INTEGRATED WATERSHED MANAGEMENT OF INLAND VALLEY-ECOTECHNOLOGY APPROACH

PROCEEDINGS OF THE INTERNATIONAL WORKSHOP

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FOREWORD

Rice has over the past 30 years or so become a major staple in the Ghanaian diet. However, the greater proportion of the grain, estimated to cost about US$100 million, is imported every year. The Ghana Government is determined therefore, to raise the level of production in the country in order to attain higher level of self-sufficiency and reduce importation.

In Ghana four main rice production systems can be found. These are: (i) rainfed upland (ii) rainfed lowland/hydromorphic, (iii) inland valley swamps and valley bottoms, and (iv) irrigated paddies. The rainfed system is beset with many production problems and hence unreliable while the uplands are also being rapidly degraded. The inland swamps including the valley bottoms and floodplains represent an important agricultural asset that can contribute to food security and poverty alleviation.

In view of the experience of the Japanese in the development of rice fields using sawah (a leveled and bunded rice field with inlet for irrigation and an outlet for drainage), the government of Japan was approached for assistance in developing simple, low cost and environmentally benign technologies for managing the inland valleys. This culminated in the signing of a joint technical agreement in August 1997 by the Governments of Ghana and Japan through the Council for Scientific and Industrial Research (CSIR) and Japan International Cooperation Agency (JICA) which established a project on "Integrated Watershed Management of Inland Valleys". The main objective of the project was the development and testing of environmentally friendly and sustainable technologies based on integrated watershed management and participatory approach for the production of rice and other crops by resource-poor farmers.

The farmer participatory research which investigated into areas such as rice agronomy, soil and water management, use of forest/plantation systems to recycle nutrients in the watershed and the socio-economics of developing watersheds for rice production has demonstrated that the sawah technology can play significant role in helping the government achieve the noble target of reducing rice importation. Since the adoption of the sawah can increase rice production by more than 50 folds, then the post harvest problems of milling, storage, packaging and marketing also need to be looked into seriously and urgently by researchers. Furthermore, researchers should move from demonstration sites to farmers fields so as to enhance widespread adoption for improved livelihood.

Prof. E. Owusu-Bennoah
Deputy Director-General
Agriculture/Forestry and Fisheries
Sector/CSIR.

OPENING CEREMONY

WELCOME ADDRESS
By
Prof. W.S. Alhassan,

The Dirctor-General Of The Council For
Scientific And Industrial Research (CSIR)

Mr. Chairman, Representatives of the Honourable Ministers, His Excellency the Japanese Ambassador, Invited Guests both from Ghana and outside, Colleague Scientists, JICA Resident Representative, Representative from WARDA, Togo, Benin, Nigeria, Ladies and Gentlemen.

It is with great pleasure and delight that I formally welcome you all to this International Workshop on Integrated Watershed Management of Inland Valley – Ecotechnology Approach.

The potentials of inland valleys in our efforts to address food security problems have been recognized long ago. Inland valleys constitute an important source of water for human use, livestock production as well as other agricultural activities including the production of rice, which at the moment seem to be the targeted crop. Ecologically inland valleys have high productivity potential for several reasons including:

i. High water availability and low risk of drought stress.
ii. High soil fertility due to silt and clay accumulation and
iii. Potential for intensified use in both dry and wet seasons.

In Ghana, inland valley watersheds cover an estimated 0.7million hectares.
Over the past decades, several of the National Agricultural Research System of sub-Saharan Africa has conducted research on the development of inland valleys. However these efforts were localized and based on limited understanding of biophysical and socio-economic constraints. These efforts benefited from an initiative by a Consultative Group for International Agricultural Research (CGIAR) Technical Advisory Committee. This initiative is the Ecoregional Programme for the Humid and Sub-Humid Tropics of Sub-Saharan Africa (EPHTA). This came into being in 1993 after the Special Programme of African Agricultural Research (SPAAR) Technical Consultation on Ecoregional Approach to Research in Cote d'Ivoire. The programme is being co-ordinated by the International Institute of Tropical Agriculture (IITA).

The Council for Scientific and Industrial Research (CSIR) of Ghana has participated in EPHTA activities since 1995 and under that programme it has conducted a lot of research into the cultivation of rice in the valley bottom and assisted several small and medium scale farmers with technologies it developed. There have been a lot of problems including:

i. severe weed infestation
ii. lack of appropriate water management technologies
iii. water-borne human diseases
iv. unfavourable socio-economic conditions

Funding support for EPHTA, since its inception has been provided by Denmark, the Netherlands and France. We are most grateful to these countries. Funding for EPHTA activities, have, in the recent past dwindled considerably.
Another initiative in Ghana and coordinated by the Ghana Ministry of Food and Agriculture is the Bottom-Land Rice Development Study, which was meant for paddy production, processing and rice supplies and marketing in Ghana. I believe other countries in the Sub-Sahara Africa (SSA) have similar experiences and initiatives all geared towards the development of technologies for sustainable agricultural production.

I am therefore very pleased that this workshop is taking place at this point in time and aimed at an integrated approach to Watershed Management of Inland Valleys. Apart from the cultivation of rice, I will advocate for research activities to be diversified to include other crops, forestry, aquaculture and livestock.

I hope at the end of this workshop we will be able to come out with a programme(s) the implementation of which will assist small holders and medium-scale farmers to improve their well-being and alleviate poverty through sustainable production technologies which will in turn increase food security and minimize natural resources degradation.

I wish once again to welcome you all especially those of you who have come from outside Ghana. I hope you will enjoy your stay.

Thank you very much.

STATEMENT
By
Mr. H.E. Hiromu Nitta,
Ambassador, Embassy of Japan in Ghana

Mr. Chairman, Mr. Edwin Philip Daniel Barnes, Chief Director, Ministry of Environment, Science and Technology, Dr. Samuel K. Dapaah, Chief Director, Ministry of Food and Agriculture (MOFA), Dr. M. Wopereis, WARDA Inland Valley Consortium (IVC), Prof. W.S.W Alhassan, Director General, Council for Scientific and Industrial Research (CSIR), Mr. Shiro Nabeya, JICA Resident Representative,

Distinquished Guest, Ladies and Gentlemen,

It is a great pleasure for me to be here with you today to identify the result of the study that was conducted with the assistance of some Japanese experts in Ghana, which can be shared by participants in this workshop from neighbouring countries in the sub-region. I understand that the objective of this workshop is to bring together policy makers, agriculturists, farmers and other stakeholder to examine and discuss the integrated watershed management of inland valleys.

Mr. Chairman, Hon. Ministers,
In Ghana and most West African countries, despite the abundance of natural resources to support food production, food supply continues to fall short of demand, due mainly to unfavourable climatic conditions and natural disasters, and due partly to human activities other observed constraints were water control and weed infestation.

Consequently, food, especially rice, requirements are met largely from increasing amounts of imports. Under the current situation the Government of Ghana is putting a high priority on the increase of domestic food production. Inland valleys have specific hydrologic conditions and have been cited as having high potential for the development of rice-based, smallholder farming systems at the village level.

It is said that the potential area for small-scale irrigated area in inland valley watersheds is estimated at 700,000 hectares, 3% of the total area of Ghana and inland valleys can support production of rice, other commonly grown cereals, vegetable, legumes, roots and tuber crops.

Mr. Chairman, Hon. Ministers,
As a result of the study, we can recognize that, given their relatively fertile soils and assured water supply, inland valley can contribute to greater stabilization of food production in particular, rice production, if current production systems and practices could be further improved through the adoption of systems that promote nutrient accumulation and retention and improved water management systems. In addition, I would like to point out that the rice farming system, with low cost and appropriate technology and farmers participation approach was verified as feasible through the study and this rice farming system is environmentally friendly from the view point of

agro-forestry. I consider that it is quite important for Ghanaian counterparts and farmers to maintain the current momentum and to make progress towards the next stage with adequate budget allowance by the government of Ghana.

Mr. Chairman, Hon, Ministers,
There can be no doubt that the regional co-operation within the West Africa sub-region is to be promoted to increase food production and to enhance food security. This workshop will be a good opportunity for sharing experience for this purpose. Within the framework of the Tokyo International Conference on African Development (TICAD) process, the Government of Japan (GOJ) is encouraging south-south co-operation, i.e. Asia to Africa, or Africa to Africa co-operation. At WARDA, my Government has been assisting her " Joint Africa/Asia Research on Interspecific Hybridization between Africa and Asian Rice species" by dispatching Japanese experts and volunteers and providing financial assistance, amounting to more than 2.7 million U.S. dollars in total since 1997. I am very happy to say that the first stage of the Research has been successfully implemented and some varieties of "New Rice for Africa" with high yield and high resistance are now available. Currently, more than 5,000 farmers in 17 countries including Ghana in West Africa are engaged in experimental cultivation, what is called Participatory Variety Selection (PVS). What I would like to emphasize is that farmers themselves can participate in the decision-making on the selection of species.

Mr. Chairman, Hon. Minister,
In closing, I hope sincerely that this workshop will become a remarkable step towards the improvement of food supply and nutrition for the people in this sub-region.

Thank you.

STATEMENT
BY
M. C. S. Wopereis,
IVC Scientific Coordinator and Representative of WARDA

Distinguished ladies and gentlemen, dear colleagues. It is a pleasure for me to say a few words at the opening of this important workshop. The potential of inland valley lowlands in West and Central Africa cannot be underestimated. There are 30 to 50 million ha of lowlands available, whereas only 10 to 25% are being used.

Inland valleys are typically low input systems. With improved water control there is tremendous scope for intensification (increased input use and input use efficiency) and diversification (use of other crops than rice, such as vegetables grown on residual moisture or supplementary irrigation, and agro-forestry or aquaculture).

Lowlands, therefore, have the potential for expansion, closure of the yield gap between actual and potential yields, increased cropping intensity and diversification in sustainable ways as these systems are usually very robust, with good soil fertility. Rice is an obvious crop for the inland valley lowlands. Currently 4 million tons of rice are being imported in West and Central Africa, costing the region 1 billion US$ of scarce foreign exchange. Increased use of inland valley lowlands has the potential to close the current gap between rice demand and regional supply.

WARDA gives great importance to Research and Development for Inland Valleys. She is the convenor of an eco-regional program on inland valley research and development: The Inland Valley Consortium (IVC). This is an initiative of 10 West African countries and of International Institutions. Some representatives of National Coordination Units of the IVC from Togo and Benin are with us today.
Mr. Chairman, the topic of this workshop: Integrated watershed management is at the heart of the IVC. Valley bottoms cannot be seen in isolation from the hydromorphic areas and the uplands. Water, nutrients and sediments are intercepted and moved downwards. Next to these biophysical factors there are many socio-economic factors to be considered.

There are people working in the uplands and lowlands in Cote d'Ivoire. Immigrant farmers from Mali and Burkina Faso are exploiting the inland valley lowlands, whereas native local farmers are growing crops like cassava or cocoa or coffee in the uplands. The social implications of inland valley lowlands in such settings need careful consideration.

Mr. Chairman, I hope that these issues and others will be dealt with in the next few days. I look forward to fruitful discussions and wish you all a successful workshop.

Thank you.

SHORT SPEECH
BY
Hon. Prof. Dominic.Fobi,

Minister Of Environment, Science And Technology (MEST)

Read By
Mr. E. P. D. Barnes
The Chief Director Of MEST.

Mr. Chairman, The Representative of the Honourable Minister, Ministry of Food and Agriculture Dr. S. K. Dapaah, Distinguished Scientists from Ghana, Togo, Benin, Nigeria, Representatives of WARDA and IITA, Invited Guests, Ladies and Gentlemen.

It is a great honour to address this important International Workshop on Integrated Watershed Management of Inland Valleys in Ghana – The Eco-technology Approach soon after my assumption of duty as the Minister of Environment, Science and Technology.

The Inland Valley Watersheds in Ghana are estimated to cover about 700,000 ha i.e. 3% of total land area of the country and represent a great potential for increasing rice production in the country. Currently only 20% of the valleys are being utilised leaving a large tract of 80% completely under-utilised. The importance of developing these inland valleys for the production of rice to feed the ever-increasing population of Ghana is obvious. Rice is now an important food crop in almost all Ghanaian homes. But the potential of the inland valleys could be realised only if the problem of conserving water in these valleys is resolved using science and technology.

In 1989, under the Valley Bottom Rice Development Project, Crop Research Institute of Council for Scientific and Industrial Research (CSIR) developed sustainable technologies for integrated soil, land and water, and crop management in the production of rice and other crops in the inland valleys. Although considerable progress was made in addressing some of the researchable constraints, there is still the need to devise a simple low cost and environmentally friendly system for managing the inland valleys that can be adapted by the resource poor farmers. The long experience in Sawah development in tropical Asia that looks not only at the valley bottoms but the total watershed is therefore worth applying to the inland valleys of Ghana. It is against this background that I find this workshop very important.

Mr. Chairman, rice production increased from 48,000 in 1970 to 281,300 metric tons in 1995, but the increase was insufficient to meet domestic demand in the country. This has meant increasing amounts of imports using scarce foreign exchange earnings. For example, Ghana imported on the average annual volume of 165,000 metric tons(mt) of rice between 1990 and 1992 at US$316 per mt amounting to US$52.14 million. Though quantities imported vary from year to year, the figure averaged 170,000 metric tons/year are expected to rise to 672,000 metric tons by

2006. It is the intention of the present NPP government to reduce if not completely halt this uncontrolled foreign importation of rice into the country.
The agricultural research institutes of the CSIR have been at the forefront in Ghana's efforts at ensuring food security. For instance, owing to the release of new and improved crop varieties including rice SIKA-MO and better cropping systems, there has been a dramatic increase in the output of various food crops. These notable achievements have been done in close collaboration with the Ministry of Food and Agriculture and farmers.

I am encouraged to note that the Food Research Institute and the Institute of Industrial Research both of the CSIR are currently addressing the low acceptability and marketability of locally produced rice including quality of paddy for milling and rice milling techniques. It is hoped these endeavours will complement the results of the Integrated Watershed Management of Inland Valleys to produce high quality local rice that is competitive, marketable and acceptable to Ghanaian consumers.

It is the policy of my Ministry to make more resources available to support scientists of the CSIR since it is only through the application of science and technology that agricultural production could be moved further beyond the present levels. While the Eco-technology Approach is being used to look at the inland valleys, this must not be done without taking into consideration the need to preserve the environment for the present and future generations.

My Ministry therefore wishes to thank the government of Japan for the assistance that they have provided in terms of capacity building and manpower development especially in the field of rice research.

I hope that the cordial relationship established will continue to grow and extend to other areas.

Thank you.

KEY NOTE ADDRESS
BY
Major Courage Quashigah(Rtd)
Minister Of Food And Agriculture (MOFA)

Read by
Mr. Samuel K. Dapaah
The Chief Director Of MOFA,

Director General of CSIR, Colleagues of the Ministry of Environment, Science and Technology, distinguished researchers from Ghana, Togo, Benin, Nigeria, Representatives of WARDA and IITA and the press. It gives me great pleasure to deliver the keynote address at this important International Workshop on behalf of the Minister of Food and Agriculture, Hon. Major Courage Quarshigah (rtd).

Kindly permit me to add my voice to the warm welcome that has been extended to our distinguished guests and especially representatives of our sister countries and researchers. Our meeting here this morning is very significant in view of the importance the new administration attaches to agriculture as a source of sustainable food security, a contributor to the reduction of poverty especially rural poverty and as a means of stabilizing our currency the cedi through import substitution and increased foreign exchange earnings with your help and guidance.

Mr. Chairman, the importance of the Agricultural Sector to the well being of Ghanaians cannot be overemphasized. The Ministry's assessment of the future development of Ghana is that given the importance of Agriculture in the economy, our quest to become a middle income country can be achieved sooner rather than later if the sector can achieve annual average growth rate of about 6% on a sustainable basis and environmentally friendly basis with the growth of key agricultural commodities such as rice leading the way.

Mr. Chairman, available statistics indicate that rice has over the past 30 years or so become a major stable in the Ghanaian diet. Gone are the days in the 1970s when the production of some 40,000 metric tons of milled rice were adequate for local consumption.

Even though rice production over the past 5 years has averaged about 135,000 metric tones of milled rice, an average of about US$100 million worth of rice is imported annually to supplement local production in spite of declining foreign exchange availability.

A number of reasons have accounted for the apparent preference of imported rice to locally produced rice. These include inadequate and uncertain supply of local rice as well as its low quality due to poor quality seeds and inadequate water management expertise for rice production.
In view of the limited success of both rain-fed upland and irrigated rice cultivation, recent attention is being focused on the development of the more than 1 million

hectares of inland valleys found scattered across the country compared to the current 130,000 hectares under rice cultivation. Research scientists of the Valley Bottom Project under the National Agricultural Research Project have carried out studies to develop appropriate technologies.

The Ghana government appreciates the important role that the Japanese government is playing through the Japan International Cooperation Agency in providing material and technical assistance in the form of experts and training for the development of sustainable and environmentally friendly technologies for our farmers.

Considering the comparative advantage and development potential that exist in the various ecologies for profitable rice production, especially in the inland valleys, the Ghana Government is determined to raise the relatively low level of rice production in the country in order to attain higher level of self-sufficiency, reduce the huge foreign exchange spent on importation and also provide jobs and raise the living standards of our rice farmers in the country.

It is in this regard that the Ministry is re-examining its policies, programmes, strategies and performances to enable agriculture compete effectively in the Domestic, ECOWAS and International markets in the shortest possible time. Among the major areas of concern to the Ministry as a result of our past experiences are:

a. learning lessons from projects and schemes which have performed well and how these performances can be replicated for similar commodities as well as different commodities across the country where feasible.

b. Outlining actions in the Ministry's Accelerated Agricultural Growth and Development Strategy (AAGDS) that need to be taken in the short, medium, and long terms to increase agricultural output for increased export earnings, improved nutritional status of Ghanaians and rising income levels by improving productivity in the acquisition of appropriate farm inputs, on-farm production technology, efficient agro-processing and effective marketing strategies.

In conclusion Mr. Chairman, I want to assure all stakeholders here present as well as our friends from Japan that the Ministry will carefully study your recommendations and give all the necessary support and motivation to make the project a success.

I thank you

PROJECT CONCEPT AND OVERVIEW

CONCEPTUAL FRAMEWORKS OF THE PROJECT

By
T. Wakatsuki
Project Co-Coordinator, Shimane University, Matsue, Japan

Inland valley systems and hydromorphic fringes cover about 50 million hectare in West Africa, of which about 10 million hectare have the potential for small scale rice farming. In Ghana the potential area for inland Valley is estimated to be 700,000 hectares or one million if flood plains are included.

Rice is cultivated under three main systems, namely rainfed upland, irrigated and rainfed lowland (inland valleys) conditions. Production under rainfed upland conditions has been very risky due to unreliable rainfall, shallow and erodible soils of low fertility. Production under big irrigation schemes has not been very encouraging. However, the numerous small inland valleys found scattered across the country where the water management is the main problem, offer the best rice ecology. There are four key concepts that support this.

Key Concept 1: The Sawah Hypothesis

1.1 Sawah hypothesis

The green revolution laid the foundation for the rapidly growing economies of Asia today. The layouts of groups of sawahs in the watershed were adapted to the local topography for efficient irrigation and drainage. Why has the green revolution not yet occurred in West Africa and Ghana in spite of its success in Asia in the 1960's? The main cause of the present agricultural and environmental crises in West Africa is the general under development of lowland agriculture. Environmentally creative technology, such as sawah farming in lowlands is not traditionally practiced in sub-Saharan Africa or in Ghana. Sawah is one of the prerequisite for realizing the green revolution as well as for preserving and even restoring ecological environments. Irrigation and drainage without sawah farming technologies has proved inefficient or even dangerous because of the negative impact on accelerating erosion. Thus, the development of irrigation has been slow. In the absence of water control, fertilizers cannot be sustained. High yielding varieties never perform high yielding. Soil fertility cannot be sustained. Therefore 'green revolution' has so far not been realized.

1.2 Sawah and Irrigation

Another frequent source of misunderstanding in West Africa is the term 'irrigated rice'. In Asia, the meaning of this term is clear, as the sawah is prepared first by farmers before completing the government assisted irrigation system. However, there are many irrigation systems without proper sawah preparation in West Africa. In the past, research on water control of inland valleys concentrated on irrigation and drainage systems, such as the central-drain system, the interceptor-canal system, the head-bund system and head-dyke system. The contour bund system, however, may be more difficult to construct and manage by local farmers than the sawah system. It may be difficult to share land and irrigation water fairly for local farmers by using the contour bund system, which may be more suitable for large-scale rice farming such as in the United States of America and Australia.

Generally speaking, the construction cost of sawah is far higher than that of irrigation facilities in terms of labor and amount of soil moved. Out of the total cost, 50-70% should be allocated for sawah construction and 30-50% for irrigation and drainage. Therefore in order to achieve sustainable development, sawah systems need to be constructed with the active participation of farmers. The key element is the sawah. For sustainable irrigation systems in inland valleys, the sawah technology should first be extended to the farmers.

Key Concept 2: Geological Fertilization Theory for the Integration of a Watershed

2.1 Geological Fertilization Theory

Fertile soils and ample water cycling secure an abundant food supply and rich human life on the earth. The distribution of fertile soils, and hence the distribution of population in the world, is related to the amount and quality of geological fertilization processes. Four geological fertilization processes can be identified, i. e.

i. the lowland soil formation process,
ii. the volcanic ash soil formation process,
iii. the loess soil formation process, and
iv. the dynamic equilibrium between soil erosion and formation.

The lowland soil formation involves the transportation and sedimentation of eroded upland topsoils by surface run off and by river water. This process is very important to obtain fertile lowland soils. Small scale examples are the valley bottom soils as shown in Fig 1. The large scale examples include the formation of fertile deltas, such as Nile, Ganges and many Asian deltas. In the sawah based farming system this geological fertilization process can be enhanced. The long term sustainability of sawah farming can be attributed to this process.

2.2 Integrated Watershed Approach

The sustainable productivity of sawah is more than 10 times greater than that of upland rice fields because of geological fertilization process and the well-known bio-physico-chemical processes of inundated sawah soils as described by Kyuma and Wakatsuki (1995). Sustainable productivity of 1 ha of Sawah may be equivalent to more than 10 ha of upland fields. This value was estimated by assuming that the mean yield of upland rice without fertilizer application is 1 t/ha and the mean yield of sawah rice without fertilizer application is about 2 – 2.5 t/ha. To sustain the yield, upland fields have to lie fallow (3-year cultivation and 12-year fallow, for example). On the other hand the lowland sawah rice can be cultivated continuously for many more years. Thus sustainable productivity of sawah is 10-12.5 times higher than

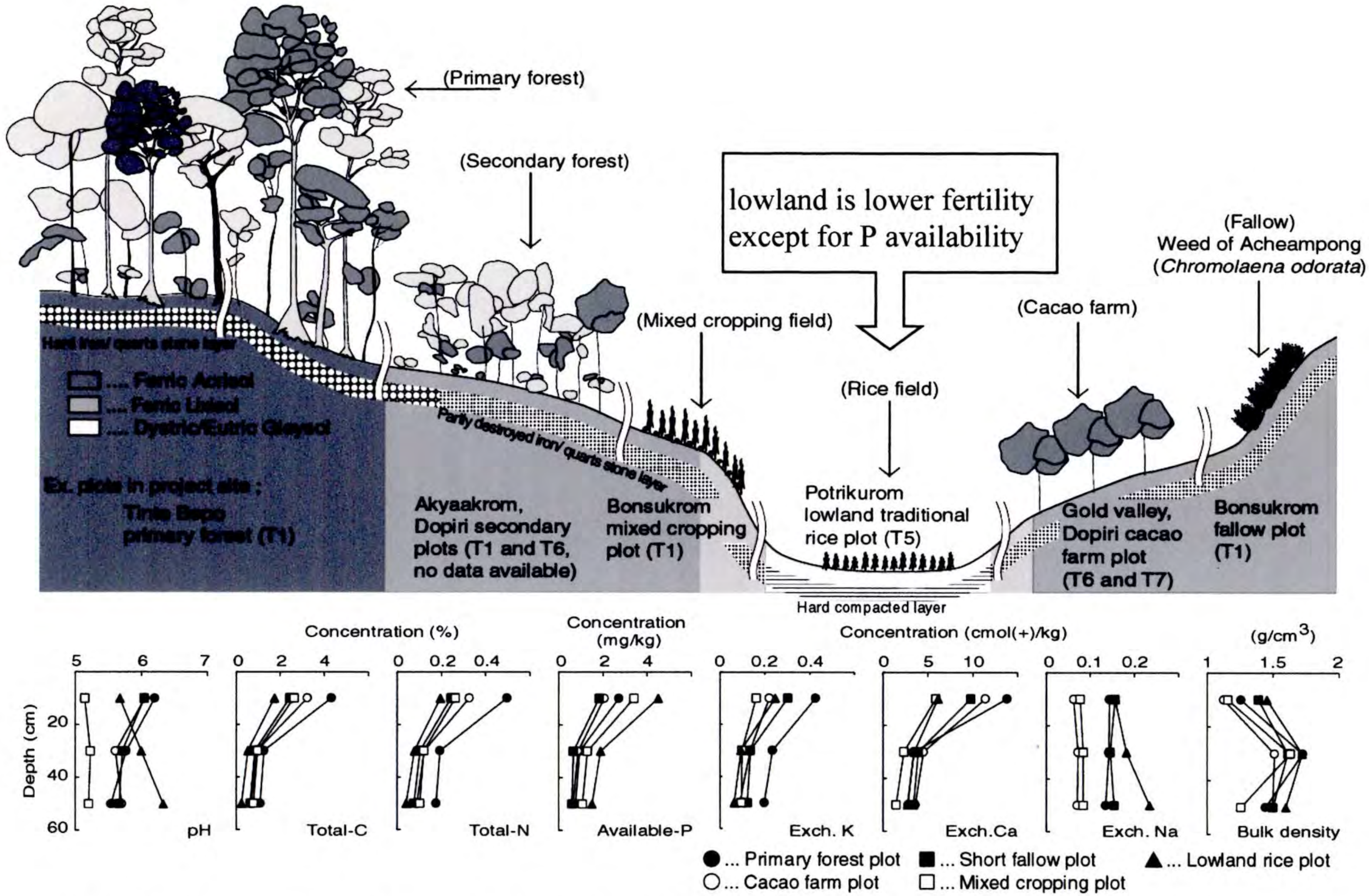

Fig. 1 . Typical soil type, land use (vegetation) and topography in benchmark inland valley watersheds. Profile characteristics of nutrients and bulk density are also shown in five land uses.

that of upland rice field, i.e., 12.5 = (2-2.5/1) x (15/3), productivity ratio (t/ha): Lowland sawah/upland rice = 2.5/1, and sustainable cropping intensity ratio (fallow period): lowland sawah rice/upland rice = 5/1.

A sustainable watershed should exhibit a dynamic equilibrium between soil formation and erosion. If the rate of soil formation far exceeds those of soil erosion, old leached soils like Oxisols may develop, and if erosion is not compensated for by soil formation, soil degradation and eventually desertification will occur. The earth's mean rate of soil formation was estimated at 0.7 ton/ha/year. Cool temperate granitic watersheds showed a rate of 0.02 tons/ha/year. Andesitic watersheds in West Sumatra, Indonesia showed a rate of 1.8 ton/ha/year.

Although the rates of soil formation in West Africa have not been measured, if one estimates a value of 1 ton/ha/year in total watershed, then 5% of lowland areas can receive fertile topsoils eroded from 95% of upland areas at the rate of about 20 tons/ha/year. The sawah system may contribute to the trapping of such eroded top soils to maintain the lowland soil fertility (Geological fertilization process No. (1) and (4) as shown in Fig 1.

2.3 Restoration of low fertility soils of inland valleys in West Africa

Issaka and Wakatsuki (1997) and Buri and Wakatsuki (1996) showed the general fertility and geographical distribution of soils of inland valleys and flood plains in West Africa. The general fertility was compared to those of Tropical Asia (Kawaguchi and Kyuma 1977) and Tropical America (Tanaka et al 1986). The results were summarized in Table 1. The total carbon and nitrogen content were low for West Africa and Tropical Asia. The mean values of available phosphorus suggest that the phosphorus status of West Africa is very low throughout the region. Base status such as exchangeable calcium and potassium and effective cation echange capacity of inland valleys of West Africa are characteristically low in majority of plant nutrients. For effective and sustainable crop production, new farming systems that are both soil restoring and enriching must be developed. As discussed above, the African adaptive sawah-based farming systems by small-scale farmers is one of the most promising systems.

Table 1. Mean values of soil fertility properties of inland valleys (IVS) and flood plains (FLP) of West Africa in comparison with lowland topsoils of tropical Asia and Japan (Hirose and Wakatsuki 1997)

Location	Total	Total	Available	Exchangeable Cation (Cmol/kg)				Sand	Silt	Clay	CEC
	C(%)	N(%)	P(ppm)	Ca	K	Mg	ECEC	(%)	(%)	(%)	Clay
IVS	1.3	0.11	8.7	1.89	0.25	0.25	4.20	60	23	17	25
FLP	1.1	0.10	7.3	5.61	0.49	2.69	10.31	48	23	29	36
T. Asia*	1.4	0.13	18	10.4	0.4	5.5	17.8	34	28	38	47
Japan	3.3	0.29	57	9.3	0.4	2.8	12.9	49	30	21	61

*Kawaguchi and Kyuma 1977

Key Concept 3: Sawah and Forestry Ecotechnology Development

3.1 Definition of Ecotechnology

The focus of research activities is to develop suitable Ecological Engineering Technologies (Eco-Technologies) for integrated watershed/rural development by increasing sustainable productivity and at the same time improving the total water cycling in a given watershed. Eco-technologies should be adaptive to indigenous farming systems and rural village society. Various areas of benchmark watersheds, from 100 to 10000 ha, which is located 40-50km northwest from Kumasi, has been selected for basic agro-ecological survey. Within these watersheds, various sites for sawah, including Adujama, Potrikrom, Biemtetrete, and Biemso No. 1 and No. 2 villages were selected for detailed survey and intensive field testing.

The term, Ecological Engineering Technology (Eco-Technology), is defined here as a ecology-based sustainable farming technologies viable to local socio-cultural systems to increase farming productivity and to improve the environment. The ecotechnology developed in this project should be adoptable to be used by local farmers to control water and to conserve water and soil. Leveling, bunding, and construction of canal and head dyke are the example of such ecotechnologies, which can be practiced as an extension of agronomic practices using locally available tools and materials. Forestry technology, such as nursery preparation and management, contour bunding and planting of the useful trees, regeneration of the water and soil conservation, and forest establishment for carbon sequestration against global warming are the examples of the ecotechnology which this project are going to develop. The ecotechnology will be the key technology to attract local farmers active participation for the improvement of basic agricultural infrastructure, such as irrigation and soil conservation measure. The ecotechnology will be able to integrate partly between agronomy and agricultural engineering.

3.2 Regeneration of Africa and the earth through the sawah and the forest based ecotechnology in 21st century

In tropical environment and ecology, sawah based farming systems have fully proved to be long term sustainable. Since sustainable productivity of one hectare of Sawah is equivalent to more than ten hectares of upland fields, development of 1 ha of sawah makes available the field for the afforestation in the degraded upland field in Africa. The total potential area for new sawah development in Africa is estimated to be 20 million ha. Thus, if we can develop 20 million ha of sawah in the next 50-100 years, we can open the afforestation area of 200 million ha, the forest can fixed carbon dioxide one billion ton annually in next 50-100 years which is roughly equivalent to reduce 10% of the present global carbon emission. Since it is estimated that such carbon fixation can sell no less than 100 dollars per ton in quite near future, global market price will be no less than 100 billion dollars annually in the next 50-100 years.

Key Concept 4. Field Work Principle: Participatory Approach for Ecotechnology Research and Development and Extension

4.1 Field Work and Ecotechnology Research and Development

Farmers field and forest are the place where major research activities for ecotechnology development and extension are done. Although the results of experimental fields and laboratory works at the research institutes will be applied, field-work should come the first.

4.2 Participatory approach and the ecotechnology development and extension: Ecotechnology comes the first, then participatory approach.

Various water management ecotechnologies will be researched and developed in collaboration with farmers, designed based on the local ecological and socio-economic conditions, constructed or practiced with the farmers' participation, and tested by ecological and socio-economic view points. In this joint study project, researchers proposed the possible various ecotechnology options to farmers. This is expecially necessary for our two main target fields, sawah based ecotechnology in lowland and forestry based ecotechnology on the upland. Field ecotechnology development comes first, then participatory approach follows. The participatory approach in this joint study project applied this principle. Farmers' participation at various steps of the ecotechnology research, development, design, construction and practices, testing and evaluation were essential. Therefore the farmers participated in this project was not only beneficial but we also worked as partners. At the same time the farmers participation was like on the job training (OJT) and furthermore an extension.

The main goal of the project is presented in Fig. 2.

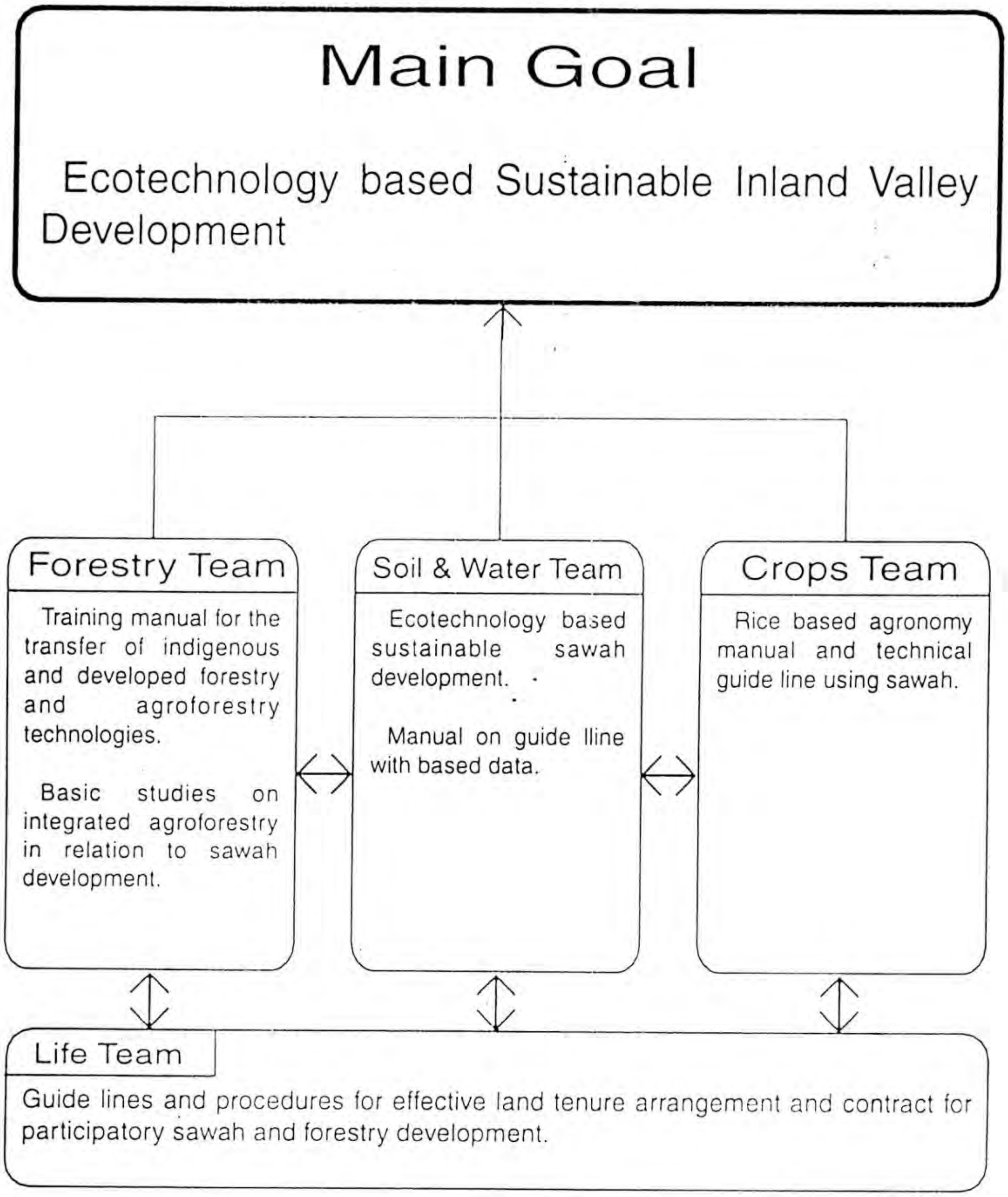

Fig. 2 Main goal of the project.

PROJECT OVERVIEW
BY
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Introduction

Rice is an important food crop ranking next to wheat in terms of imported food crop. Since the self-sufficiency rate of local rice production is less than 40% scarce foreign exchange is utilized to meet the growing total consumption. It is estimated that within the next ten years, consumption of rice would reach between 400,000 – 480,000 metric tons. This would require that local rice production should be increased to more than 600,000 metric tons, if self-sufficiency as envisaged under the nation's Vision 2020 is to be attained.

In Ghana, rice is produced in all the ten regions covering the major ecological zones. Four main rice growing systems available are:

i) Rainfed upland
ii) Rainfed lowland/hydromorphic iii)
iii) Inland valley swamps and valley bottoms and
iv) Irrigated paddies.

The first two ecologies account for nearly 75% of production area, the inland valley swamps (IVS) represent 23% and the irrigated paddies only 2% of rice production area.

With the increasing awareness of the limited potential for intensification of rice production in the uplands the thrust of rice research sine 1989 has been on the sustainable development of profitable technologies and an enabling policy environment that would enable rice farmers to utilize the IVS for rice and rice-based cropping systems. This would reduce the pressure on the rapidly degrading uplands. The IVS including the valley bottoms and flood plains constitute an important agricultural hydrological asset at the local, regional and national level that can contribute to future food security and poverty alleviation. There is approximately 1.0 million hectares of inland valleys in the country. Considering the success of the Green Revolution in South-East Asia and their experience in the development of paddy fields, using the integrated watershed management approach, assistance was sought from the Japanese Government to assist in developing simple low cost and environmentally friendly technologies for managing our inland valleys.

In August 1997, the Governments of Ghana and Japan through the Council of Scientific and Industrial Research (CSIR) and Japan International Cooperation Agency (JICA) signed a joint technical agreement establishing the Project on Integrated Watershed Management of Inland Valleys in the Republic of Ghana.

Project Objective
The main objective is the development and testing of environmentally friendly and sustainable technologies based on integrated watershed management and participatory approach for the production of rice and rice-based crops, animals and fish by resource- poor farmers cultivating the inland valleys.

Study Framework
To achieve this objective there is the need to gain an in-depth understanding of such dynamic processes as water and nutrient fluxes, land cover and landuse dynamics and socio-economic changes at the watershed level. Studies are therefore being carried out in forestry, soil and water management, crop production and socio-economics, which will all, lead to finding an option balance between the different use functions. Technologies developed would thus be sustainable. The studies, located at Adugyama, Potrikrom, Biemso No1 and Biemso No2 all in the Ahafo Ano South District (Fig.1), are organized along the following four main themes:

1. Soil and Water
- Water balance studies
- Design, construction and testing of SAWAH systems.
- Water table monitoring along strategic transects.
- Land use monitoring.
- Fertility and water quality monitoring.
- Soil characterization.

2. Forestry
- Integrated agro-forestry for sustainable development in small inland valleys.
- Development of community and private nurseries.
- Reforestation for timber production and environmental amelioration.
- Woodlots for firewood and charcoal production.

3. Crop Production
- Screening crop species and varieties for adaptability to Sawah conditions.
- Development of appropriate and sustainable rice and rice-based cropping system for the Sawah.

4. Life
- Baseline survey on landuse system, major farming, forestry, and water-borne diseases.
- Baseline survey on marketing, preservation and post-harvest issues of rice production.
- Socio-economic monitoring and evaluation of Sawah technologies.
- Adoption and impact analysis of Sawah technologies.

Technology Transfer
Technology transfer activities would be conducted by all members from Soil and Water, Forestry, Crop production, and Life teams.

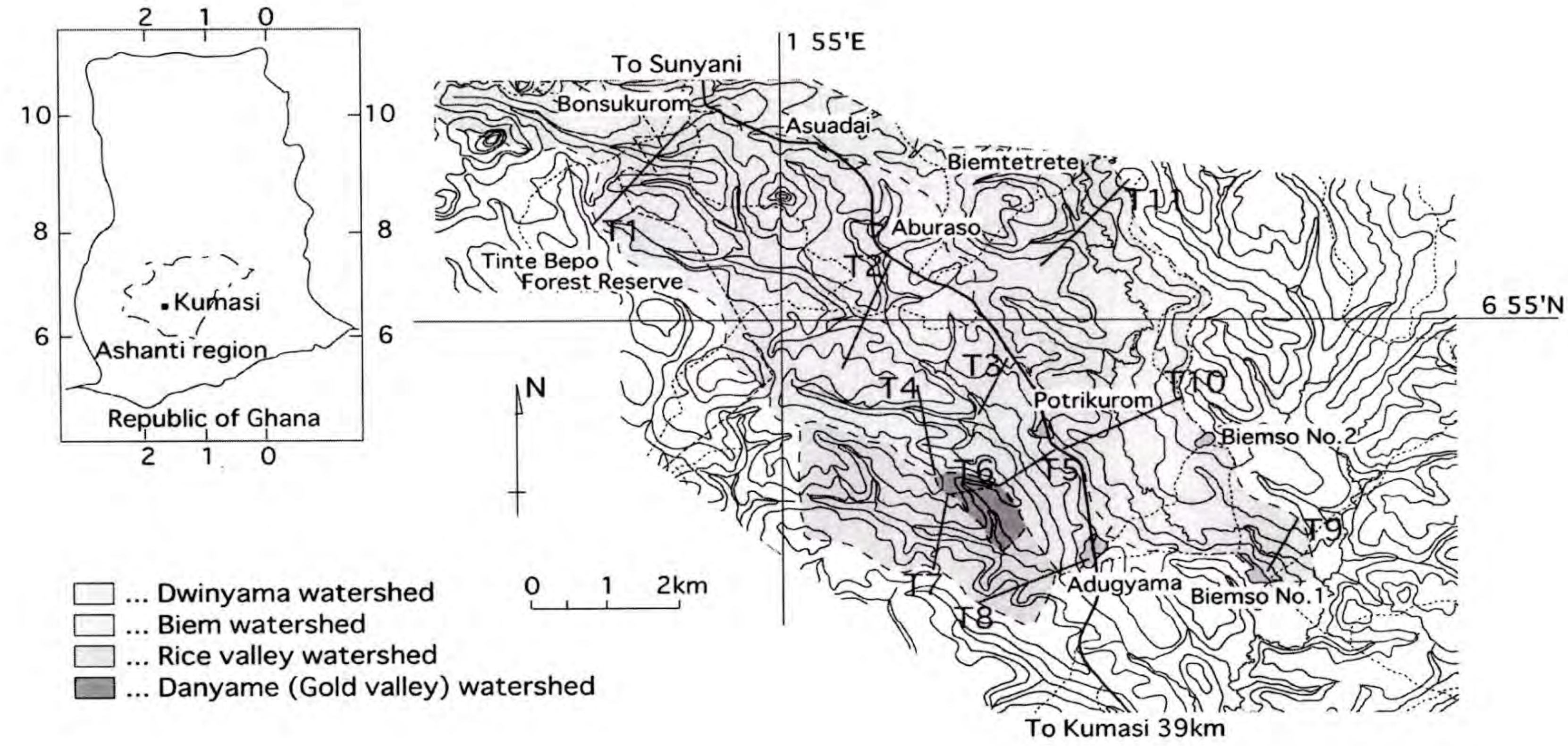

Fig.1 **Project Area showing sawah demonstration sites.**

Major achievements.

- The main thrust has been the selection, design and construction of different Sawah systems at Adujama, Potrikrom and Biemso.
- Farmers in these villages have been introduced to improved crop production practices resulting in rice yields of more than 3 tons/ha.
- Cultivation of cowpea after rice under Sawah appears promising.
- Plantation of different timber species has been established.

Informal studies on the traditional farming systems and land use have been carried out at Adujama and Biemso No.1. There has also been marketing studies and socio-economic analysis, all of which is on going and would be continued in the next quarter of the year.

Future Thrust (2000-2001)

- Comparative studies of the different Sawah systems at Adujama, Potrikrom and Biemso with the traditional system. All activities will be started simultaneously for effective comparison.
- Hydrological monitoring of the different Sawah systems.
- Physical and chemical monitoring of soils under Sawah and traditional systems.
- Determination of nutrient fluxes from the uplands to the valleys.
- Comparison of the various agronomic packages under different Sawah and traditional systems.

Socio-economic evaluation of Sawah and traditional farming systems.

- Established of community nursery at Biemso and Adujama.
- Development of new sites if requested by farmers.
- Report writing and publication of final Project Report.
- Development of training manual on Sawah technology.

INVITED PAPERS

CONSTRAINTS AND OPPORTUNITIES FOR RICE CROPPING IN WEST AFRICA'S INLAND VALLEY LOWLANDS

By

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ABSTRACT

Determinants for use of lowlands for rice cropping and investment in water control measures were determined through surveys in 179 villages and major cities in central Côte d'Ivoire. Results indicate that market access and population pressure are driving forces for lowland use. Major determinants for investment in water control measures were land ownership, distance to major cities and the number of immigrants active in the lowlands. Possibilities to improve rice productivity and profitability along a water control gradient from rainfed to irrigated lowland were investigated in the same region. Average farmer yield in the rainfed area was 3.9 t ha^{-1} and in the irrigated area 4.1 t ha^{-1}. Rainfed yields were close to irrigated yields, despite much lower input use. We attributed this to poor soil fertility levels at the irrigated site. Improved soil fertility and weed management resulted in a 1 t ha^{-1} yield gain over farmer practice, in both rainfed and irrigated systems. Such improvements were not associated with higher risk and highly profitable, with value/cost ratios > 5 in the rainfed lowlands and without additional costs in the irrigated lowlands. Our research suggests that providing farmers with information on best-bet management of available resources is critical.

Introduction

The lowland ecology in West and Central Africa has great potential for rice production development in the sub-region. Mainly sheltered in inland valley bottoms, there is a potential of 30 to 50 million hectares in West and Central Africa alone that can be targeted for dissemination of improved rice production technologies. About 10 to 25% of inland valley lowlands are being used (mainly for rice), and without water control measures, rice yields are usually low, i.e. about 1 t ha^{-1} (Andriesse et al., 1995). Potential yield, limited by solar radiation and temperature only has been estimated at 7 to 8 t ha^{-1} in the savannah and humid forest ecologies (Becker et al., 2001). There is, therefore, great potential for expansion of the lowland area used for rice, and for improving yields, as the yield gap between actual and potential yields is very large.

Inland valley lowlands have usually relatively fertile soils. They are generally considered as robust, in contrast to the more fragile uplands. The single most important biophysical constraint to lowland development is lack of water control. With improved water management, intensification becomes possible, i.e. it may no longer be too risky for farmers to use external inputs, such as fertilizer. Increased use of inputs and improved input use efficiency may lead to higher and more sustainable rice yields. Better water control may also open up possibilities for diversification, such as aquaculture, or growing other crops, like vegetables in the dry season on residual moisture, or using irrigation water from a shallow groundwater table. Water control measures may range from simple bunding to more sophisticated control measures based on dams or stream derivation. Other important biophysical constraints, next to water control, are weed infestation, poorly adapted rice cultivars, iron toxicity, and pest and disease infestation levels (e.g. Jamin and Andriesse, 1993).

Important socio-economic factors are: organizational problems at the village level, access to capital and labour, land tenure, access to input and output markets, human health concerns, socio-cultural perceptions related to inland valley use, lack of agricultural machinery for land preparation and harvesting, and competition with other activities. (E.g. Lidon and Legoupil, 1995 and Jamin and Andriesse, 1993).

Wopereis et al. (1999) and Donovan et al. (1999) showed that sub-optimal soil fertility and weed management in irrigated systems in the Sahel and the Sudano-savanna region of West Africa resulted in average losses of 70% of applied nitrogen (N), and, therefore, large yield losses. They also identified N as the most limiting nutrient to rice growth in irrigated lowlands, before phosphorus (P) and potassium (K). Häfele et al. (2000) demonstrated that with improved soil fertility and weed management an average yield gain of 2 t ha^{-1} could be obtained in irrigated systems in Mauritania and Senegal, resulting in an increase in net revenues of 40 to 85% to farmers' practice. Wopereis et al. (2000) used the term integrated crop management to indicate the need to provide farmers with crop management options (baskets of choices), adapted to their needs, from land preparation to harvest and post-harvest activities. They proposed a complete 'integrated crop management basket' for irrigated systems in the Sahel. Similar work is needed for rainfed and irrigated lowlands in the savanna and humid forest zones.

Rice farmers in irrigated lowlands in the savanna and humid forest zones are usually given 'blanket fertilizer recommendations'; i.e. often a combination of 100 kg urea ha^{-1} applied in two equal splits and 200 kg NPK composite basal fertilizer ha^{-1}. Blanket recommendations are questionable, as best-bet soil fertility management will depend on many factors, such as native soil fertility, target yield, potential yield, farmer crop management, and fertilizer and paddy prices (Häfele et al., 2001). Knowledge to develop more site-specific recommendations is usually not available. However, the current blanket recommendation of 100 kg urea ha^{-1} and 200 kg NPK composite fertilizer ha^{-1} seems not to give enough emphasis to N. We hypothesized that a recommendation of 200 kg urea ha^{-1} and 100 kg NPK ha^{-1} would be more appropriate, and cheaper, as NPK fertilizer is usually more expensive than urea.

A first objective of the work reported here was to obtain information on the distribution and use of lowlands, and their diversity in terms of water control technologies as well as land ownership in central Cote d'Ivoire. A second objective was to investigate the magnitude of the yield gain that can be obtained by improving soil fertility and weed management in farmers' fields in inland valley lowlands with different degrees of water control.

Materials and methods

Village survey

We selected 11 out of 19 districts 'sous-prefectures' in the Bandama valley region in central Côte d'Ivoire: i.e. Botro, Bouaké, Brobo, Diabo, Djébonoua, Katiola, Sakassou, Béoumi, Bodokro, Dabakala and Boniérédougou. We randomly selected 179 villages from a total of 857 villages (i.e. about 20%) occurring in this region. From December 1999 to May 2000, we visited all sample villages and obtained information on lowland use, ownership, water control methods, and general information, such as presence of dispensary, school, water pumps etc. We will refer to lowlands in or near villages as rural or village lowlands. A large number of lowlands located in capital cities of each district were also included in the survey. We will refer to these lowlands as urban lowlands. More details can be found in Sakurai (2001).

Field trials

Field trials were conducted in rainfed and irrigated rice growing areas in the district of Bouaké in the Bandama valley region in central Côte d'Ivoire, along the main road from Bouaké to Katiola during the 2000 wet season (July – December). The irrigated rice area that was studied is located near the village of Yebouekro. The irrigation scheme (110 ha) has complete irrigation and drainage facilities and was developed with funding from the government of Japan. Irrigation is by gravity and dam-based. Current recommended fertilizer rate is 100 kg urea ha^{-1} in two splits (one and two months after transplanting) and 200 kg NPK composite fertilizer (10% N, 20% P_2O_5 and 20% K_2O) ha^{-1} as basal.

The rainfed area is located near the village of Bamaro. Fields are bunded, but no good drainage canal system exists, often resulting in severe floods at the start of the wet season. Farmers do not use any fertilizer, and hand weed. Yebouekro and Bamaro are at about 3km distance. Options to improve soil fertility and weed management were discussed with farmers and extension staff from national extension agencies at the onset of the 2000 wet season. For the irrigated area the following treatments were identified:

TF: farmers' practice

T1: farmers' practice but new recommended fertilizer management: 200 kg urea ha^{-1} in two splits, i.e. at mid-tillering and panicle initiation, and 100 kg complex NPK fertilizer (10-20-20) as basal.

T2: farmers' practice but recommended weed management: early application of herbicide at 20 DAT

T3: new recommended fertilizer and weed management (combining T1 and T2)

For the rainfed area the following treatments were identified:

TF: farmers' practice

T1: farmers' practice but new recommended fertilizer management: 100 kg urea ha^{-1} at mid-tillering and panicle initation, in two equal splits

T2: farmers' practice but recommended weed management: early manual weeding at 27 DAT

T3: new recommended fertilizer and weed management (combining T1 and T2)

Fields of collaborating farmers were split in two. On one half, the farmer managed his field according to his own itinerary. In the other half, the T1, T2 and T3 treatments were installed. Size of these subplots varied per field, but was at least 100m^2. At rice maturity 100 m^2 in the cental area of each subplot was harvested and threshed, and grain yield and grain water content determined. In addition, a separate 1m^2 area was sampled for yield component analysis in each subplot. All grain yield results were corrected to 14% water content. All fields were harvested at physiological maturity, often before farmers harvested their fields themselves. Losses due to late harvesting are, therefore, not included in the data provided here. In the irrigated area, farmers were asked not to apply fertilizer on part (5m x 5m) of their fields. These so-called 'T0 plots' were harvested at rice maturity as well, and used as a proxy for soil fertility status. Soil samples were taken (10 composite samples in each subplot) before the start of the season for analysis of pH, and plant available N, P and K.

Farmers were interviewed throughout the growing season about the management practices employed on the farms within the study. Observations included field size, use of basal fertilizer, timing of crop management interventions, as well as the dosage and cost of inputs, services, and labour and paddy price. Partial budget techniques (Crawford and Kamuanga, 1991) were used to compare the treatments in terms of their costs and returns.

Results and discussion

Village survey

Out of the 179 villages surveyed, 152 (i.e. about 85%) had one or more lowlands. A total of 101 villages used the lowlands for cultivation during the 1999WS, and 84 of the villages grew rice. Most of the other villages produced vegetables. Out of the 152 villages with lowlands, 121 villages had grown rice in the past. Since only 84 villages grew rice in the 1999WS, this means that almost one fourth of the villages had stopped growing rice.

We divided the 152 villages with lowlands into two groups: one group contained the villages that used lowlands for cultivation and the other one contained the villages that did not use lowlands for cultivation. Table 1 gives average characteristics of both groups. We found that villages cultivating lowlands are located closer to the capital city of the district, are more populated and have more immigrants. In addition, dispensaries were established earlier in villages using lowlands than in villages not using lowlands. These results suggest that developed and populated villages tend to use lowlands, possibly due to scarcity of upland areas.

The total number of lowlands within reach of the 152 lowlands was 285 (Table 2). Of these 285 lowlands, 127 were used for rice in the 1999WS, and 37 were used for vegetable production.

Table 1 Characteristics of sampled villages.

	All the villages with lowlands	Villages using lowlands	Villages not using lowlands	Significantly different or not[2]
No. of villages	152	101	51	n.a.
Village location				
Distance to SP (km)	15.1	13.9	17.4	1.83*
Travelling time to SP (min)	53.1	50.4	58.4	1.02
Walk to SP (%)	44.7	45.5	43.1	0.08
Distance to Bouaké (km)	44.1	45.0	42.1	0.61
Population				
Village population as of 1988	394	430	321	2.15**
Village of Baoulé (%)	79.6	81.2	76.5	0.46
Number of immigrants	14.1	19.0	4.3	2.05**
Village facilities				
Primary school (%)	51.3	54.5	45.1	1.19
Years since primary school	14.2	15.4	12	1.11
Dispensary (%)	13.2	14.9	9.8	0.76
Years since dispensary	1.25	1.6	0.6	1.65*
Hand pump (%)[1]	82.9	78.2	92.2	4.64**
Years since first hand pump	14.9	14.5	15.6	0.57
No. Of functioning hand pumps	1.19	1.2	1.18	0.35
Public water supply by SODECI (%)	7.9	9.9	3.9	1.66
Market (%)	11.2	11.9	9.8	0.15
Market days in a week (1-7)	1.8	1.7	2.1	1.32
No. Of shops	1.4	1.6	1.1	1.22

[1]If SODECI is operating in the village, this variable is zero even if there exist hand pumps.
[2]When two means are compared, the numbers in this column are t-statistics and when two proportions are compared, the numbers in these columns are Pearson's Chi-square statistics. ** and * indicate significance levels of 5% and 10% respectively

Table 2 Land use, ownership and water control methods used in urban and village lowlands in the Bandama region in central Cote d'Ivoire.

Variable	Urban lowlands		Village lowlands	
	No.	% (of total number of lowlands sampled)	No.	% (of total number of lowlands sampled)
Total number of lowlands sampled	73	100	285	100
Land use				
Lowlands used for rice in 1999WS	72	99	127	45
Lowlands used for rice in 1999WS or in the past	72	99	224	79
Lowlands used for vegetables in 1999WS	64	88	37	14
Ownership				
Owned by government	15	21	0	0
Owned by village or village chief	0	0	117	41
Owned by individuals	53	73	149	52
Owned by absentees	7	10	21	7
Water control for rice				
Bunding	63	86	61	27[1]
Canals	38	52	58	26[1]
Tanks	3	4	16	7[1]
Modern dam	8	11	10	5[1]

[1]Percentage is calculated per number of lowlands used for rice in 1999WS or in the past

As many as 224 lowlands were used for rice in the past, indicating that rice cropping is being abandoned. Farmers blamed this on lack of water and increasing problems with weeds, possibly due to water scarcity. In contrast, almost all urban lowlands produced rice, and most of them produced vegetables as well. None of the sample urban lowlands had been abandoned for rice cropping. This seems to indicate that other factors contributed to the abandonment of rice cropping in the village lowlands as well, such as access to markets, opportunity for cash income from vegetable production and off-farm activities, factors that are mostly lacking in rural villages.

Land is usually not a private property in sub-Saharan Africa, and hence there are few real 'land owners'. We use 'land owners' in our analysis to indicate who controls the use of lowlands. Ownership of the lowlands can be largely classified into four types of land ownership: local government, village or village chief, individuals living in the village or town, and individuals living outside the village or town (absentee owners). In our survey, more than 50% of rural lowland was owned by individual persons living in the village, and about 30% of the lowlands were owned by the village or village chief. In the urban lowlands, local government authorities owned about 20%, the remainder was mostly owned by individuals living in the city.

Water control is the key factor to increase yield and reduce risk in lowlands. In our village sample, 224 lowlands were used for rice in the past. Out of them, only 10 lowlands are irrigated by water stored behind modern dams. We found tanks (water storage behind small dams constructed by villagers) in 19 lowlands. Canals and bunds were the most important technologies to control water and were constructed more often in urban than in rural lowlands. Our results imply that rice production in urban lowlands is more intensified than in village lowlands.

We determined what drives adoption of canals and bunding using probit regression models. Regression results revealed (Table 3) that canals are more frequently constructed in lowlands owned by absentee landlords, located closer to Bouaké and situated in non-Baoulé villages. Bunds are more frequently constructed in lowlands owned by absentee landlords and situated in non-Baoulé villages. Bunding was also positively correlated with the number of immigrants. Hence we can conclude that the type of land ownership does affect investment in water control technologies in lowlands. Individualized ownership by absentee landlords encouraged investment, while other types of ownership discouraged it.

Land ownership of urban lowlands can largely be classified into two types: ownership by local government authorities and individual ownership. The regression analysis showed (Table 4) that local government ownership is a significant positive factor associated with canal construction. In addition, migrant rice farmers construct canals more often than local rice farmers. No driving factor was found for bund construction in urban lowlands. This is probably due to the fact that most (55 out of 64) urban lowlands have bunds, regardless of ownership and other characteristics.

Field experiments

Farmers' practice (TF) in the irrigated system resulted in an average rice grain yield of 4.1 t ha^{-1}.

Table 3 Determinants of water control technologies in 213 village lowlands, of which 43 have canals and 49 are equipped with bunds.[1)]

	Canals	Bunds
Independent Variables		
Land Ownership		
Village	Not significant	Negative ***
Village Chief	Negative ***	Negative ***
Individual Villagers	Negative ***	Negative ***
Absentees	Positive **	Positive ***
Lowland Characteristics		
Distance from Village (km)	Not significant	Not significant
Size of Lowland (ha)	Not significant	Not significant
Village Location		
Distance to Bouaké (km)	Negative ***	Not significant
Population		
Village Population	Not significant	Not significant
Baoulé village	Negative ***	Negative ***
Number of Immigrants	Not significant	Positive **
Village Facilities		
Years since Primary School	Not significant	Positive *
Market	Not significant	Not significant

1) Probit model is used for the estimation of coefficients. ***, ** and * indicate significance levels 1%, 5% and 10% respectively.

Table 4 Determinants of water control technologies in 64 urban lowlands, of which 31 have canals and 55 are equipped with bunds.[1)]

	Canals	Bunds
Independent Variables		
Land Ownership		
City Government	Positive **	Not significant
Individuals	Not significant	Not significant
Lowland Characteristics		
Distance from City Centre (km)	Not significant	Not significant
Size of Lowland (ha)	Not significant	Not significant
Utilization Rate (%)	Not significant	Not significant
Migrant farmers	Positive **	Not significant
Number of rice farmers	Not significant	Not significant

1) Probit model is used to explain the two variables (canals and bunds). ** indicates significance level 5%.

Exact crop management practices followed by farmers have not yet been compiled. Yields were, however, very variable and ranged from 2.1 t ha^{-1} to 7.7 t ha^{-1}. Grain yield was increased on average by 0.7 t ha^{-1} by applying the new recommended fertilizer rates (T1). Our recommended weed management practice (T2) did not result in a significant yield gain; average yield was even slightly lower than farmers' practice. Improving both soil fertility and weed management (T3) resulted in an average yield gain of 1.1 t ha^{-1}. The coefficient of variation for T3 was considerably lower than for farmers' practice, indicating that with the recommended practice higher and more stable yields were obtained.

Farmers' practice (TF) in the rainfed system resulted in an average grain yield of 3.9 t ha^{-1}. Exact crop management practices followed by farmers have not yet been compiled. Yields varied from 2 t ha^{-1} to 6.5 t ha^{-1}. Grain yield was increased on average by an average 0.6 t ha^{-1} by applying the new fertilizer management strategy (T1). The new weed management strategy (T2) did result in a slight but not significant yield gain of 0.2 t ha^{-1}. Improving both soil fertility and weed management (T3) resulted in an average yield gain of 0.9 t ha^{-1}.

Yield variability in the rainfed system was considerably lower than in the irrigated system. This is surprising, especially because fields in the rainfed system were severely damaged in the early growth stages by flooding and case worms. Rice fields recovered, however, very well. The large variability in the irrigated system may be due to the large variability in sowing dates, and resulting spikelet sterility due to cold for late sowing dates. Sowing dates ranged from mid-July to early October among the 16 sample farmers in the irrigated area. This aspect will be investigated in more detail as soon as the yield components of the different subplots have been analyzed.

T0 yields in the irrigated system were on average only 2.6 t ha^{-1}, indicating that soils were relatively poor. This may be due to the land scraping and levelling that was done to install the scheme. Analysis of the soil samples will give a better insight in the differences between soil fertility in the rainfed and the irrigated sites. T0 yields in the irrigated area can be compared with farmers' yields in the rainfed area, where no fertilizer was applied. The difference is a striking 1.3 t ha^{-1}, indicating that Bamaro farmers profit from a much more fertile soil than Yebouekro farmers. Differences in native soil fertility need to be taken into account when giving fertilizer recommendations to farmers. Future research will look into possibilities of using the framework for soil fertility management developed by Häfele et al. (2001) for irrigated systems in the Sahel in the rainfed and irrigated lowlands of the savanna and humid forest zones.

A first rough financial analysis of the T3 treatment compared to the TF treatment revealed that improved soil fertility and weed management in both rainfed and irrigated systems was highly profitable. The cost/benefit ratio for Bamaro (rainfed area) was 5.4, i.e. much higher than the threshold of 1.5 to 2 recommended by Crawford and Kamuanga (1991). Yield gains in the irrigated system with the T3 treatment were obtained without additional costs. Our research suggests that providing farmers with information on best-bet management of available resources is critical.

Table 5 Grain yields (t ha^{-1}, 14% water content) obtained at the experimental sites in Yebouekro (irrigated) and Bamaro (rainfed), Bandama valley, central Côte d'Ivoire. T0: non-fertilizer plots at the irrigated site in Yebouekro. TF: farmers' practice; T1: farmers' practice, but recommended fertilizer management; T2: farmers' practice, but recommended weed management; T3: recommended fertilizer and weed management. Treatments in a row followed by a common letter are not significantly different according to the Duncan Multiple Range Test with $\alpha = 0.05$.

	T0	TF	T1	T2	T3
Rainfed area					
Yield (t ha^{-1})		3.9b	4.5a	4.1b	4.8a
SD (t ha^{-1})		0.9	0.9	0.9	0.9
Irrigated area					
Yield (t ha^{-1})	2.6c	4.1b	4.8a	3.9b	5.2a
SD (t ha^{-1})	1.4	1.6	1.3	1.5	1.1

Table 6 Economic evaluation of improved soil fertility and weed management (T3) using partial budgeting at the irrigated site of Yebouekro and the rainfed site of Bamaro, Bandama valley, Central Côte d'Ivoire. TF: farmers' practice; T3: recommended fertilizer and weed management.

Parameter	TF / T3	Units	Bamaro (rainfed)	Yebeoukro (irrigated)
Season			WS 2000	WS 2000
No. of farmers			16	16
Yield	TF	t ha^{-1}	3.9	4.1
	T3	t ha^{-1}	4.8	5.2
Additional costs[1]		1000CFA ha^{-1}	21	-1
Gross added product[2]		1000CFA ha^{-1}	114	134
Treatment net benefit[3]		1000CFA ha^{-1}	93	135
Value / Cost ratio[4]			5.4	n.d.[5]

[1] Additional costs: cost of the treatment – cost for the non-controlled treatment
[2] Gross added product: paddy price * yield increase – additional costs caused by higher yields
[3] Treatment net benefit: gross added product – additional costs
[4] Value / Cost ratio: gross added product / additional cost
[5] n.d.: not determined, because additional costs are negative

Conclusions

Market access and population pressure were two major factors affecting the use or non-use of lowlands. Individualization of land ownership has taken place in villages with better access to markets and higher population density. For the rural lowlands, individual ownership by absentee landlords encouraged investment. Canals and bunds were more frequently constructed in lowlands owned by absentee landlords, located closer to Bouaké and situated in non-Baoulé villages. Bunds were positively associated with the number of immigrants and level of education at village level. In the urban lowlands, land ownership by local government authorities were shown to be a positive factor for canal construction. In addition, migrant rice farmers are more likely to construct canals. No significant determinant was found for bund construction, probably because most urban lowlands have bunds.

Improved soil fertility and weed management was shown to be highly profitable for both irrigated and rainfed farmers in this region. Yield gains of 1 t ha^{-1} were obtained in both rainfed and irrigated systems. Partial budgeting showed the profitability of the improved management practices. Our research illustrated the importance to develop best-bet integrated crop management recommendations for low, medium and high input lowland systems.

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PROJECT PAPERS

Details all final forms of full papers were uploaded in this home page, i.e. JICA/CRI Sawah Project final report 2001: Integrated watershed management of inland valleys in Ghana and West Africa

"THE WAY FORWARD"

'The way forward'
DISCUSSION SESSION

Summary by

Marco Wopereis,

Farmers have stressed the need to have adequate small-scale machinery to develop inland valley lowlands into sawahs. Especially power tillers are needed for puddling and levelling. They mentioned frequent breakdown of power tillers and the need for training on repairs. With increased production the need is felt for small-scale equipment for harvesting and post-harvesting (threshing and milling). One NGO present has expertise in post-harvest issues (Technoserve). Access to credit is a major problem for farmers. It was proposed to include the banking sector more in project execution to overcome credit problems.

The need was felt to implicate national extension authorities and NGOs more in the next phase of the project. They should be part of the project from the design stage onwards.

There was consensus that in a next phase, the project should focus on two major components: (*i*) adaptive research and technology dissemination (scaling-up) and (*ii*) strategic research on key issues that are still unsolved. Strategic research would result in technologies or information that could be fed forward into the adaptive research and technology dissemination component.

The current project has developed 4 hectares of sawah lowland. Activities were focused on this small land area for good reasons, as the project focused on research. Scaling up would imply moving away from the current demonstration sites to more on-farm activities. This scaling-up activity concerns sawah development but potentially also other technologies developed within the first phase of the project or outside the project. To enable effective diffusion of the sawah technology, there is a need to determine the potential for sawah development in Ghana within the humid forest agro-ecology and in other agro-ecologies in Ghana. Moreover, guidelines (i.e. brochures in simple language) are needed. Such brochures need to explain the technology but also need to include information on the financial side, i.e. investments needed and a cost/benefit analysis. Diffusion will also require the organization of training courses ('train trainers'), and adaptive participatory on-farm research.

The need was felt to link diffusion activities to other initiatives on inland valley development, such as the FAO special program for food security or the inland valley consortium. The importance of rice for Ghana was emphasized and it was stated that the Ghana government wishes to decrease rice imports drastically. It was, therefore, proposed that Ghanaian research institutes consider bundling their forces and establish a rice centre for focused research and training on this important food crop.

With sawah development, application of fertilizer and insecticides are likely to increase. Biodiversity, i.e. flora and fauna in the inland valley lowlands will be affected and hydrology changed. These ecological implications need to be studied. Strategic research is clearly needed on such environmental and biodiversity issues, farmers' health and agricultural productivity and policy issues (especially related to land tenure). Other complementary technologies to the sawah technology that were presented in the workshop, such as aquaculture, agro-forestry, soil fertility and weed management and the use of cowpea after rice still require more research. Ghana universities can contribute to such research activities through the involvement of MSc and PhD graduate students. Strategic research should ideally be conducted at the sites that were used in the first phase of the project, i.e. in the Mankran area, where the Inland Valley Consortium has also their key site. This would ensure optimal use of existing information and data.

The need was felt for the establishment of an effective database and information management system on inland valley development to share results among scientists and extension agents, and to ensure that data are not lost. Such a database would also stimulate regional interaction on inland valley development, for example with the other IVC member countries, as it would facilitate data and information exchange. The database could also be used to feed into simulation models. If properly validated, simulation modelling can speed up research, and reduce research costs.

Summing up, there was consensus among the workshop participants that the way forward is to develop a project that consists of two major components: a strategic research component and a strong development component. The strategic research (R) component would ensure that sustainability issues related to sawah development are further investigated and that remaining key research issues are addressed. The development component (D) would ensure that proven technologies, such as the sawah system, are made accessible to many more farmers, in a participatory way, involving farmers, NGOs, national research and extension agencies, and financial institutions from the start. The emphasis of the project would be on the D side.

CLOSING CEREMONY

CLOSING REMARKS
BY
Mr. Shiro Nabeya,
The Resident Representative Of JICA In Ghana

Mr, Chairman, Distinguished Scientists, Ladies and Gentlemen.
For the past three days I have keenly listened with interest to statements by politicians and presentations by you scientist on this workshop. The objective of the workshop for the past three days has been for scientist, farmers and other stakeholders to examine the outcome of our joint research on Integrated Watershed Management in Inland Valleys in relation to improved rice development.

Mr. Chairman, according to the Director-General of the CSIR, Prof. W. S. Alhassan, the potentials of inland valleys for rice production has long been recognized and a series of research work have already been carried. He cited some of the constraints in the inland valleys development as ***lack of appropriate water management, water-borne human diseases etc.***

The West Africa international institutions – WARDA, IITA have carried out similar research in inland valley bottoms for efficient agricultural production. There is already an inland valley research consortium (IVC) within WARDA. This emphasizes the great potential and importance of inland valley bottoms development for efficient and increased rice production.

The main goal of the sawah technology is to promote sustainable production systems at watershed level ecologically, socially and economically. The uniqueness of the sawah project is its integration especially with recognition of beneficiary participatory approach. The farmer involvement approach in the sawah technology development gives on-the-job training to the farmer. This makes the technology practical and adaptable by farmers.

This joint research on sawah is not an academic research exercise, but a practical demonstration on improving the lives of poor rural farmers. The improved incomes farmers derive from the sawah application have dawned on farmers to intensify the use of inland valleys especially in the piloted project areas.

According to the CRI survey, there is an upsurge in the use of inland valleys for rice production especially in Ashanti Region. Sawah has the potential not only in Ghana but also in the West African sub-region, for self-sufficiency in rice production and food security.

Mr. Chairman, this forum has not only examined the sawah as an ecotechnology but has also shared comparative ideas among stakeholders from WARDA, IITA and Ghana's CSIR. These ideas may be useful to the Ghanaian research institutions such as CRI, WRI, FORIG, MOFA, NGOs, farmers that etc who have participated in this workshop, for further improvement of the sawah technology, and vice versa.

Fortunately, the sawah project team will make guidelines for dissemination and application of the idea. These guidelines could be distributed to the stakeholders interested in the sawah technology.

It is my hope that the comments made by other scientists during the examination of the sawah technology, will be accepted in good faith by the sawah project team to enable them further improve upon this very important technology.

Ladies and gentlemen, it will take political will of the government of the Republic of Ghana and influence of research scientists to adapt and sustain the sawah technology. It is hoped that political statements in the opening ceremony will be realized.

I take this opportunity to thank the Ghanaian and Japanese scientists and all others who have participated in the sawah project. I also thank you all participants from WARDA, IITA and those from other African countries who have participated in the workshop and also for your valuable contributions. May you have a safe return home. Before closing, please clap your hands to all presenters and the workshop organizers.

Thank you very much. Medase.

CLOSING REMARKS
BY
Prof. E. Owusu-Bennoah,

Deputy Director-General, CSIR
(Agriculture, Forestry and Fisheries Sector)

Distinguished Ladies and Gentlemen,
It is a great honour to be asked to close this 3-day all important International Workshop on Integrated Watershed Management of Inland Valleys in Ghana – The Ecotechnology Approach.

The main goal of the project we were told was the development of sustainable production systems at watershed level, which allows intensification and diversification of the lowland production system and stabilising improved production system on the upland.

The results which have been produced under the project have been well presented and exhaustively discussed at this workshop.

I am particularly happy to see that scientists from different disciplines and Institutes have come together to work harmoniously on this project. I hope that this multidisciplinary and multi-institutional approach to doing research in this country would be sustained.

Ladies and Gentlemen, I am convinced that a lot has been learnt at the demonstration sites which should encourage us to move from the demonstration site to the on-farm. Unless this is done very quickly scientists will as usual be accused of shelving their scientific results in their laboratories to gather dust. A lot of resources have gone into this project and the Sawah technology should be transferred to farmers in the forest zone as early as possible. I wish to assure our scientists that the research component of Ghana Agricultural Sub-sector Services Investment Programme (AgSSIP) would support such useful technology transfer. You will recall the statement made by the Chief Director of MOFA that the present Government intends to reduce rice import by 50% by the end of the year. I believe that this is possible through science and technology. The Sawah technology can play a significant role to help the government achieve her noble target.

While recommending the Sawah technology, there are some gray areas which I suggest should engage the attention of scientists.
Firstly, the issue of the environment and biodiversity have not been properly addressed in the project. It is known that the Inland Valleys are the home to some important flora and fauna such as crabs, snakes, canes, raphia etc. These flora and fauna should be preserved for the present and the future generation. Should we destroy the rare flora and fauna in the inland valleys for the sake of rice production? What would be the long term effect of continuous application of agricultural inputs such as fertilisers and insecticides on the health of the Sawah practitioners?

Secondly, the problem of processing and marketing have not been actively taken into consideration, with the adoption of the Sawah technology, production of rice is expected to increase more than 50 folds. If this target is achieved then what happens to post-harvest problems of storage, milling and marketing of the produce? We are all very much aware of the frustrations rice farmers go through with the marketing of their produce. This should not happen to our Sawah practitioners. I wish to encourage this project not only to concentrate on the technology of producing rice in the inland valleys but that it should take on board other Institutes that are involved in processing and marketing of rice as well. It is high time that we adopt a holistic approach to solving problems associated with rice in this country.

Finally, ladies and gentlemen, let me appeal to the organisers of this workshop to consider publishing proceedings of this workshop for the benefit of those who were unfortunate to be here with us.

This workshop has been well organized and the contributions to the discussions of the various papers by participants had been excellent. Our foreign participants also made the workshop rich by sharing their experiences with us.

As we depart to our various countries and destinations, I hope we will carry with us the memory of good friendship that we have been able to establish among ourselves during the last three days.

Let me on behalf of the Director-General of CSIR thank the Japanese Government for the assistance that they have provided in the execution of this project. It is my sincere hope that this project will not be stopped by JICA but that it will be continued in the near future.

And on this note, ladies and gentlemen, I wish to declare this 3-day International Workshop on the Integrated Watershed Management on Inland Valleys – Ecotechnology Approach officially closed.

I thank you and may the Good Lord bless you all.

INTERNATIONAL WORKSHOP ON INTERGRATED WATERSHED MANAGEMENT OF INLAND VALLEYS - ECOTECHNOLOGY APPROACH

(6TH –8TH FEBRUARY 2001, NOVOTEL, ACCRA-GHANA)

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INTERNATIONAL WORKSHOP ON INTEGRATED WATERSHED MANAGEMENT OF INLAND VALLEY – ECOTECHNOLOGY APPROACH.
6^{th}.-8^{th}. February 2001 Novotel, Accra

PROGRAMME

1^{st} DAY (6^{th}. February 2001)

OPENING CEREMONY

09:00	Registration
09:30	Introduction of Chairman
09:35	Chairman's Remarks- Prof. E. Owusu-Bennoah
09:40	Welcome Address- Director-General, CSIR- Prof. W. S. Alhassan
09:50	Statement by Japanese Ambassador in Ghana-
10:00	Statement by WARDA IVC Coordinator- Dr. M. Wopereis
10:05	Short Address by the Minister, MEST
10:10	Keynote Address by the Minister, MOFA
10:30	Chairman's Closing Remarks
10:35	Coffee Break

TECHNICAL SESSION

CHAIRMAN: Director, Crops Research Institute (Dr. J. A. Otoo)

11:00	The Concept of Integrated Watershed Management- Prof. T. Wakatsuki, Co-Project Coordinator
11:40	Overview of the project- Dr. E. Otoo, Project Coordinator
12:20	Discussion
12:50	Lunch

Afternoon Session:

CHAIRMAN: Director, Water Research Institute (Dr. C. A. Biney)

14:00	Ecological Factors Affecting Rice Cultivation in the Inland Valleys of Africa. – Dr. M. Wopereis WARDA .- IVC Coordinator
14:40	Sustainable Agricultural Resources Management and Promotion of Inland Valley Cropping in West Africa (Dr. G.Tian (IITA)
15:20	Discussions
16:00	Close
19.00	Cocktail Party

2nd DAY (7th February 2001)

Morning Session:

CHAIRMAN: Director. Soil Research Institute (Mr. R. D. Asiamah)

09:30 Development of the Sawah System in some Inland Valleys of Sub-humid Tropics of Ghana (Ashanti Region) – Dr. W. E. I. Andah

- The Participatory Approach for Dyke and Canal Construction at Biemso No. 1 in the Ahafo Ano District of Ashanti Region -Dr. J. T. Adomako
- Evaluation of Four Rice Environments for Sustainable Rice Production- Dr. R. N. Issaka,
- The Effect of Organic and Inorganic Fertilizers on Rice Growth and Yield within the Forest Agro-Ecology of Ghana - Dr. M. Buri
- Charaterisation and Evaluation of Inland Valleys of the Sub-humid - Tropics for Sustainable Agricultural Production: Case Study of Ghana – Dr. D. Kubota

11:30 Discussions

12:00 Lunch

Afternoon Session:

CHAIRMAN: Director. Savannah Agric. Research Institute (Dr. A. B. Salifu)

13.00 Agronomic practices in Sawah development - Dr. E. Otoo

- Comparative Advantage of Method of Crop Establishment Under Sawah – Dr. E Otoo
- Across-location Screening and Selection of Rice Varieties - Dr. K.Dartey
- Comparative Studies of Rice-fish Culture and Rice Monoculture - Mr.J. Ofori
- Screening of Improved Cowpea Lines in Inland Valleys in Ghana – Dr. H. Adu-Dapaah

15.00 Discussions

15:30 Effective land tenure arrangement and other socio-economic aspects in Sawah development. Sawah Technology: A Participatory Approach in the Traditional Farming Systems of Inland Forest Ecology - Mrs. J. Haleegoah

- Sawah Development Impact on the Structure of the Landscape of Biemso No. 1 - Ms. M. Nawano
- Adoption Studies of Improve Technology - Dr. A.A. Dankyi

16.30 Discussions

17:00 Close

3rd DAY (8th. February 2001)

Morning Session:

CHAIRMAN:	Director, Forestry Research Institute of Ghana. (Dr. J.R. Cobbinah)	

09:30 10.0	Integrated Agroforestry in Sawah Development - Dr J. Cobbinah (Dr J. Cobbinah, Dr. D. Kubota and Mr. Owusu-Sekyere)
11.30	Discussion
12.00	Lunch

Afternoon Session:

CHAIRMAN:	IVC Coordinator (Dr. M. Wopereis, WARDA/ Dr. D. Keating, IITA)

13:00	The Way Forward.
	General Discussions
14.00	Coffee Break

CLOSING CEREMONY

CHAIRMEN	Deputy Director General, Agriculture, Forestry and Fisheries Prof. E. Owusu-Bennoah (CSIR) Resident Representative, JICA.
14: 30	Chairmen Closing Remarks
15:00	Close