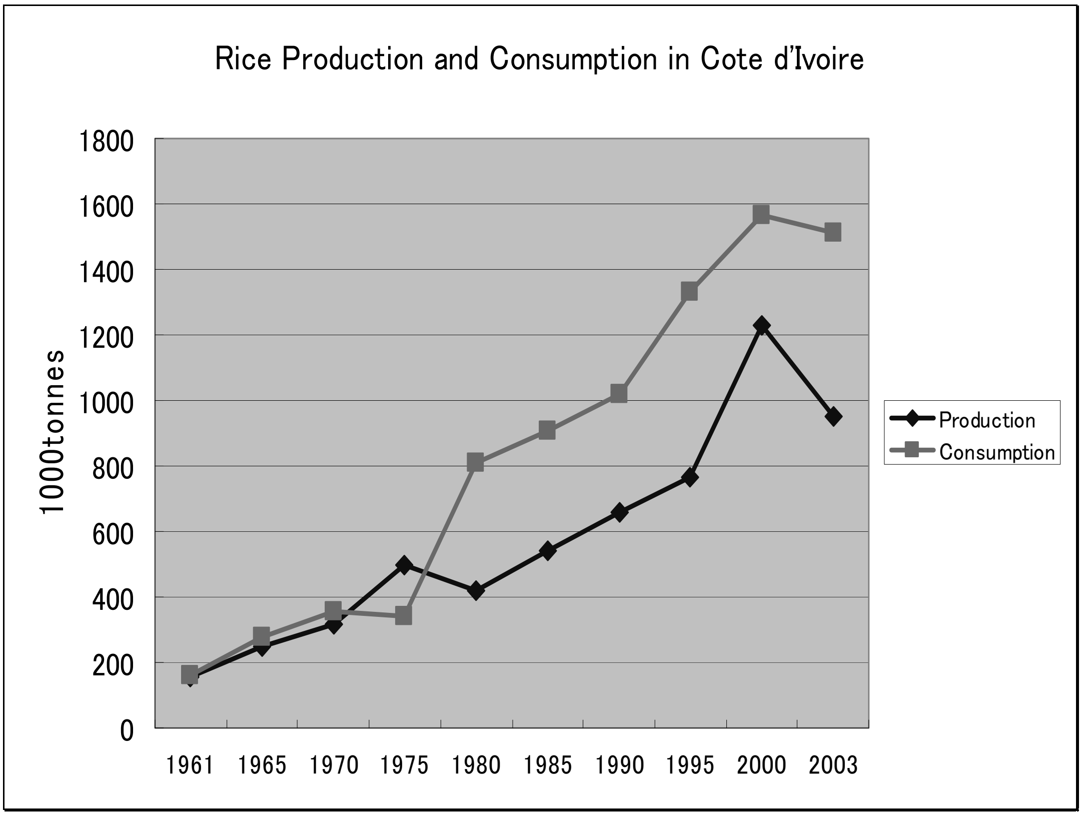
Rice Producing Countries in Africa listed in the FAOSTAT			
Central Africa (7)	Cameroon	Eastern Africa (10)	Burundi
	Central African Republic		Comoros
	Chad		Djibouti
	Democratic Republic of the Congo		Eritrea
	Gabon		Ethiopia
	Republic of the Congo		Kenya
	Sao Tome and Principe		Rwanda
Western Africa (16)	Benin		Seychelles
	Burkina Faso		Tanzania
	Cape Verde		Uganda
	Cote d'Ivoire	Southern Africa (12)	Angola
	Gambia		Botswana
	Ghana		Lesotho
	Guinea		Madagascar
	Guinea-Bissau		Malawi
	Liberia		Mauritius
	Mali		Mozambique
	Mauritania		Namibia
	Niger		South Africa
	Nigeria		Swaziland
	Senegal		Zambia
	Sierra Leone		Zimbabwe
	Togo		

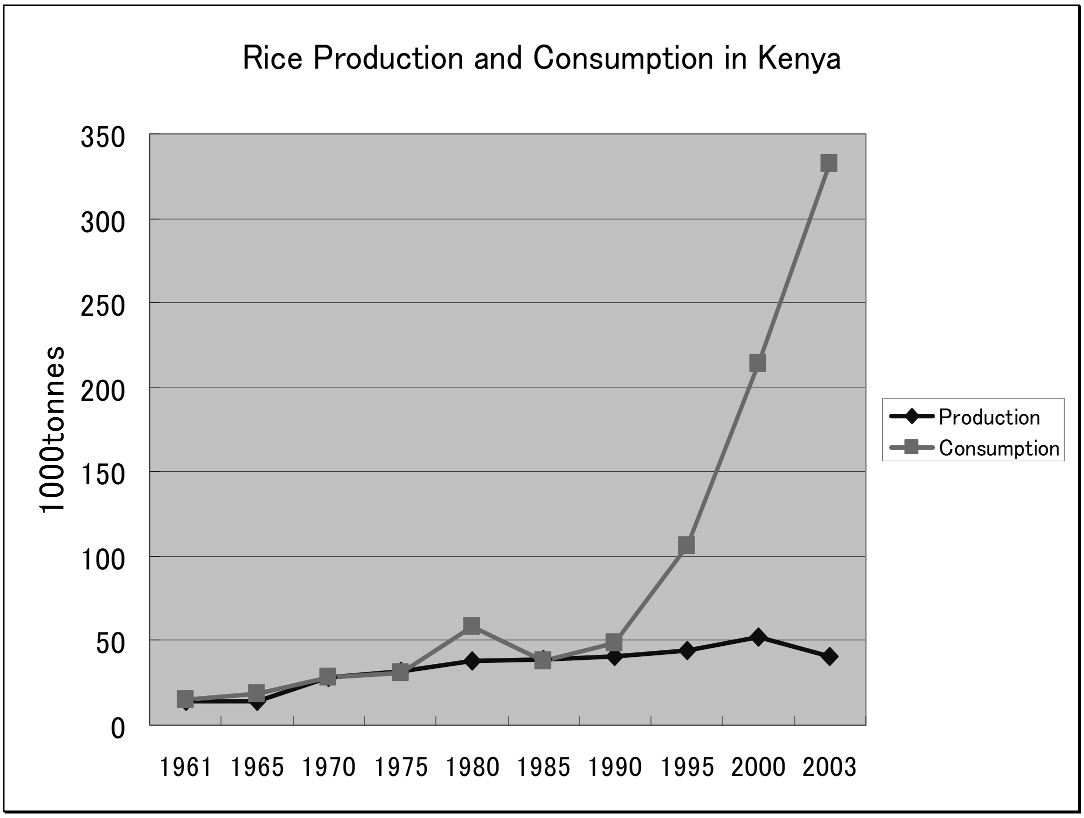

Rice Production and Consumption in sub-Saharan Africa
1000tonnes
25000
20000
15000
10000
5000
0
1961 1965 1970 1975 1980 1985 1990 1995 2000 2003
Production
Consumption

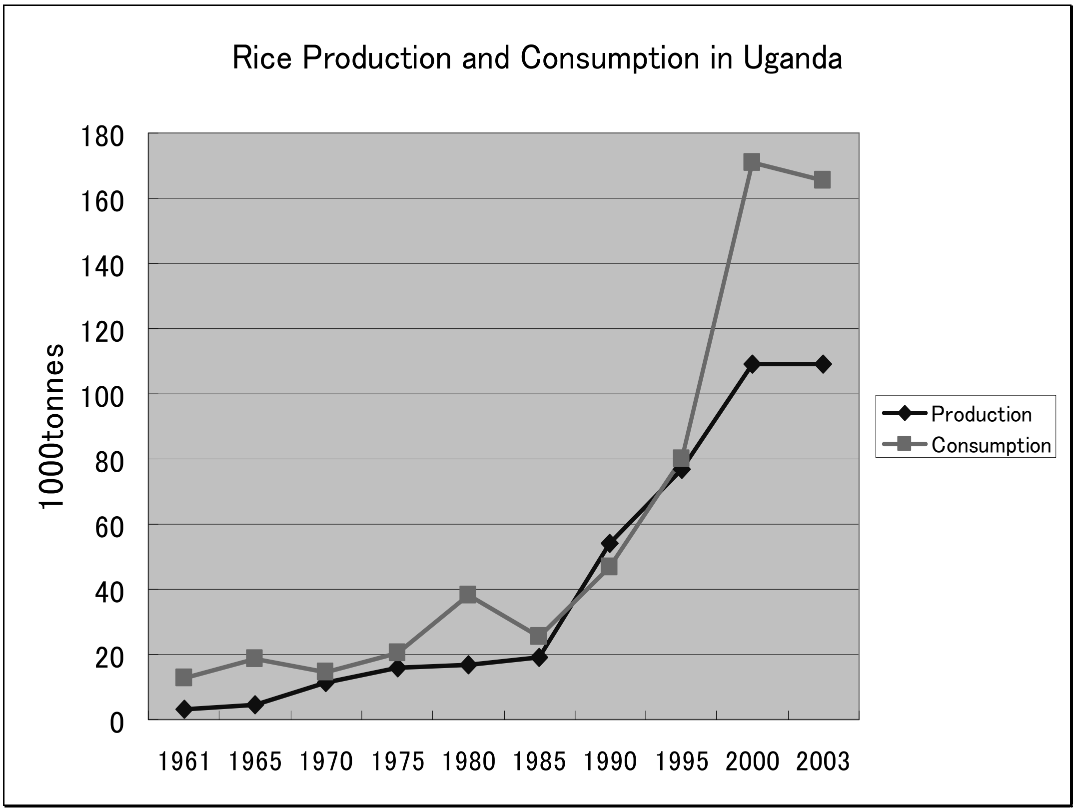

Rice Production and Consumption Gap in Sub-Saharan Africa
Rice Production and Consumption in Western Africa
Rice Production and Consumption in Eastern Africa
Rice Production and Consumption in Central Africa
Rice Production and Consumption in Southern Africa
1000tonnes
Production
Consumption
1961 1965 1970 1975 1980 1985 1990 1995 2000 2003

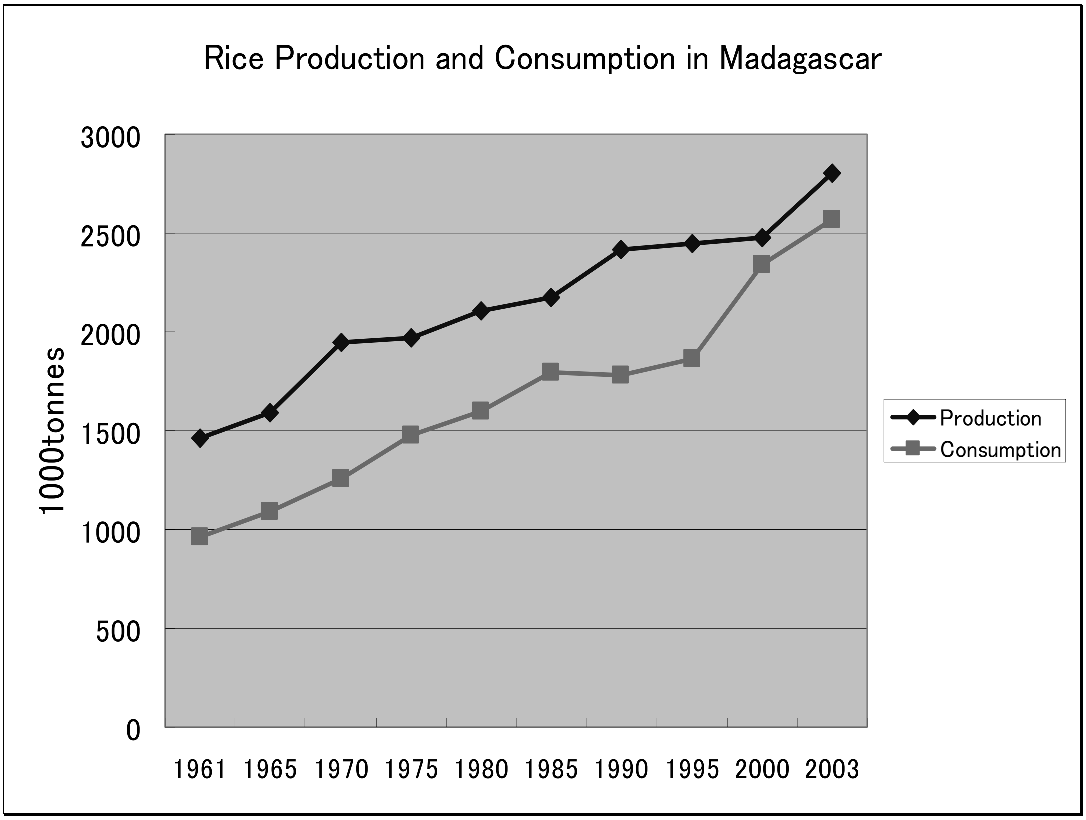

Rice Production and Consumption in Nigeria
6000
5000
4000
3000
2000
1000
0
1000tonnes
1961 1965 1970 1975 1980 1985 1990 1995 2000 2003
Production
Consumption

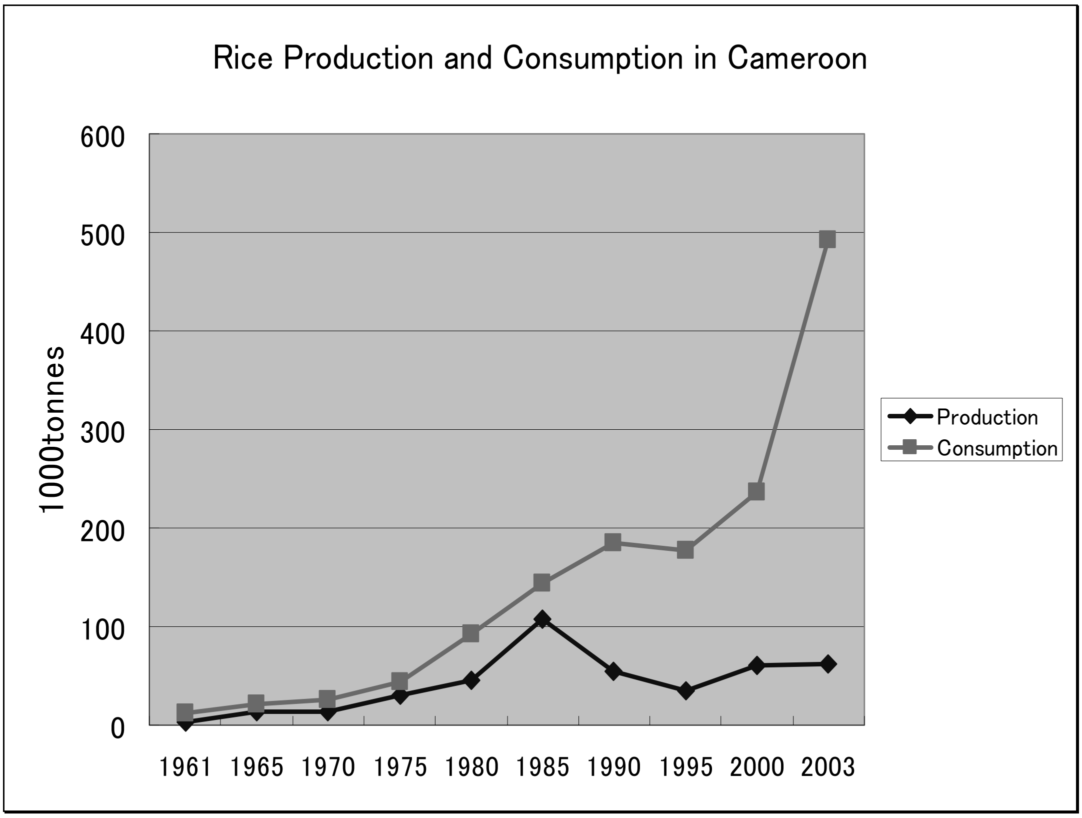

Rice Production and Consumption in Ghana
800
700
600
500
400
300
200
100
0
1000tonnes
1961 1965 1970 1975 1980 1985 1990 1995 2000 2003
Production
Consumption

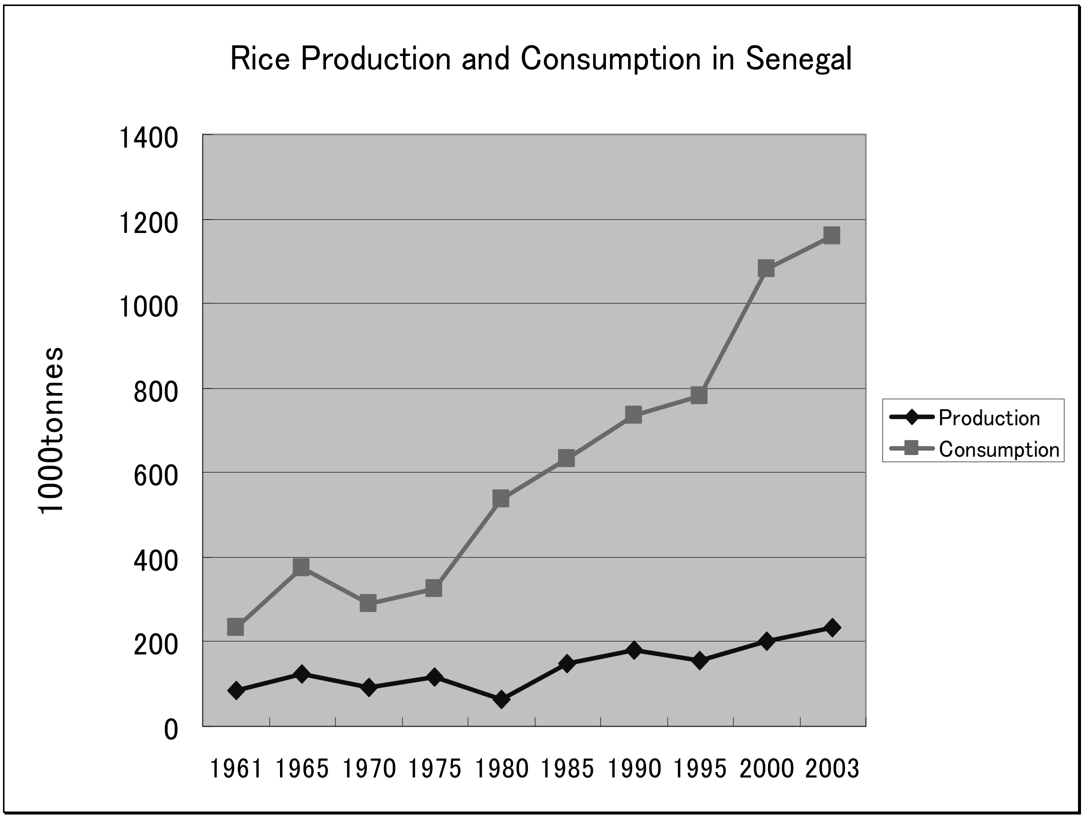

Rice Production and Consumption in Cote d'Ivoire
1000tonnes
0
200
400
600
800
1000
1200
1400
1600
1800
1961 1965 1970 1975 1980 1985 1990 1995 2000 2003
Production
Consumption

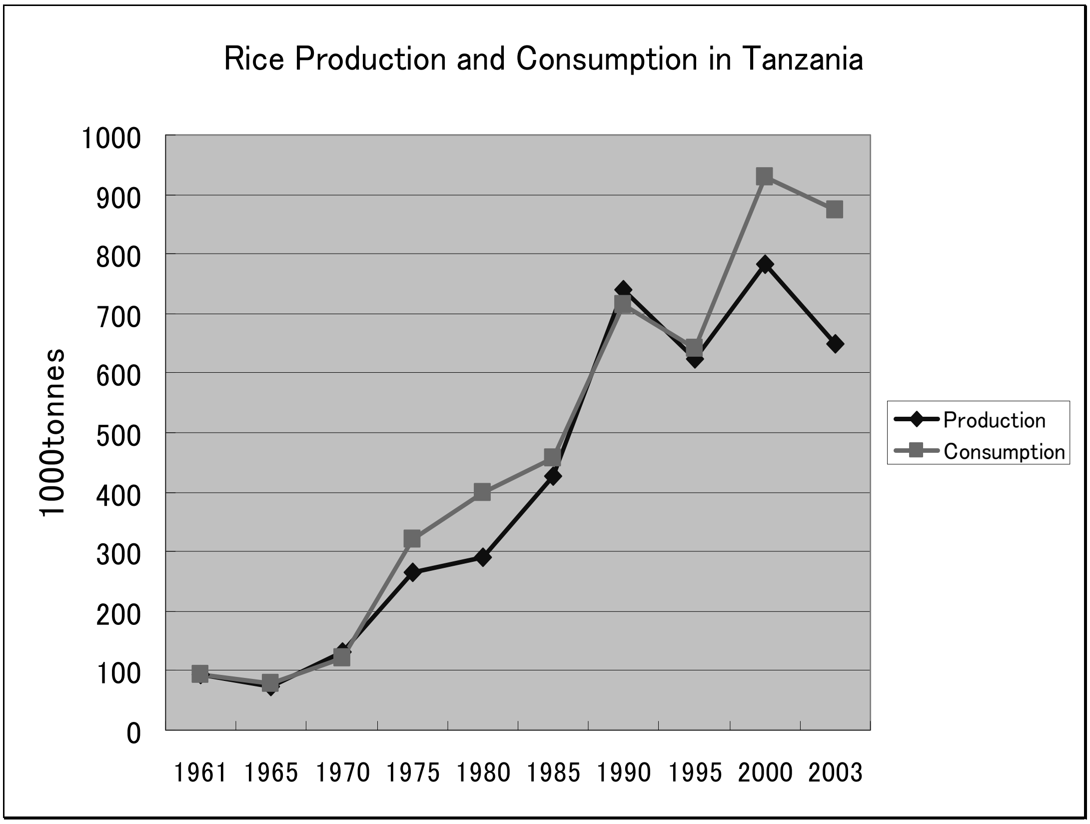

Rice Production and Consumption in Kenya
1000tonnes
0
50
100
150
200
250
300
350
1961 1965 1970 1975 1980 1985 1990 1995 2000 2003
Production
Consumption

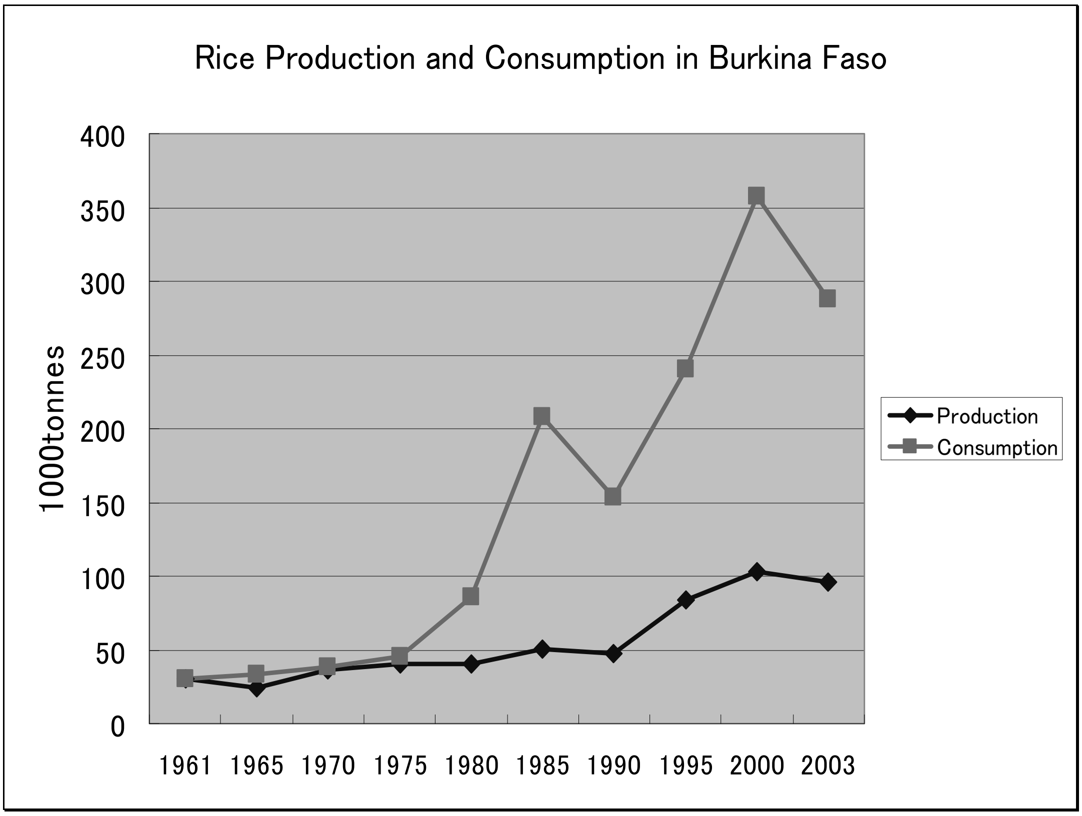

Rice Production and Consumption in Uganda
1000tonnes
180
160
140
120
100
80
60
40
20
0
1961 1965 1970 1975 1980 1985 1990 1995 2000 2003
Production
Consumption

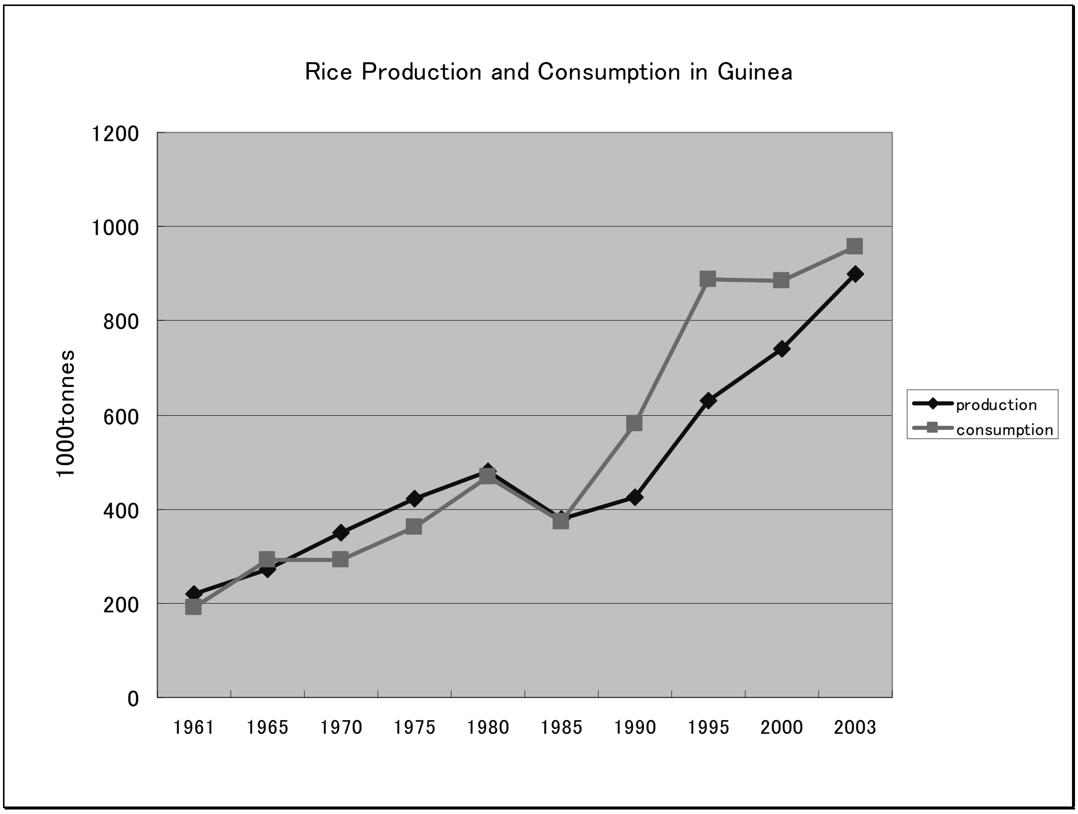

Rice Production and Consumption in Madagascar
1000tonnes
3000
2500
2000
1500
1000
500
0
1961 1965 1970 1975 1980 1985 1990 1995 2000 2003
Production
Consumption

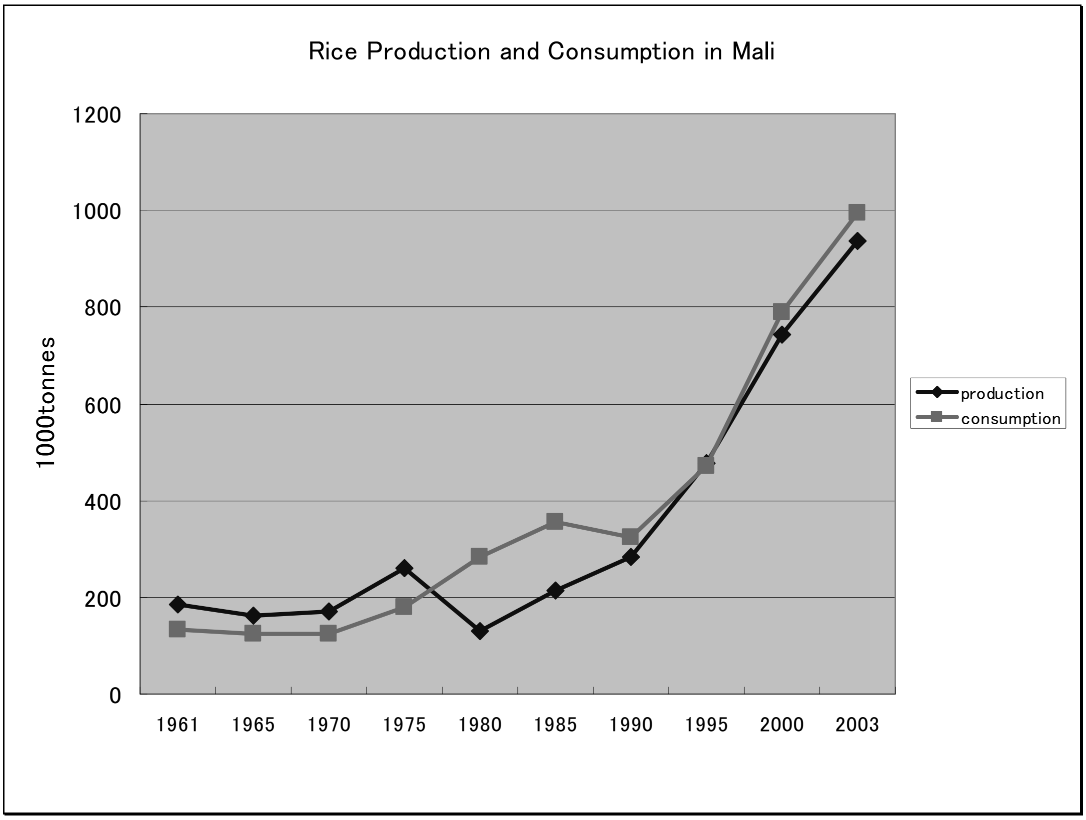

Rice Production and Consumption in Cameroon
1000tonnes
600
500
400
300
200
100
0
1961 1965 1970 1975 1980 1985 1990 1995 2000 2003
Production
Consumption


Rice Production and Consumption in Senegal
1000tonnes
1400
1200
1000
800
600
400
200
0
1961 1965 1970 1975 1980 1985 1990 1995 2000 2003
Production
Consumption


Rice Production and Consumption in Tanzania
1000tonnes
1000
900
800
700
600
500
400
300
200
100
0
1961
1965
1970
1975
1980
1985
1990
1995
2000
2003
Production
Consumption


Rice Production and Consumption in Burkina Faso
1000tonnes
400
350
300
250
200
150
100
50
0
1961
1965
1970
1975
1980
1985
1990
1995
2000
2003
Production
Consumption


Rice Production and Consumption in Guinea
1200
1000
800
600
400
200
0
1000tonnes
1961
1965
1970
1975
1980
1985
1990
1995
2000
2003
production
consumption


Rice Production and Consumption in Mali
1200
1000
800
600
400
200
0
1000tonnes
1961
1965
1970
1975
1980
1985
1990
1995
2000
2003
production
consumption

Profile

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1977 年名古屋大学大学院農学研究科博士課程修了。1979 年 12 月からナイジェリアにある国際熱帯農業研究所(IITA)でポストドクトラルフェローとしてダイズとカウピーの根粒菌の研究に従事。1983 年から九州東海大学農学部で土壌肥料学の講師を勤めたのち、1986 年、農林水産省北海道農業試験場に採用され、1993 年に九州農業試験場に異動。この間一貫して圃場における根粒菌利用の研究に従事。1998 年 6 月から国際農林水産業研究センター(JIRCAS)に勤務。JIRCAS では国際プロジェクト研究の調整業務や研究企画業務に従事。2003 年 11 月から JIRCAS 沖縄支所長として研究運営管理を担当し、同時に、カンキツグリーニング病プロジェクトのリーダーをつとめる。2005 年 4 月、名古屋大学農学国際教育協力研究センター教授、現在に至る。専門分野は土壌生物学、農学分野における国際協力研究。

Academic career

Professor Shuichi Asanuma graduated from Post-Graduate School of Nagoya University in 1977.

Professional career

Professor Shuichi Asanuma started his professional career as a post-doctoral fellow for the International Institute of Tropical Agriculture (IITA), Nigeria, from 1979 to 1883, working on rhizobium of soybeans and cowpea. In 1983, he started to work as a lecturer for the faculty of agriculture, Kyushu Tokai University, Japan. In 1986, Professor Asanuma joined the Ministry of Agriculture, Forestry and Fisheries of Japan (MAFF), and worked as a soil microbiologist for the National Agricultural Experiment Station of MAFF, in Hokkaido from 1986 and in Kyusyu from 1993. He was transferred in June 1998 to Japan International Research Center for Agricultural Sciences (JIRCAS), an organization of MAFF, as the international research coordinator and later as the head of research planning section. Professor Asanuma assumed the Okinawa Subtropical Station of JIRCAS in November 2003 as the director, leading its research and management, citrus greening disease project particularly. Since April 2005, he has worked as a professor of International Cooperation Center for Agricultural Education (ICCAE), Nagoya University. His fields of specialization is soil microbiology and international cooperation study in agricultural areas.

閉会の辞

名古屋大学農学国際教育協力研究センター第 7 回オープンフォーラムは、『アフリカにおける稲作振興の現状と今後の日本の役割―NERICA の研究と普及を例として―』を大テーマとして掲げ、2006 年 10 月 20 日に開催されました。当フォーラムには、ICCAE スタッフを含め総勢34名の参加者にご参加いただき、私自身とても楽しい一日を過ごさせていただきました。基調講演、および、8名の講演者の方々に興味深いご講演をいただき、また、活発な議論も交わされました。厳しいスケジュールのなか、意見をもっと交わしたいというご希望があったかもしれません。

当フォーラムが、重要な議論を交わす場となったことは間違いありません。アフリカでの人材育成プロジェクト、稲作振興活動、および国際協力の様相を概観するための多くの情報を交換し、共有することができました。

まず、基調講演をいただきましたオニャンゴ先生に御礼申し上げます。オニャンゴ先生のご講演では、NERICA および介入戦略について包括的にご紹介いただき、生理学的パラメーター、育種プログラム、肥料使用、人材育成等に関する研究についてご発表いただきました。

名古屋大学の山内先生には、変動気候環境下における水ストレス耐性に関わる根の重要な役割について発表していただきました。作物研究所の石井先生には、過去77年間における日本での陸稲育種の成果についてお伺いしました。石井先生の発表内容は、水田比率が低いアフリカで稲作を振興するにあたり、重要な情報となります。ケニア国立農業研究所のオケチ研究部長とわたくしの発表では、NERICA を農村に普及させるにあたっての重要な要素として、農民の関心度、トレーニング、教育、農民の年齢といったことを挙げさせていただきました。近畿大学の若月先生のご講演では、「緑の革命をもたらすのは水田である」とのご結論に基づき、緑の革命を実現するために農民自身が水田システムを確立させなければならないとのことでした。このため陸稲の優先順位は低いかも知れませんが、ともあれ、アフリカの農地にいかに NERICA を普及させ根付かせるかが大きな問題となります。農林水産政策研究所の櫻井先生のご講演では、天水低湿地稲作生産の集約化および緑の革命の可能性について、調査データの分析から見解をいただきました。天水低湿地稲作の水管理技術に投資を行い、栽培者が革新技術を利用しやすくすべきとの櫻井先生のご意見でした。また、市場アクセスの重要性についても指摘されました。

JIRCAS の神代先生には、アフリカ向けコメ品種の改良を行う JIRCAS の研究活動についてご発表いただきました。NERICA の乾燥耐性は在来品種に比べて低いとのことでした。JICA の内島先生のご講演は、アフリカにおける JICA の NERICA 普及活動、特に、日本の役割として、試験栽培や種子増殖等の技術協力に応える新規プロジェクトをご紹介いただきました。笹川アフリカ協会の伊藤先生には、ギニアとウガンダにおける NERICA 普及活動をご紹介いただき、大きな障壁を乗り越えるためにがんばっておられる様子を伺うことができました。NERICA だけではアフリカ大陸の食料をすべて賄なうことはできないとのご指摘もいただきました。

これらの発表や議論を通じて、過去・現在においてどんなプロジェクトが実施されてきたのか、わたしたちがこれから向かうべき方向、考えるべき課題は何かについて、理解することができました。アフリカの稲作促進について、生産・インフラ・人材育成・収益性の観点から議論を交わし、研究機関の相互協力につ

いても意見が出されました。本フォーラムでもたれた講演と議論の多くは、研究もしくは活動に関連する内容でした。技術的側面・社会経済的側面に焦点を当て、参加者の皆様だけでなく、その他の研究者の方々、政策策定に関わる方々、専門家、そして農村の方々にとっても理解しやすいものでした。当然のことながら、アフリカでの稲作振興をNERICAのみに限らず、より全体的に考えるべきとの意見も出されました。

私の印象としましては、NERICAの研究と普及に関する情報とデータを可能な限り多く蓄積することで、より効率的に活動できるようになり、協力活動の輪も広がると考えます。より強固で安定した組織的協力体制を築いていかなければなりません。

最後に、当フォーラムにご参加いただきました皆様の積極的な姿勢に、重ねて感謝申し上げます。ICCAEスタッフ一同、当フォーラムから得た知見と展望をもとに今後とも努力していく所存でございます。

ICCAEを代表し、心より皆様に御礼を申し上げます。

名古屋大学農学国際教育協力研究センター長
（2006年10月当時）

竹谷　裕之

Closing Remarks

First of all, let us express my sincere gratitude to all the participants for a nice day in the Seventh ICCAE Open Forum on 20th October, 2006. With the big theme of ‘‘Recent progress in rice promotion in Africa and role of Japan, NERICA as an example of research and dissemination”, thirty-four participants including ICCAE staff joined this forum. It was a great honour to us to have the attractive keynote address and eight presentations, as well as impressive discussions in the forum. The participants might have liked to express their comments more on the issues; we are sorry for holding the forum on a tight schedule.

We undoubtedly had impressive and significant discussions. We exchanged and shared a great deal of information and views on rice promotion activities and international cooperation including capacity building projects implemented in Africa.

Thanks to Professor Onyango for his keynote address which gives us comprehensive views about NERICA and intervention strategies for it, including research on physiological parameters, breeding program, fertilizer usage, and capacity building.

Professor Yamauchi showed us important roles of roots in relation to water stress tolerance under fluctuating weather condition. Chief researcher Ishii from National Institute of Crop Science showed us achievements of upland rice breeding of past 77 years in Japan. The information and knowledge he gave us could be extremely valuable when we consider rice promotion in Africa where the sawah ratio is not high. In my presentation with Mr. Okech from KARI-Kibos, Kenya, I talked about the factors of training, education, their interest, and young farmers which could be important when we disseminate NERICA to the villagers. Professor Wakatsuki from Kinki University did conclude his presentation as “no sawah, no green revolution”. He suggested that the farmers should establish the sawah system for realizing their green revolution. It is supposed that, based on his conclusion, we would give lower priority to upland rice based on his conclusion,. A big question we have here is; how we could disseminate and fix NERICA to farmland in Africa. Dr. Sakurai from Policy Research Institute talked about intensification of rainfed lowland rice production and potential green revolution using a great deal of analysis and filed survey data. Dr. Sakurai concluded that investment in water control technologies for rainfed lowland would lead wealthy cultivators to use innovative technologies. Additionally he pointed out that the market access is important as a constraint.

Director Kumashiro from JIRCAS introduced the research activities implemented by JIRCAS, for improving rice varieties for Africa. He also mentioned the relatively low drought tolerance of NERICA compared with the local varieties. Mr. Uchijima, Project Management Officer of JICA, presented JICA’s NERICA dissemination in Africa, and introduced their new projects implemented as a role of Japan, aimed at technical cooperation for trial cultivation, seed multiplication, and some like that. The program officer of SAA, Mr. Ito introduced impressive SAA’s NERICA dissemination activities in Guniea and Uganda;

they are overcoming the big bottlenecks. He also pointed out that NERICA alone cannot feed the African continent.

Through all the presentations and discussions, we could understand where we are coming to and what issues we should think about, considering what projects we have implemented so far, and what are ongoing. Rice promotion in Africa was discussed from some points of view: productivity, infrastructure, capacity development and profitability, and institutional cooperation. The presentations and discussions we had in the forum included research-oriented or activity-oriented issues, focusing on technological and socioeconomic aspects. They are extremely understandable not only for us but also for researchers, policy makers, experts, even villagers. Of course, some participants pointed out that we should think about rice promotion from a holistic point of view so as to consider NERICA included in the way.

I have an impression that, if we can accumulate information and data concerning research and dissemination of NERICA as much as possible, we can work on it effectively and collaboratively more. We should establish strong and stable relations each other, that is, we should promote our cooperation so as to implement them in a further systematic way.

It is my greatest pleasure to have had this forum, appreciating all of the participants for creatively joining it. I believe, through the forum, the ICCAE staff must find what we can do from now on. On behalf of the ICCAE staff, I would like to express my sincere appreciation for your creative participation. Again, thank you very much for your kind cooperation for the Seventh ICCAE Open Forum.

Hiroyuki Takeya
Director
International Cooperation Center for Agricultural Education (ICCAE)
Nagoya University, Japan
(as of October 2006)

編集後記

まず、私どもの怠慢のため、プロシーディングの刊行が 3 年も遅れてしまいましたことを心よりお詫び申し上げます。ご承知のように、この間のネリカを巡る事情だけでなく、2008 年 5 月に横浜で開催された第 4 回アフリカ開発会議(TICAD IV)を契機として、アフリカ稲作振興に向けた強い風が吹き出したことなど、周りの状況は大きく変化しています。

3 年前のオープンフォーラムでは、ケニアのネリカ栽培試験、日本の陸稲育種の歴史、国際研究協力機関のアフリカ稲作の研究、Sawah システムの普及、稲作・米販売を巡る農村社会経済条件、それから JICA の取り組みなど、今でも意味があると思われる大事な発表がありましたので、刊行物としてまとめておくことは大きな意義があると考えています。

3年前のオ―プンフォーラムにも関わらず、ご講演していただきました先生方にはご多忙のなか貴重なお時間をさいていただき、校正を引き受けてくださいましたことを重ねて感謝申し上げます。本プロシーディングが関係者の皆様のお役に立つことがございますと望外の喜びでございます。

みなさまからいただきましたアドバイスを糧とし、今後とも皆様のお役に立てますようオープンフォーラムの企画やその記録の編集業務に精進してまいる所存でございます。

編集担当
名古屋大学農学国際教育協力研究センター

Editor's Postscript

First of all, we have to apologize the three years delay of this publication for proceedings of the Seventh ICCAE Open Forum.

As you know, a strong wind favorable for rice dissemination in Africa has been blowing since the Fourth Tokyo International Conference on African Development (TICAD IV) held in Yokohama, Japan, in May 2008. The circumstances surrounding NERICA have also dramatically changed.

The Seventh ICCAE Open Forum was held three years ago, in 2006, and yet the presentations given in the place are still extremely significant: cultivation trials in Kenya, history of upland rice breeding in Japan, research by international research collaboration institutes on rice cultivation in Africa, dissemination of Sawah system, socioeconomic factors in the rural areas in cultivation and marketing of rice in Africa, activities implemented by JICA, and many other important topics.

We would like to appreciate the speakers for their sharing the time in proofreading and in giving us many pieces of advice, in spite of the time lag of three years. The experience we have obtained through the editorial work will be a great help for our future ICCAE activities.

It is a greatest pleasure if this publication of these significant proceedings will be a help to those whom concerned.

Editor
Secretariat,
International Cooperation Center for Agricultural Education (ICCAE)
Nagoya University

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