West Africa Rice Development Association

Annual Report 1997

CGIAR

West Africa Rice Development Association

01 BP 2551, Bouaké 01, Côte d'Ivoire

WEST AFRICA RICE DEVELOPMENT ASSOCIATION ANNUAL REPORT 1997

About the West Africa Rice Development Association

The West Africa Rice Development Association (WARDA) is an autonomous intergovernmental research and development association with a mission to strengthen West Africa's capability for technology generation, technology transfer and policy formulation, in order to increase the sustainable productivity of rice-based cropping systems while conserving the natural resource base and contributing to the food security of poor rural and urban households.

Conducted in collaboration with the national agricultural research systems of member states, academic institutions, international donors and other organizations, the work of WARDA benefits the mostly small-scale West African farmers who cultivate rice, as well as the millions of African families who eat rice as a staple food.

WARDA was formed in 1971 by 11 countries with the assistance of the United Nations Development Programme (UNDP), the Food and Agriculture Organization of the United Nations (FAO) and the Economic Commission for Africa (ECA). It now comprises 17 member states: Benin, Burkina Faso, Cameroon, Chad, Côte d'Ivoire, The Gambia, Ghana, Guinea, Guinea-Bissau, Liberia, Mali, Mauritania, Niger, Nigeria, Senegal, Sierra Leone and Togo. WARDA is a member of the Consultative Group on International Agricultural Research (CGIAR), a network of 16 international research centers supported by public- and private-sector donors (see inside back cover).

The headquarters and main research facilities of WARDA are located at Mbé, near Bouaké, Côte d'Ivoire. Regional research centers in St-Louis, Senegal and Ibadan, Nigeria focus on Sahel irrigated rice and lowland rice breeding respectively.

Donors to WARDA in 1997 were: the African Development Bank, Canada, Denmark, the European Union, France, the Gatsby Foundation, Germany, the International Development Research Centre (IDRC), the International Fund for Agricultural Development (IFAD), Japan, Korea, the Netherlands, Norway, the Rockefeller Foundation, Spain, Sweden, the United Kingdom, the United Nations Development Programme (UNDP), the United States of America, the World Bank and several WARDA member states.

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ISBN 9291131148

About the Consultative Group on International Agricultural Research

The Consultative Group on International Agricultural Research (CGIAR) is a consortium of some 53 public- and private-sector bodies that provide funding for 16 international agricultural research centers, including WARDA. Founded in 1971, the CGIAR is cosponsored by the Food and Agriculture Organization of the United Nations (FAO), the United Nations Development Programme (UNDP), the United Nations Environment Programme (UNEP) and the World Bank.

The CGIAR's mission is to contribute, through research, to sustainable agriculture for food security in developing countries. In pursuit of this mission, the CGIAR focuses on five major research thrusts: increasing productivity, protecting the environment, saving biodiversity, improving policies and strengthening national research. It collaborates with a wide range of partners, especially national agricultural research systems, advanced research institutions in the North and the South, universities, the private sector, non-government organizations and farmers' associations.

CGIAR centers

CIAT	Centro Internacional de Agricultura Tropical
CIFOR	Center for International Forestry Research
CIMMYT	Centro Internacional de Mejoramiento de Maiz y Trigo
CIP	Centro Internacional de la Papa
ICARDA	International Center for Agricultural Research in the Dry Areas
ICLARM	International Center for Living Aquatic Resources Management
ICRAF	International Centre for Research in Agroforestry
ICRISAT	International Crops Research Institute for the Semi-Arid Tropics
IFPRI	International Food Policy Research Institute
IIMI	International Irrigation Management Institute
IITA	International Institute of Tropical Agriculture
ILRI	International Livestock Research Institute
IPGRI	International Plant Genetic Resources Institute
IRRI	International Rice Research Institute
ISNAR	International Service for National Agricultural Research
WARDA	West Africa Rice Development Association

WARDA

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1997

West Africa Rice Development Association

Association pour le Développement de la Riziculture en Afrique de l'Ouest

Correct citation: WARDA 1998. WARDA Annual Report 1997. Mbé, Côte d'Ivoire.

Cette publication est aussi disponible en français, sous le titre: ADRAO Rapport annuel 1997.

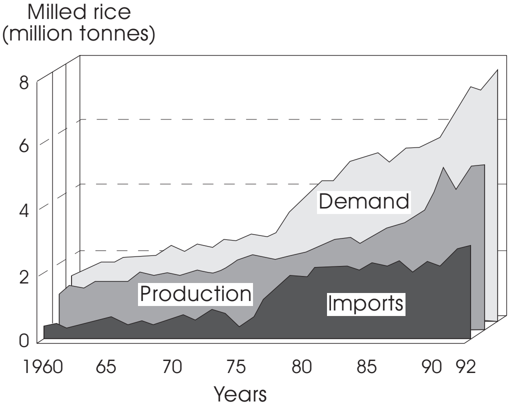
Cover: Participants at a seed multiplication workshop engage in a lively exchange of views

Contents

Message from the Director General and Chairman of the Board of Trustees

THE POTENTIAL impact of WARDA's research is vast. A glance at the graph opposite shows why.

At 5.6% a year, the demand for rice in West Africa is growing extremely rapidly. About half this growth is accounted for by rising human population. The other half is explained by the behavior of people in cities, who switch to rice from other cereals as their incomes rise. They do so because rice is, quite simply, nicer to eat and easier to cook than pearl millet or sorghum.



Trends in rice demand, production and imports in West Africa, 1960-1992

The rising demand continues to suck in imports—though not as rapidly as during the second half of the 1970s. The Food and Agriculture Organization of the United Nations (FAO) projects imports to rise to 4 million tonnes a year by the year 2000, draining approximately US$ 1 billion from precious foreign exchange earnings.

Imports are slowing down largely because domestic production is starting to rise more rapidly. Most of this rise is due to the expansion of rice cropping into previously uncultivated inland valleys. But there have been gains in yields too, including some remarkable success stories on the region's irrigation schemes. An important contributory factor since 1994 is more costly imports. As world prices firm up and West African currencies devalue, farmers are learning that rice can be a profitable crop.

If yield increases still play a relatively small part in rising production, this is not because of a failure to develop new technology nor, as has sometimes been claimed, because that technology is irrelevant to producers' needs. Rather, it is because the conventional systems for delivering technology to producers are, with few exceptions, unequal to their task. Varietal release committees haven't met for over a decade in some countries, while public-sector seed multiplication and extension services are almost universally overstretched and underfunded. But new partnerships are forming to fill the vacuum left by government. Non-government organizations (NGOs), previously weak or non-existent, have recently proliferated in some countries. Many of them are now involved in multiplying and disseminating new varieties, often through community-based seed production schemes.

What does all this mean for WARDA? First, the strong demand for rice means equally strong demand for new technology. Given an appreciating domestic market in which efficiency nevertheless remains a prime concern, technology that increases yields and cuts costs will be more in demand than ever. Secondly, WARDA's route to maximum impact is clear: priority should go to raising production in inland valleys with good access to urban markets. It is these areas—already filling up with migrants from elsewhere—that offer the best chances of creating jobs, raising incomes and alleviating poverty. Thirdly, WARDA and its traditional partners, the national research institutes, need to take advantage of West Africa's diversifying institutional landscape to quicken the pace of technology transfer.

Foreword

This report provides ample evidence that WARDA is well advanced down its chosen path towards impact. Let us dwell briefly on a few examples.

As envisaged in our medium-term plan, we are increasing our emphasis on the lowlands. While our plant breeders develop new varieties that combine a high yield with resistance to the many stresses of this environment (p. 19), our agronomists have demonstrated the potential of improved water control to bring out the best in the new technologies, achieving a dramatic impact on the lives of resource-poor women farmers (p. 14). As part of the plant breeding work, we are exploring the indigenous African rice *Oryza glaberrima* as a source of resistance to lowland stresses. We have already successfully developed interspecifics between *O. glaberrima* and *O. sativa* for the uplands. There could be immense payoff from a spillover to the lowlands of the germplasm and breeding techniques developed through that work.

While our major impact on economic growth will come through research in the lowlands, work in the uplands will also contribute to growth and will be especially important for reasons of sustainability and equity. Last year's report described the exciting potential of the new interspecifics to boost yields and stabilize shifting cultivation systems through better control of weeds. This year we report on our efforts to introduce legumes to resource-poor farmers (p. 29). Besides increasing incomes and food security, these plants will restore soil fertility and further contribute to the control of weeds. Their widespread adoption by farmers would help allay global environmental concerns.

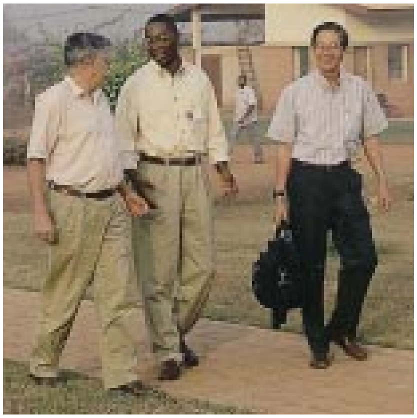
WARDA has signalled its commitment to impact by launching a new program on technology transfer (p. 45). The program, which will operate through multi-agency partnerships, will enable the Association to broaden its impact by acting as catalyst and matchmaker. Early in 1998 we invited the leaders of national research to a meeting at Mbé to discuss the program's approach and how it should be implemented.

WARDA is also part of a new drive to transfer technology to the countries that have so far benefited least from regional research and development (R&D). Under a project funded by the World Bank's Special Program for African Agricultural Research (SPAAR), farmers in Guinea are now testing the new interspecifics originally developed in Côte d'Ivoire (p. 24). This project shows how quickly technology can be transferred when political will is matched with the provision of adequate resources. It also shows the power of training when it is linked to a specific technology transfer project, rather than being carried out in the abstract.

Heads together: directors of national research meet WARDA's Director General and program leaders to plan the new drive to transfer technology to farmers' fields

Lastly, WARDA has introduced West African countries to two powerful new tools to support policy making for the rice sector. The first, developed by a WARDA systems analyst, is a conceptual framework for understanding the evolution of rice production systems (p. 9). This sounds academic—but it could have enormous practical value for the region, saving taxpayers' money by preventing mistimed and therefore inappropriate development interventions. The second tool is the policy analysis matrix (PAM), a means of assessing a country's comparative advantage for producing rice or other commodities (p. 50). This was developed by economists in the USA but has been vigorously promoted by WARDA in West Africa through training and collaborative research. Used well, both tools should improve the *quality* of impact achieved from regional R&D.

The excellence of WARDA's scientific program, and the dedication of its staff, give us every confidence that our drive to increase impact will succeed. Our member states share that confidence. At its 1997 meeting in Accra, WARDA's Council of Ministers passed a



New faces at WARDA: Michael Goon (right), Justin Kouka (center) and Willem Stoop (left)

resolution urging them to honor their financial commitments to the Association. Several have responded by paying their dues promptly and in full. At the same time, the Council expressed its gratitude to the Consultative Group on International Agricultural Research (CGIAR) for its continuing support over more than a decade (see box).

Now to some housekeeping matters. Following a recommendation of the Board of Trustees, we began a search in early 1997 for a Deputy Director General for Administration and Finance. We are pleased to report that Michael Goon has now been appointed to the post. He brings to it some 25 years of management experience in both the private and public sectors.

Michael is not the only new face in WARDA's management team. The year also saw the appointment of Gabriel Dao as Human Resources Officer and Justin Kouka as Executive Assistant to the Director General. The team will be complete once we have recruited a Head of Finance and a Deputy Director General of Programs, which we expect to do soon. During 1997 WARDA benefited greatly from the services of Charles Renard and Willem Stoop, who acted successively in an interim capacity in the latter post.

Let us end where we began—with a further thought on the potential impact of regional rice research. We estimate that our research on upland interspecifics alone could lead to the production of nearly half a million additional tonnes of rice a year. That would dent the region's import bill to the tune of US$ 125 million annually. Just imagine the new hospitals, schools, roads and houses that West Africa could build with such a sum of money!

Resolution of the Council of Ministers

The Council of Ministers,

- Considering the substantial financial support granted to WARDA by members of the CGIAR and the donor community that has strengthened and consolidated the Association;
- Considering that this support is vital for the Association and has led to the scientific achievements obtained for the benefit of rice production in the region;
- And in recognition of the satisfactory performance and contribution of the Association to national agricultural research systems research and capacity building;

Expresses its sincere thanks and appreciation to all donors and organizations for their substantial and continuing support to the Association; and

Resolves that the Chairman of the Council of Ministers conveys this message to the donor community through a letter to the Chairman of the CGIAR.

Accra, Ghana, 19 September 1997
The WARDA Council of Ministers

Just Faaland
Chairman, Board of Trustees

Kanayo F. Nwanze
Director General

WARDA's Changing Program

Willem Stoop
Interim Director of Programs

NOT MANY readers of this annual report will have scrutinized the inside front cover—the place where we put our institutional blurb. Even if you're an exception, you may still not have noticed a small but crucial change since last year's report: we've reworded our mandate statement.

The new wording—mentioning development alongside research, policy alongside technology, and technology transfer alongside technology generation—reflects the recent evolution of WARDA's program towards the broader role currently envisaged for most of the CGIAR's research centers. Both the structure and the content of our program have evolved, keeping pace with changes in the way we and our partners think about our objectives and how best to meet them.

Let's look first at structure. We will touch only briefly on this, since it was dealt with at some length in our 1996 Annual Report.

In early 1997 a new organizational chart came into effect, representing a radical break with the past. We now have four programs—Rainfed Rice, Irrigated Rice, Policy Support and Technology Transfer—coming under a single Director of Programs. The Program Division also contains several support units, including Biometrics, Training and Fellowships, and the Information and Documentation Center.

This structure, which emerged as a result of our medium-term planning exercise, was proposed by management in June 1996 and endorsed by WARDA's Board of Trustees at its November 1996 meeting. Its rationale, explained in our 1996 Annual Report, is to pursue greater efficiency and impact by integrating research with training and information and by strengthening the links between research in the Sahelian zone and that in the humid and subhumid zones. The creation of a new Policy Support Program reflects our growing awareness of government policy, alongside the choice of technology, as a determining factor in the success or failure of interventions. We have also recognized our responsibility for achieving an impact from research by creating a new Technology Transfer Program. (Originally, this program was called Information and Technology Transfer, but in 1997 we decided to hive off the information function as a separate support unit, in view of the fact that it serves WARDA as a whole.) The new structure is built round 18 projects that focus on specific problems identified as priorities during our planning exercise. Relations with national partners are, as before, mediated through task forces and consortia.

Several important concepts determine the content of our program. I will attempt to describe and illustrate each of these in turn.

First, like other CGIAR centers, WARDA spans a large portion of the research spectrum, from strategic to adaptive. In so doing we add value to our program, since our participatory on-farm activities at the adaptive end of the spectrum inform our strategic laboratory-based research, ensuring that this remains firmly geared to farmers' needs.

As regards strategic research, our Rainfed and Irrigated Rice Programs have established some exciting new biotechnology projects in collaboration with advanced research institutions in the North. Through these projects, sophisticated tools and techniques such as gene tagging are being mobilized to solve practical problems faced by the smallholder that have so far proved intractable when tackled using conventional plant breeding approaches. Applications include the identification of genes for tolerance to drought and soil acidity, and for resistance to rice yellow mottle virus (RYMV) and blast. These genes will serve to develop varieties that are able to cope with these constraints, which are common in large parts of Africa, not just in the west of the region. The use of anther culture has made it possible to cross the African rice species *(Oryza glaberrima)* with the by now far more widespread Asian species *(O. sativa)* to produce a new, more weed-competitive plant type that should prove immensely valuable in stabilizing and enhancing the productivity of upland shifting cultivation systems. The crosses are bringing into the service of mankind the valuable gene pool of *O. glaberrima,* hitherto threatened with extinction as local farmers replaced it with the higher-yielding *O. sativa.*

At the adaptive end of the spectrum, the crosses are being tested using participatory on-farm evaluation techniques that reinstate the farmer—female as well as male—as the central protagonist in an integrated research and development process. Through its experiences WARDA is contributing to the international debate on participatory research methods and facilitating the adoption of such methods by national institutions in West Africa.

Secondly, WARDA's research is, of course, multidisciplinary. This is a much used word, but it is salutary to remind ourselves of just how important it is to maintain a multidisciplinary focus in research. Vigilance is needed to prevent a relapse of the scientist into the comfortable disciplinary orientation of the past—a fault that characterized some of our research before the 1996 reorganization. The switch to a project-based program has banished that tendency, at least for the time being. However, to complement its strength in the biological sciences WARDA still needs to increase its capacity in the social sciences, particularly anthropology and sociology.

A good example of the multidisciplinarity of WARDA's current program is our research on integrated approaches to the control of pests and diseases. The aim of this research is to develop and disseminate new knowledge-intensive practices that rely on ecological principles, minimizing the use of external chemical inputs that are harmful to the environment and to human health. In a special project with the UK's CAB International, entomologists and plant breeders in both national and international institutes have worked together to tackle a severe new pest of lowland rice in the region, the African rice gall midge (ARGM). The task force structure has proved invaluable in involving national partners in the research effort and broadening its coverage—both vital steps towards understanding and solving the problem at regional level. A similar approach is being used against rice yellow mottle virus (RYMV), with pathologists and breeders working together. In both cases, the aim is to develop a package of control measures with the resistant plant as its central component. Agronomists will be responsible for testing the package with farmers, while socio-economists evaluate its adoptability and impact.

A third concept important in shaping WARDA's program is that of cross-sectoral research. This goes one step further than multidisciplinarity, building bridges between whole sectors that, in the past, have been separated by watertight barriers. WARDA's flagship cross-sectoral project concerns the links between water-borne diseases and lowland rice cultivation, long suspected but never conclusively established because previous research on the subject did not integrate epidemiological data with data on agriculture and socio-economics. This project has shown that in fact rice cultivation has little effect on the incidence of malaria, except when new irrigation schemes are launched in dry areas. In 1997 project researchers made another important step forward with the finding that resource-poor households in areas prone to malaria have had little exposure to the use of bednets—a subject that should be taken up by educational and public awareness programs. Crucial in disseminating this technology more widely is the role of women in taking health-related decisions on family expenditures.

Fourthly, WARDA's research integrates the pursuit of gains in agricultural productivity with the conservation of natural resources. Nowhere is this integration more evident than in the development of the new, weed-competitive plant types—a project that helps conserve biodiversity, limit deforestation and sustain shifting cultivation systems at the same time as raising farmers' rice yields. Our work on integrated pest management and on the introduction of legumes to upland farming systems also fulfil this criterion, which is one that donors are increasingly emphasizing as they evaluate new project proposals for funding. The high profile of environmental concerns in WARDA's program should make it particularly appealing to donors.

Fifthly, the addition of technology transfer to the mandate—or perhaps I should say its rehabilitation within the mandate, for WARDA has always been a development association as well as a research institute—adds a dimension to our program that is also entirely in keeping with donors' priorities, reflecting as it does their desire to achieve a near-term impact from the investments they make in us. WARDA's past experience has shown that technology transfer is a formidable bottleneck in agricultural development, many technologies remaining "on the shelf" instead of finding their way onto farmers' fields. We regard our new program as a tremendous opportunity to link with new partners in the pursuit of imaginative solutions to the problem. However, we must take care not to raise expectations too high. With its limited staff and resources, WARDA can take part in only a few activities, and even then mostly in a facilitating rather than an implementing capacity. The program, which is described more fully elsewhere in this report, will be structured round a few projects, based partly in Côte d'Ivoire and partly elsewhere in the region, with the emphasis on drawing and spreading lessons from experiences rather than on maximizing our direct involvement in field activities.

Sixthly, as WARDA's program matures it brings increasing opportunities to maximize the spillover benefits from research. Two good examples of this come to mind, both of them described in this report. The first is the way in which WARDA's participatory on-farm research methods, first developed for the evaluation of the new interspecific rice varieties, are now being applied to the introduction of legumes. Legume introduction is an area of research badly in need of a new approach—many researchers in West Africa have been called to try it in the past, but few legumes have actually been chosen by farmers! Is it too much to hope that the new participatory methods will, by drawing farmers into the research process, prove successful in increasing adoption rates? A second and more powerful example of spillover is the "migration" of the approach used to develop interspecific hybrids from the uplands to the lowlands. Already proving their value in upland rice varieties, the genes for stress resistance found in *O. glaberrima* will shortly be deployed in the next generation of improved plants for the lowlands—an environment in which they could make an even greater impact.

The seventh and last concept that I shall mention is the most important one: WARDA's program is people-centered. This is a fact, not a sententious sales pitch. But which people? For this too is changing. Our research remains geared to the needs of the resource-poor farming family, but larger-scale farmers can and do also benefit. Besides rice producers, we have an impact on poor urban consumers, whose food bills fall as technology creates a surplus in the market place. Our traditional partners are national public-sector scientists, but now we work with non-government organizations and the private sector too. We concentrate on West Africa, but increasingly we expect to reach beyond our core mandate region to the rest of the continent. Eventually, the benefits of our research will be felt by the suppliers of goods and services in the developed world, as a wealthier Africa starts to suck in more imports.

The shifts in WARDA's program show it to be a healthy institute—one that is keeping abreast with changing needs in a rapidly changing world. Working here is exciting. I hope that the feature articles that follow will convey some of that excitement to readers.

Timing is Everything

EFFORTS TO develop African rice production are often dogged by inappropriate interventions. But how can decision makers know what will succeed and what won't? WARDA scientists have developed a tool that should help improve the design of future projects.

Forward to the past

Researchers visiting the Sakassou irrigation scheme were puzzled. They had demonstrated the practice of transplanting to farmers in the hope that the farmers would adopt it when establishing their plots. But the farmers had persisted in what the researchers took to be their traditional practice of direct seeding. Yet when asked why, the farmers said that transplanting was old hat.

The researchers had fallen into a trap—one that is obvious once you know how rice ecosystems evolve, but difficult to spot if you don't. They had mistaken the evolutionary stage of the system. Far from stubbornly adhering to a traditional practice, the farmers were one step ahead of the researchers. Having long ago switched from direct seeding to transplanting, they had now switched back again as the scarcity of labor once more limited production.

The Sakassou scheme is near Côte d'Ivoire's second major city, Bouaké. Practices on the scheme are advanced by African standards. Farmers use high-yielding varieties, fertilizers and pesticides. They also employ paid labor for such tasks as weeding and harvesting. Labor is scarce because of the alternative opportunities for employment in Bouaké.

The cyclical recurrence of direct seeding in rice ecosystems is the outward sign of more profound structural changes that occur as the systems evolve. According to Michael Dingkuhn, systems analyst with WARDA's Rainfed Rice Program, understanding these changes is vital in targeting interventions designed to increase or sustain production. It can also throw light on where research priorities should lie.

Transplanting is practised when labor is plentiful, but disappears as systems modernize

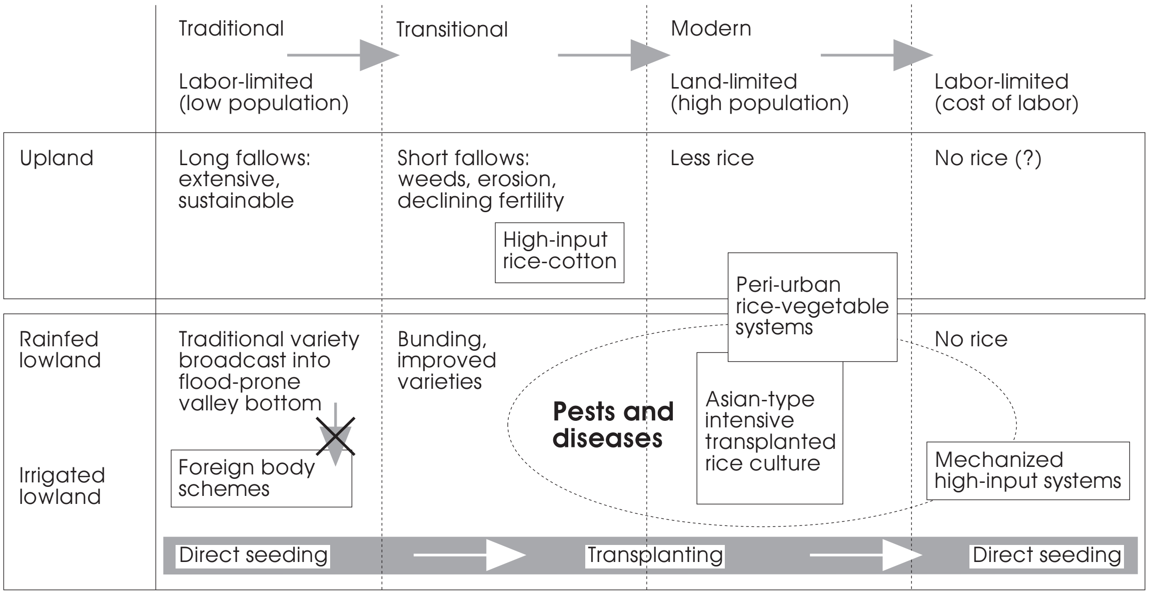
That's why Dingkuhn and his colleagues have developed a model of the evolutionary process. They believe the model should prove a useful tool for research managers, policy makers and planners. "It's a kind of map, showing what technologies and strategies are likely to succeed in different situations," Dingkuhn says.

The model

Currently undergoing validation, the model (Figure 1) consists of a matrix in which rice ecosystem is plotted against stage of evolution. It distinguishes two main ecosystems—upand and lowland—each of which evolves from a traditional form, through a transitional stage, to a modern form. In the case of the lowlands, which are initially rainfed, the evolution involves conversion into a third type of ecosystem, irrigated lowland.

In traditional systems, production is limited by the availablity of labor rather than land. The human population is low, the objective of production is

Figure 1. The evolution of rice ecosystems



subsistence, and the labor used is mainly from the family or village. Farming families in these systems grow multiple crops, harvest tree products and, in the drier areas, raise livestock. The challenge for farmers is how best to allocate labor between different enterprises. Intensifying rice production competes with other objectives, particularly if more labor is required.

In traditional upland systems, farmers practise slash-and-burn agriculture with long fallow periods. This system is sustainable for as long as population remains low. Farmers in traditional lowland systems are usually women, who broadcast tall-growing rice varieties into valley bottoms prone to flooding. In both types of system, the shortage of labor dictates the use of direct seeding.

During the transitional stage, the production system starts to come under pressure from rising population levels. In the uplands, fallow periods shorten, leading to declining soil fertility, weed infestation and erosion. Lowland valleys fill up, with the result that pests and diseases begin to spread more easily. The response to these problems is various, but wherever they can producers turn to the market as an escape route out of poverty. High-input rice-cotton systems develop in the uplands, where legumes may also ease pressures on the resource base while boosting cash income. In lowlands near towns, farmers take the first steps to improve water control by introducing bunding. They may also start to use improved varieties, fertilizers and other inputs.

In the next stage of evolution, production is limited by the availability of land, as populations rise still further. In upland areas, rice starts to disappear from the system as other crops become more lucrative. In the lowlands, two sorts of development occur: labor-intensive Asian-type "rice only" systems, and a more diverse peri-urban rice-vegetable system. In both cases, rice is no longer direct seeded but is transplanted, absorbing surplus labor in the pursuit of higher yields and a higher quality and therefore more valuable crop.

Beyond this stage lies a further one in which production is once again limited by labor, as people, especially men, leave the land to take better paid urban jobs. As at

Sakassou, farmers revert to direct seeding in response to renewed labor shortages. By now rice is almost entirely absent from upland systems. Demand for the commodity is met largely by highly mechanized, high-input irrigated systems of the kind now common in Asia.

Because evolution occurs faster near urban centers, the same type of system may simultaneously display its traditional, transitional and modern forms, depending on geographical location. Development is octopus-shaped—concentrated round urban centers, but with tentacles that reach out along major roads.

The power of the market

The market is the driving force behind system evolution. It acts like a magnet, attracting potential producers to peri-urban areas and providing the incentive to increase and intensify production.

The record of public-sector irrigation development in Côte d'Ivoire shows this clearly. Of the several hundred hectares of lowland valleys developed during the 1970s and 80s, only those close to large towns are still productive. Production has intensified on schemes near Gagnoa, Daloa and Korhogo, where farmers now have access to inputs and regularly use double cropping. Other schemes, in contrast, lie abandoned—although a few have been artificially resuscitated through external aid.

The power of the market is illustrated by another category of lowland development in Côte d'Ivoire. Around major cities such as Bouaké, mixed cash cropping systems combining rice with maize, tubers and vegetables have evolved spontaneously, without external intervention. Such is the demand for rice in Bouaké that the crop is produced despite the fact that local ecosystems are not ideal for it, being short of water. The production of rice here is driven entirely by the market, not by physical conditions.

Most rice growers around Bouaké, as around other major cities in the south, are from northern Côte d'Ivoire or Burkina Faso, where conditions are drier and farming is riskier. Their move southwards is a response to the opportunity, offered by the market, to earn a higher and more reliable income. With them the northerners bring their knowledge of water control, moving willingly into the uninhabited valley bottoms while the southerners stay on the uplands. The general migration southwards to the cities further reinforces the role of the market in stimulating rice production, as many migrants give up agriculture altogether in favor of better paid urban jobs.

Spontaneous peri-urban development takes different forms, according to location. Not all aspiring commercial producers need move south to earn a living. Around towns such as Korhogo in northern Côte d'Ivoire, many now grow crops such as cashew, cotton, mango and groundnut, on small dam-fed irrigation schemes. Similar production systems are found in southern Mali and Burkina Faso. They are characterized either by proximity to a local urban center, or by good road links to the markets of the south. Once again, the market is the major factor determining the pace of development.

Implications

WARDA's new model has important implications for research and development. Its chief value lies in helping decision makers avoid the wastage associated with inappropriate interventions.

City markets drive system evolution

A technology must be introduced at the right time if it is to be widely adopted. For example, trying to introduce bunds in a sparsely populated lowland area with poor access to towns is futile, since farmers will have no incentive to produce more rice. Waiting until population rises and a road is built, connecting the area to a nearby market, will increase the chances of success.

Bunds, however, are a relatively cheap intervention. Researchers may lose face when farmers don't adopt them, but the loss to the public exchequer is low. Far more serious losses occur when large amounts of capital are poured into new irrigation schemes in traditional lowland systems that are not yet ready for such development. These are "foreign body" schemes—unlikely to "take" in their new surroundings, on which they are typically imposed through external intervention without adequate consultation with the farming community.

Large-scale irrigation development is much more likely to succeed at a later stage of evolution, when labor once again limits production and the market for rice is stronger. At this stage, with the whole rural economy more developed, mechanization can be introduced with less risk that tractors and combines will break down irretrievably for want of spare parts. Yields rise to record levels as farmers turn to sophisticated inputs and management techniques.

Modern irrigation schemes imposed on traditional systems tend not to be efficient

The cyclical recurrence of direct seeding also has important implications for lowland development. The shift to transplanting during the transition phase occurs gradually, as land becomes the major factor limiting production. It incurs little risk for producers, who achieve better control over the quality of the crop by adding what is in effect an additional selection procedure. In contrast, the switch from transplanting to modern direct seeding is fraught with danger. Direct seeding renders the crop extremely susceptible to weeds, so farmers must pre-irrigate and apply herbicides before sowing. They must also use pure seed, as there is no longer an opportunity to select through transplanting. Such seed can only be supplied by a well developed seed sector. Modern direct seeding thus presupposes an effective input supply system backed by good advisory services—two areas that have been poorly addressed by many African countries.

Considerations such as these go a long way towards explaining the delayed arrival of the Green Revolution in Africa. In Asia, the revolution was really an evolution, for which Asian irrigated systems, intensely cultivated for thousands of years, were ready. In contrast, the delta regions of Africa—those of the Senegal, Niger and Limpopo rivers, for example—have been developed for irrigation only recently. The absence of any prior tradition in irrigation left farmers ill-prepared for the abrupt change in techniques dictated by modern irrigation development.

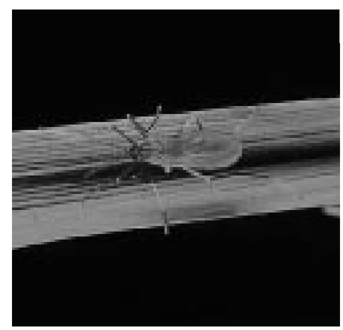
The model provides useful guidance for the allocation of research resources. The long lead-in time for research—typically 10 years to develop new technology and at least 3 to adapt it—makes it all the more important to understand the direction in which systems are heading, so that technology is ready by the time it is needed.

The gradual reduction in area of upland rice implies a shift of resources towards the lowlands, as these become the rice environment of the future. WARDA's current medium-term plan envisages such a shift. Already, the Association's plant breeders have begun applying the new interspecific crossing techniques, originally developed for upland rice, to the development of new varieties for the lowlands.

Within the lowlands, more resources should be directed towards the study of pests and diseases. While lowlands remain underdeveloped, the challenge from these is relatively low. But a sharp increase in pest and disease problems may be expected 5 to 10 years from now, as development intensifies. The risk is all the greater since most of the germplasm so far used to develop lowland varieties consists of *Oryza sativa* material introduced from Asia this century. Having had less time to adapt to African stresses, this germplasm is less diverse than native African *O. glaberrima* material and therefore more susceptible to pests and diseases. The African rice gall midge and rice yellow mottle virus are examples of pathogens native to Africa that have already switched their allegiance from wild rices to *O. sativa* varieties as hosts. Genes from *O. glaberrima* varieties that confer resistance should be transferred to lowland varieties as soon as possible—a task that highlights the importance of the new work on developing interspecifics for the lowlands.

In research on pests and diseases, as in several other areas, the fact that Africa lags behind Asia on the evolutionary path can be turned to its advantage. "The region can learn from Asia's mistakes," says Dingkuhn. "By putting more resources into integrated pest management and the study of natural enemies, we can avoid repeating the overuse of pesticides that had such damaging effects on Asian ecosystems."

Research on the lowlands should be stepped up...



...especially on lowland pests and diseases

Valuable tool

WARDA's original research has led to the development of a valuable tool to aid strategic thinking about the rice sector in West Africa. The tool should prove particularly useful in ex-ante impact assessment, helping to avoid the research and development failures of the past.

Two important messages have so far emerged from studies based on the model. First, the market is the major determinant of what constitutes an appropriate intervention. Secondly, the key to successful development is evolution, not revolution. Timing is everything.

Why Water Control Matters

SIMPLE INTERVENTIONS to control the water supply could bring massive gains in lowland rice yields and improved food security for resource-poor women farmers. A project coordinated by the Inland Valley Consortium (IVC) and implemented by WARDA is showing how.

Improved water control could unlock the potential of the lowlands

Second thoughts

The women were sceptical at first. They thought the researchers had come to take away their land. And even when they understood what the researchers wanted to do, they didn't believe they would benefit from it.

But the researchers—WARDA's Mathias Becker and David Johnson—eventually managed to persuade the women to participate. Now the valley bottom they farm, at the village of Poundiou in northern Côte d'Ivoire, has simple contour bunds down one side of it, while on the other the fields have been left unbunded, in the traditional style. The researchers are measuring the difference in rice yields between the two.

And the women? They're starting to have second thoughts. At the end of the 1997 season—a year in which their neighbors' rice crops were destroyed by floods and drought—they were able to salvage a small but valuable harvest.

Unlocking the potential

Inland valleys such as Poundiou represent an important underused resource for West African rice production. Only about 10% of the area they cover is cultivated at present, so there is ample room for expansion. There is also room for substantial growth in yields, which are currently only about 1.5 t ha^{-1}. Unlocking the potential of these valleys through judicious investment in water control could make the region self-sufficient in rice.

But what exactly constitutes judicious investment? Yield responses to water management interventions vary enormously according to both the physical and the socio-economic characteristics of different sites. Physically, features such as topography, the permeability of the soil and the amount and distribution of rainfall are important determinants of whether a site needs to retain more water, or to get rid of excess water by draining it. Assuming it will prove possible to grow more rice, socio-economic factors such as proximity to urban markets and access to inputs determine whether or not farmers will find it profitable and feasible to do so.

Poundiou is one of several inland valley sites selected by WARDA and IVC for research on this issue. Its physical characteristics are typical of the Guinean savanna. Rainfall is low and the valley is broad and well drained, so retaining water rather than draining it is the key to development. Socio-economically, Poundiou's position is intermediate. The area is not densely populated (20 persons km^{-2}) and the valley itself has been cultivated only for the past 15-20 years. Large urban markets are distant, but access to them, via a tarred road, is good. "Farmers here grow rice mainly for subsistence at present," says Pieter Windmeijer, agro-ecologist and technical coordinator of IVC's activities. "But production for market is poised to take off. There is a weekly market in the village and traders now come to buy rice."

Benefiting the poor

Surveys by WARDA and IVC scientists revealed four main types of household in the Poundiou area:

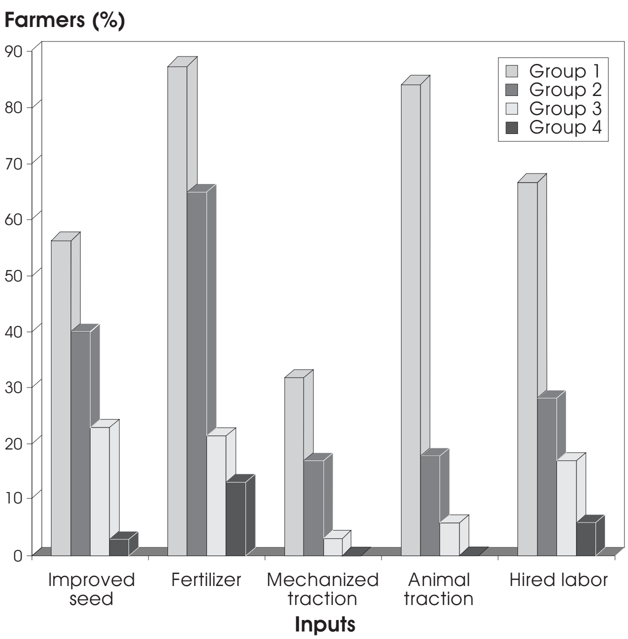
- At the top end of the social scale are households consisting typically of a young to middle-aged married couple, cultivating mainly cotton and some other crops, almost exclusively in the uplands. These households have the largest farms, the highest cash incomes and make the greatest use of hired labor and purchased inputs.
- In second place are households that also cultivate cotton but that place more emphasis on other crops such as upland rice, yam and maize. The wives in these households often have small lowland rice plots, cultivated for subsistence or cash. These farmers tend to be older than farmers in the first group.
- The third tier in the hierarchy consists of women farmers who cultivate both upland and lowland plots. The women are divorced, separated or widowed—or else have husbands who have migrated to nearby towns in search of work. Some of them farm alone, but others have children who help them. Their main crop is rice, grown for both subsistence and cash, but they also grow some groundnuts and maize.
- The fourth and most disadvantaged group consists of elderly women farmers who cultivate only lowland fields. They grow only rice, almost entirely for subsistence. Their access to inputs is extremely limited compared to that of other groups (Figure 2).

The scientists decided to focus their efforts on the poorest farmers—those in the third and fourth groups. Designing interventions that will benefit such farmers is notoriously difficult. They need simple technologies that require little or no extra capital outlay or labor.

During the surveys, most of these farmers had cited the lack of water control as their most serious constraint. Rainfall amount and distribution in the savanna zone vary greatly from year to year, with the result that the extent and duration of flooding is never predictable. Investing in inputs under such conditions is risky. Fertilizer, and even the rice crop itself, can get swept away when storms occur. Even when they don't, the ideal water conditions that lead to high yields are likely to arise only in part of the toposequence. Because farmers can't know which part in advance, they must apply inputs over the whole in order to capture the yield increases. That keeps costs high in relation to benefits.

Total control of the water resource would be too expensive for these farmers. But partial control using bunds—raised compacted footpaths between the plots—seemed feasible. Long used in the productive lowland rice systems of Asia and elsewhere, bunds serve as buffers, retaining water in the plot but also preventing excessive inflow. Stabilizing the water supply in this way raises crop yields in several ways, mainly by helping to control weeds.

Figure 2. Level of inputs used by four farmer groups at Poundiou, northern Côte d'Ivoire



Bunds are an appropriate low-cost intervention, especially near urban markets

Mathias Becker (right) and a research assistant inspect a farmer's rice field

Farmers can build bunds using a hoe, at the same time as they prepare their seedbeds. The task requires little extra labor, which can be supplied from the family in the case of women with children or husbands living on the farm.

Along with the bunds, the scientists decided to test a range of innovations and management practices that farmers in the lowlands could use. They include improved seeds, fertilizers and more effective weeding, either by hand or with herbicides. The improved varieties used were WITA 3 and WITA 4, both developed by WARDA in collaboration with the International Institute of Tropical Agriculture (IITA).

The experiment got off to a bad start. The farmers cooperated with the researchers to build the bunds, only to see them destroyed by freak storms during the early part of the 1997 season. The storms also washed away the rice crop. The farmers rebuilt the bunds and replanted, but then came a mid-season drought. To cap it all, the plots were invaded by perennial wild rice, a noxious weed that is extremely difficult to control.

All this led to low yields. But the farmers were impressed when they found that, while others had lost their entire crop, they at least were able to harvest something. The data collected by WARDA's scientists showed why.

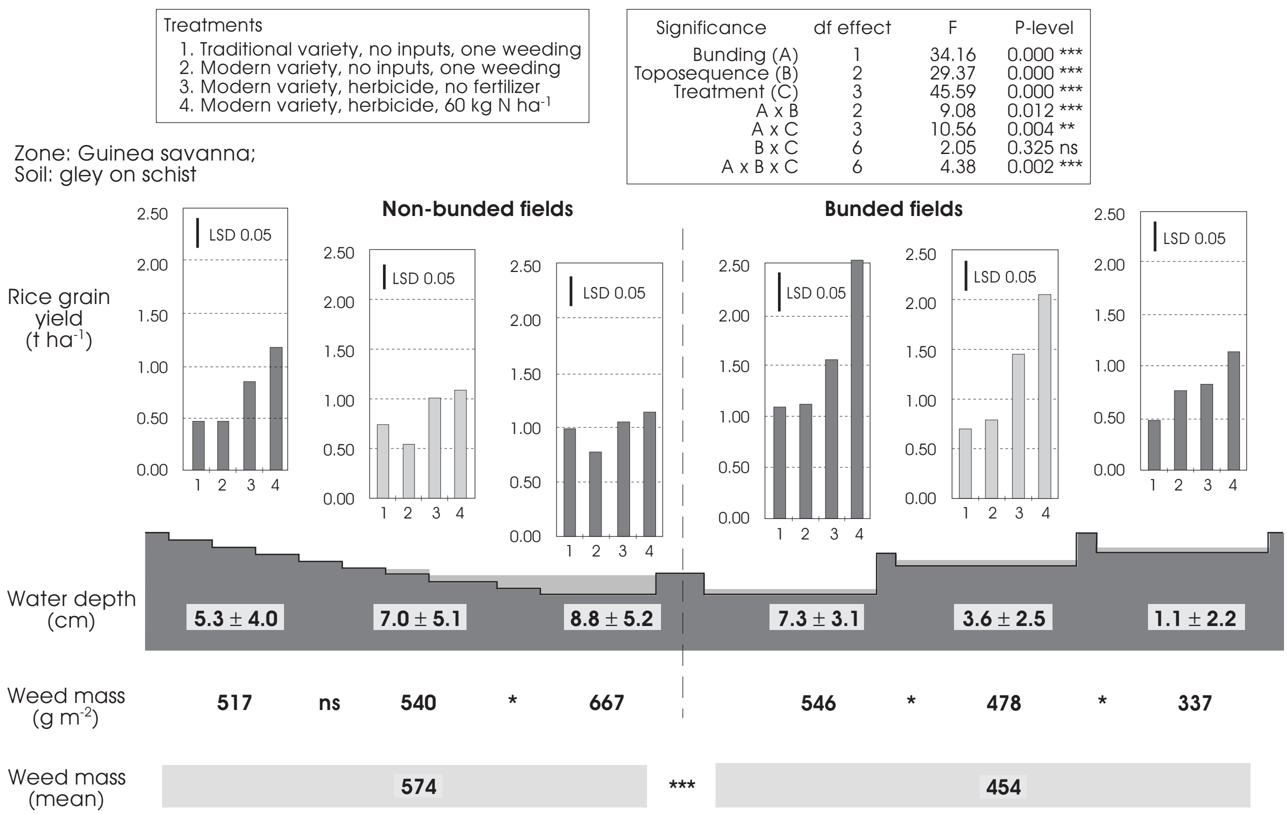
Dramatic results

Despite the poor season, bunding had a dramatic effect on water control and rice yields (Figure 3).

Bunding reduced fluctuations in the depth of flooding and retained water in plots further away from the valley bottom, providing more uniform growing conditions over a wider area. It increased yields by an average of 30% across the toposequence, reducing weed biomass by 25%. The increased yields, combined with the reduced labor requirement for weeding, should markedly increase the profitability of rice production.

Bunding interacted significantly with other treatments. Most marked was the effect on the efficiency of fertilizer use in the lower and middle parts of the toposequence. Fertilizer applied in open fields tends to

Figure 3. Effect of bunding and crop management on rice grain yield,weed biomass and water table fluctuations. Poundiou, wet season 1997



get flushed away with escaping water. It also gets lost to the atmosphere, as the alternating wet and dry conditions oxidize it. The introduction of bunds prevented both sources of loss.

Besides bunding, the timing of fertilizer applications and weeding also gave significant yield increases. Delayed weeding is already well known for its adverse effects on yields. “Farmers must weed within 28 days of planting,” says Johnson. “After that the damage is done and yields will be sharply reduced.” The timing of fertilizer applications is a more complex phenomenon. The rice plant uses nitrogen at two stages of its growth cycle: at 2-3 weeks after emergence, during early tillering; and again at panicle initiation, 65 days or so before harvest. Split applications at these two points in the cycle are therefore far more efficient than a single application or than applications at other times. Becker calculates: “For each kilogram of fertilizer applied you get an additional 3 kilograms of grain. Bunding raises that to 8 kilograms, and split applications to 13.”

If farmers get everything right they can achieve yield gains of 1.5 t ha^{-1}, doubling their current yields. But that’s a big if. In the short term at least, more modest gains can be expected—but these are still well worth making. “What the research shows us,” says Becker, “is that improving water control is the starting point in releasing the potential of the lowlands. Other innovations, especially improved seeds and fertilizer, don't work without it."

Gender issues

Will the women of Poundiou benefit from the WARDA-IVC project, or were they right all along to be sceptical? The researchers have uncovered two major issues that need to be addressed to ensure that those intended to benefit really do so.

First, although women may find the time to build bunds, men control access to the fertilizers and other inputs needed to obtain the best yields. In his 5 years of work at the site, Windmeijer has never seen a woman buying fertilizer. In households with a married couple, fertilizer is sometimes applied to food crops, but only once the needs of the cash crops have been met. Households consisting of women farming by themselves seldom use any inputs at all.

Second, here as in so many other situations in developing countries, when a farm enterprise managed by women shows signs of becoming profitable, their husbands or other men in the neighborhood usually try to muscle in on it. Making lowland rice production more worthwhile runs serious risks of depriving women of their plots, especially in areas where land tenure is not secure.

Looking ahead

A third issue affecting adoption relates to the nature of the technology. Although bunds improve water control, they still do not create the uniform conditions needed to ensure the fertilizer-seed package performs equally well in all parts of the toposequence. "In 1997 it was less effective further up the slope, because there was less water there. But that's just where you'll get the best yields in a year of high rainfall," says Windmeijer. Thus, even with the improved system, farmers still have to apply the package to all parts of the slope in order to capture the ideal conditions that will occur on only part of it.

The solution would be to control the water even better. That could be achieved by building a small concrete dam with a wooden sluice, feeding irrigation channels that would convey water to farmers' fields by gravity, as is done elsewhere in Côte d'Ivoire. "This is a more expensive intervention that would require farmers to pool their resources," says Windmeijer. "But it's still relatively cheap. And it would ensure a better return on investments."

This next step down the development path is not one the researchers are eager to take just yet. In the short term, they'd rather gain the full confidence of participating farmers, watch them adopt bunding as a permanent feature of their fields, and measure the impact on their incomes as sales at the village market start to climb.

Tougher Plants for the Lowlands

THE IMPROVED rice varieties grown by West Africa's lowland farmers produce higher yields than land races, but most are vulnerable to the lowlands' unique stresses. The next generation of plants created by breeders will be better able to cope.

Environment of the future

At over 5% a year, demand for rice is increasing faster in West Africa than anywhere else in the world. The increases in production needed to meet that demand will have to come largely from the region's lowlands, which are more fertile than the uplands and have the added advantage of providing opportunities for irrigation.

Traditional lowland rice varieties are tall-growing types prone to lodging when fertilizer is applied to them. Yields from these are low, usually no more than 1.4 t ha^{-1} or around 38% of the world average. "With improved water control and a change of variety, we can achieve 3 t ha^{-1}," says B.N. Singh, WARDA's lowland plant breeder. "Add some fertilizer, and we're talking in terms of 4 to 6 t ha^{-1}." The potential for yield gains of this magnitude makes the lowlands West Africa's major rice growing environment of the future, transforming the prospects for regional food security.

The new generation of improved varieties is now starting to flow into farmers' fields

But to perform that well consistently, the new varieties will need to be able to cope with the stresses encountered in the lowlands. Few of those available at present are able to do so. The biggest threat to future yield gains is from pests and diseases, which are likely to become more widespread as the lowlands develop. But the next generation of technologies also needs to be able to withstand some challenging abiotic stresses, including iron toxicity and drought.

That generation is now starting to come on-stream. The late 1990s are witnessing a quantum leap in the number of improved varieties released or being multiplied for dissemination across the region. Many of the new plants combine high yields with resistance or tolerance to one or more of the lowlands' most important stresses (see box overleaf).

The varieties are the fruit of nearly a decade of work by WARDA and its national partners. Singh joined the Association in 1991, shortly after it took over responsibility for lowland breeding efforts from the International Institute of Tropical Agriculture (IITA). He now works directly with WARDA's 17 member states, as well as feeding improved germplasm into regional trials through the International Network for Genetic Evaluation of Rice (INGER). Collaboration with national colleagues is organized through WARDA's Lowland Rice

Lowland varieties released or under on-farm testing in 1997

- Côte d'Ivoire:
  WITA 1: High-yielding, adapted to the forest zone, tolerant to iron toxicity
  WITA 3: High-yielding, adapted to the moist savanna zone, tolerant to iron toxicity
  WITA 7: High-yielding, tolerant to iron toxicity and resistant to RYMV
  WITA 8: High-yielding, tolerant to iron toxicity and resistant to RYMV
  WAB 638-1: High-yielding, good eating quality

- Nigeria:
  WITA 1: High-yielding, tolerant to iron toxicity
  WITA 4: High-yielding, tolerant to iron toxicity and drought
  Cisadane: Tolerant to ARGM

- Niger:
  WITA 8: High-yielding, tolerant to iron toxicity and resistant to RYMV
  WITA 9: High-yielding, tolerant to RYMV

At Sakassou, the participating farmers were unanimous in selecting WITA 8 as their preferred variety

Breeding Task Force, a network of national and international scientists that meets annually to plan activities, evaluate results and organize the exchange of germplasm and information.

To introduce the varieties to farmers, Singh and his colleagues are conducting participatory varietal selection trials. Initial results suggest the new varieties will prove highly popular. At the Sakassou irrigation scheme in Côte d'Ivoire, where trials are being conducted in collaboration with the country's Agence Nationale pour L'Appui au Développement Rural (ANADER), all the participating farmers chose the same variety—WITA 8—out of the six tested on their fields.

A problem virus

The most threatening disease in the region is rice yellow mottle virus (RYMV). Its symptoms, as its name suggests, are a mottled yellowing of the young plant, whose subsequent growth is stunted. Since it was first observed in Kenya in the late 1960s, RYMV has spread to Sierra Leone, Côte d'Ivoire, Nigeria, Niger, Burkina Faso, Mali, Tanzania and Madagascar, where it now causes serious economic losses.

Regional screening for resistance began in 1975 at Rokupr, Sierra Leone, under a cooperative progam with IITA. Efforts at IITA itself started in 1982, once the disease had been identified in Nigeria. By 1983, the scientists had found CT 19, a moderately resistant early-maturing lowland variety from India. Genes from this and other sources of resistance were incorporated into a high-yielding background. This work culminated in the development of WITA 7, WITA 8 and WITA 9, three resistant varieties that have already been released in some countries and are at the pre-release stage in several others. RYMV is often found in association with iron toxicity, so it is vital to combine resistance to the two stresses in the same plant. WITA 7 and WITA 8 both have this combination.

Problem sorted, you might think. But Singh is keeping his fingers crossed, as resistance could break down. WARDA plant pathologist Séré Yacouba has already found that variability in the virus can destabilize varietal resistance in both time and place. WITA 7 and WITA 8 both showed symptoms of the disease in trials conducted in Niger in 1997. Yacouba believes resistance could be made more durable by simultaneously using other control methods to keep the pathogen and its vectors at moderate levels. He and his colleagues are seeking to develop such methods.

To get a grip on the variability problem, the team in WARDA's pathology laboratory has purified different isolates of the virus from Côte d'Ivoire, Burkina Faso, Mali and Niger and developed antibodies to them. These are being used as diagnostic tools to establish variability and map its extent.

A plague of midges

In 1988 rice farmers in southeast Nigeria were hit by a new insect pest that wiped out up to 90% of their crop. At the height of the epidemic, around 50 000 hectares were affected.

The culprit was *Orseolia oryzivora* , otherwise known as the African rice gall midge (ARGM), a tiny mosquito-like insect that multiplies rapidly, laying its eggs on the leaves of the rice plant. When the eggs hatch the larvae migrate to the plant's growing point, where they feed while secreting a substance that inhibits the formation of panicles. Affected tillers do not produce a single grain of rice.

ARGM is another relative newcomer to Africa, having first been noted in northern Cameroon in the 1950s. Besides Nigeria and Cameroon, it is now found in Burkina Faso, Mali, Sierra Leone, Tanzania and Uganda. The insect differs from its Asian cousin *O. oryzae*. As a result, many resistant Asian rice varieties succumb when they get to Africa. Virtually all the new varieties developed for the lowlands over the past 25 years are susceptible to the pest.

"That's worrying," says Singh. "But at least we've got one solution." In 1991, he and Mark Ukwungwu from Nigeria's National Cereals Research Institute (NCRI) identified Cisadane, a variety imported from Indonesia, as combining relatively high yields and good grain quality with tolerance to the midge (Table 1). These findings were confirmed when the variety was tested under farmer management by Ukwungwu and Charles Williams, an entomologist working on a special project on ARGM between WARDA and the UK's CAB International. Cisadane was accepted for release in 1997 and is now being multiplied and disseminated to farmers by local non-government organizations (NGOs) in areas vulnerable to infestation.

Cisadane gives only partial protection, however, so the search continues for additional sources of resistance. Under the WARDA/CAB International project, screening trials are being conducted in a "hot-spot" for ARGM infestation in southeast Nigeria. As in RYMV, the search is complicated by the pest's genetic variability. To overcome this problem, the trials have been extended to a broader range of locations in four other countries through the regional Integrated Pest Management Task Force—

Table 1. Yields of Cisadane and farmers' check varieties at sites with differing levels of ARGM infestation

		Mean yield (kg ha^{-1})		Yield difference as:	
Infestation level	N	Cisadane	Farmers' check	kg ha^{-1}	% of check
0-10%	7	2810 ± 530	2798 ± 540	12	0.4
10-20%	7	2407 ± 446	1865 ± 370	541	29
20-30%	4	1211 ± 259	736 ± 330	475	65
30-40%	6	1166 ± 308	687 ± 242	480	70
40-50%	8	1280 ± 434	1023 ± 340	257	25
50%	6	785 ± 491	413 ± 193	372	990
All sites	38	1666 ± 211	1326 ± 199	340	26
>10%	31	1408 ± 207	993 ± 163	415	42

another networking arrangement between WARDA and national institutes.

Iron in the soil

The severest abiotic stress in the lowlands is iron toxicity. Iron is widely present in West Africa's lateritic soils, but only becomes soluble under anaerobic conditions when soils are waterlogged. Once released it moves with water, gradually trickling downhill to concentrate in flooded valley bottoms.

"Iron now occurs at toxic levels in around 30 to 40% of West Africa's lowland area," says Kanwar Sahrawat, one of WARDA's soil scientists. The first signs of toxicity in the rice plant are bronze spots, which appear on the tips of lower leaves before coalescing and advancing down the blade. In severe cases, the entire leaf may turn a deep, purplish brown.

When iron toxicity occurs early in the growth cycle of rice it need not be too damaging, attenuating as the plant's roots become more vigorous. But when it strikes during panicle formation it has serious effects on yields, which are typically reduced by up to 50%. Losses are greater when toxicity is accompanied by nutrient deficiencies.

Until 1997, the only tolerant variety available to farmers was Suakoko 8, found over a decade ago in Liberia and released both there and in Sierra Leone. This traditional variety is a tall plant with a low yield potential and is therefore suitable only for severely toxic conditions in rainfed lowlands. Several of the new varieties released in 1997 combine higher yields with a degree of tolerance, but performance can probably be improved still further.

Sahrawat has been screening these and other varieties for their tolerance. Starting in 1992 and 1993, he conducted field experiments at two sites in Côte d'Ivoire—Korhogo, where toxicity is high, and Mbé, where it is low. His results (Table 2) show striking differences between varieties. The best performers under toxic conditions belonged to the TOX series, derived from crosses originally made by IITA. Among them was TOX 3100-32-2-1-3-5, recently released as WITA 3. The improved variety most commonly available in Côte d'Ivoire, Bouaké 189, did relatively poorly.

Sahrawat's results show that genetic tolerance to iron toxicity can contribute significantly to rice production in toxic soils. Traditional varieties that are tolerant are

Rice varieties showed marked differences in their susceptibility to iron toxicity

Table 2. Performance of 15 cultivars at two sites with low (Mbé) and high (Korhogo) iron toxicity in Côte d'Ivoire, 1992

Cultivar	Grain yield (t ha^{-1})		Iron toxicity score at Korhogo
	Korhogo	Mbé	
TOX 3100-32-2-1-3-5	5.04	6.35	2
TOX 3107-39-1-2-1	5.00	5.65	2
Suakoko 8 (control)	4.85	4.44	3
ITA 408	4.42	6.49	3
ITA 247 (control)	4.37	4.68	3
TOX 3118-6-E2-3-2	4.33	5.72	3
TOX 3081-36-2-3-1	4.33	5.54	3
TOX 3027-43-1-E3-1-1-1	4.26	5.79	3
TOX 3118-42-1-1	4.09	6.36	3
ITA 326	3.95	4.50	3
TOX 3050-46-E3-3-3-3	3.31	6.52	3
TOX 85C-C1-10-WAS	3.29	4.70	5
TOX 85C-C1-17-WAS	3.24	4.70	7
Bouaké 189 (local control)	2.87	5.64	7
TOX 3052-46-3-3-1	2.76	5.96	5

tall growing and prone to lodging when fertilizer is applied. There is an urgent need to isolate the genes conferring tolerance and transfer them into improved short-statured plants with good grain quality.

Oryza glaberrima to the rescue

Most of the improved varieties currently available to lowland farmers have been developed from recently imported Asian *Oryza sativa* germplasm that has as yet acquired little resistance to West African stresses. That makes it all the more urgent to exploit the genetic diversity of West Africa's indigenous rice species, *Oryza glaberrima.* Grown in the region for thousands of years but largely displaced by the higher-yielding *O. sativa* today, *O. glaberrima* is known to be a rich source of resistance to both biotic and abiotic stresses.

WARDA scientists have already developed promising interspecifics between *O. glaberrima* and *O. sativa* for use in the uplands (see WARDA Annual Report 1996, p. 13). These lines compete well with weeds and resist several other stresses, while retaining the high-yielding character of Asian germplasm. Now the plan is to adopt the same approach to the creation of new varieties for the lowlands.

In the early 1990s, Singh and his colleagues began screening the regional *O. glaberrima* germplasm collection held at IITA in the search for new sources of resistance or tolerance. Their efforts have been richly rewarded: the scientists have found 18 varieties with drought tolerance; resistance to RYMV has been confirmed in five lines originally screened by scientists at IITA; and the biggest prize is three lines—TOG 7106, TOG 7206 and TOG 7442—that have shown excellent resistance to ARGM.

The next step was to cross these lines with high-yielding *O. sativa* plants. Making crosses between species is a hit-and-miss business in which many of the offspring are infertile. Predictably, conventional crossing techniques have so far led to disappointingly slow progress. Following a path successfully taken by Monty Jones, WARDA's upland rice breeder, Singh and his colleagues are now turning to anther culture to overcome the sterility barrier and speed up the production of viable lines. For RYMV, studies using genetic markers are under way to isolate genes with a view to transferring them by genetic engineering.

Most lowland farmers are women. They stand to benefit greatly from the new technology

The germplasm and techniques originally applied to the development of upland rice varieties are thus spilling over into WARDA's work on technologies for the lowlands. Given the high potential of the lowlands, the long-term pay-off could be even greater here than in the uplands.

Towards West Africa's Green Revolution

The improved varieties currently available to lowland farmers offer significant yield increases over traditional plant types. But the next generation of plants will go one better, incorporating resistance or tolerance to many of the region's most problematic stresses.

Once these tougher plants reach farmers' fields, the West African lowlands could become the cradle of a new Green Revolution in rice production. It will be a revolution markedly different from its Asian predecessor. Genes, not chemicals, will guard the crop against insect pests; farmers will play a major part in selecting the new technology; and women, who are the majority of farmers in the lowlands, should benefit alongside men.

Guinea's Catching Up

GUINEA HAS become the first country in West Africa to benefit from a new drive to transfer rice technology in the region. The new interspecific plant type developed by WARDA is proving popular with the country's farmers.

Hands off

There wasn't a WARDA staff member in sight. The Guinean trainees were on their own as they walked round the experimental plots.

But the lack of supervision wasn't a case of WARDA's scarce resources being stretched too thin. "We deliberately left them to their own devices," explains upland rice breeder Monty Jones, who was responsible for organizing the trainees' activities. "We didn't want to influence their choices."

The trainees, at WARDA's Bouaké headquarters for a 1-week intensive course, were doing something important for the future of upland rice in their country—selecting new genetic materials to introduce to farmers. The plots they were inspecting contained 150 varieties considered promising for Guinean conditions. Around 50 of them were interspecifics—the progeny of crosses between the Asian species *Oryza sativa* and the African *O. glaberrima*—developed by WARDA in Côte d'Ivoire and already proving popular with farmers there. These plants combine a high yield potential with resistance to a wide range of stresses, including weeds.

Jones' "hands-off" attitude to the trainees' task is the hallmark of WARDA's new approach to varietal selection. "Just like farmers, national scientists feel a stronger sense of ownership of the technology if they play a leading part in selecting and adapting it," he says. "That way the chances of successful technology transfer and adoption are far greater."

Seventy per cent of Guinea's rice area is upland, ripe for the introduction of new technology

New project

It was Moctar Touré, of the World Bank's Special Program for African Agricultural Research (SPAAR), who set the ball rolling. He came to WARDA in mid-1996 with a proposal to put new World Bank money into rice technology transfer in West Africa. The idea was to concentrate on countries that had so far benefited little from regional research and development (R&D) efforts.

Among such countries, Guinea seemed an obvious place to start. Despite its small size, it is among West Africa's top five rice producers in terms of area cultivated. Yields are low, usually less than 2 t ha^{-1}, but could rise substantially if farmers had access to improved varieties and other inputs. Around 70% of Guinea's rice area is upland, for which little new technology has yet been developed. This area is ripe for the transfer of the new interspecific plants.

Under the SPAAR proposal, WARDA would train Guinea's research and extension teams in all aspects of rice-related adaptive research and development. The training would be accompanied by the direct introduction of new varieties onto farmers' fields, using the participatory varietal selection methods already successfully developed in Côte d'Ivoire.

Intensive training

Ten researchers and extension officers from the Institut de Recherche Agronomique de Guinée (IRAG) and the Service National de la Promotion Rurale et de la Vulgarisation Agricole (SNPRV) came to WARDA's Bouaké headquarters in February 1997. They spent a week studying varietal improvement and technology transfer, with special emphasis on the techniques of participatory varietal selection (see box).

During the week, WARDA's scientists worked with the trainees to plan the drive to test and disseminate new technology. Over a 3-year period, conventional on-station and on-farm trials would be complemented by a new set of participatory varietal selection trials. On their last day, the trainees went to the experimental plots at Bouaké to make the initial choice of the varieties that would be shown to farmers. They chose 25 varieties, 9 of which were interspecifics.

On their return to Guinea the trainees gave a glowing account of the training they had received. But Baba Gallé Camara, SNPRV's Director General, wasn't satisfied. He knew that, to ensure success, it was vital to involve the lower-level staff who would actually implement the trials. It was also important to ensure that the Guinean research and extension services assumed ownership of the technology transfer process.

To this end, Camara organized a second intensive training course, held in Guinea itself in May 1997, just before the start of the cropping season. Researchers and extensionists who had been on the first course served as trainers, together with WARDA's Monty Jones. The participants, 25 in all, consisted of 2 or 3 technicians and field assistants from each of the areas in which on-farm research was to be conducted, plus the coordinators of the national research and extension teams.

New interspecific plants have already proved popular in Côte d'Ivoire

Participatory varietal selection

WARDA's scientists have developed a simple methodology for participatory varietal selection trials. The trials take place over a 3-year period.

In the first year, an innovative farmer is chosen within the community to grow a range of new rice varieties. Local farmers are invited to visit the farmer's fields three times during the cropping season: at the vegetative growth stage, when early vigor and the ability to suppress weeds can be assessed; at flowering, when characteristics such as height, duration and resistance to pests and diseases become evident; and after harvest, when grain quantity and quality can be appreciated. At the end of the third visit, the researchers ask the farmers to name up to five varieties that most attract them, and to state the reasons for their choices. Trials on cooking characteristics and taste are also carried out at this time.

During the second year, the farmers are given seed of the varieties they have named and invited to try it out for themselves, comparing it with their traditional varities. In the third year, the farmers are asked to pay for the seed if they wish to continue using it.

Trials conducted along these lines in Côte d'Ivoire have proved a successful way of stimulating demand for new varieties in the farming community. By involving farmers in varietal development, they ensure the final product meets consumers' needs.

Together they developed detailed plans for the season, including experimental protocols and data collection and management procedures. Finally, seeds were distributed and the season got under way.

Operation Rainfed Rice

Baldet Mamadou couldn't help noticing it. Several farmers had bulging pockets as they left the demonstration plots.

Should he intervene? He and the other technicians had worked hard to organize the open day. The farmers had been told that the plots were strictly for demonstration only. Now it seemed there wouldn't be much left for the next batch of visitors to look at.

But Mamadou decided to let the smuggling continue. After all, it proved that the day had been a success. The farmers had been so keen to try the new varieties out in their own fields that they had been unable to resist the temptation to help themselves to panicles, despite being promised seed later. Some had taken a panicle each from up to seven varieties.

After harvest, farmers make a final selection of the varieties that interest them

The scene is a farm near Faranah, on Guinea's central plateau. Mamadou is one of the WARDA-trained technicians now responsible for implementing participatory varietal trials. The trials, held here and at seven other locations in 1997, exposed over 200 farmers to 30 new rice varieties. During the same season, a further 116 farmers evaluated three WARDA varieties in conventional on-farm trials, while 13 varieties were tested on-station. Operation Rainfed Rice, the government's program to extend the new varieties, is in full swing.

According to Aly Condé, head of extension at SNPRV, farmers at every location were enthusiastic about the new varieties. Three of the interspecifics—WAB 450-1-B-P-91-HB, WAB 450-1-B-P-138-HB and WAB 450-1-B-P-38-HB—proved especially popular. The farmers appreciated not only their rapid development and ability to combat weeds but also their resistance to diseases and tolerance to drought.

The first year of the operation has provided enough information to enable the Guineans to narrow the choice of new varieties to ten, seven of them interspecifics. For the 1998 season they plan to more than double the number of farmers participating in on-farm trials and to increase the experimental area on each farm. WARDA is backing the expansion by multiplying seed.

As the operation intensifies, the demand for seed among farmers is likely to outrun supply. With the national seed services already working flat out, the government has enlisted the support of several non-government organizations (NGOs) to help fill the gap. Among them is Sasakawa Global 2000, whose representative in Guinea attended the in-country training course and has since become a champion of the new technology. Sasakawa will play a lead part in seed multiplication for the 1998 season.

A matter of taste

Billo Barry, coordinator of Operation Rainfed Rice, agrees with Condé that the new interspecifics were popular with farmers. But both men are anxious to carry out more tests on taste and cooking characteristics before they decide to go for full-scale promotion. That's because some traits in demand in Guinea are specific to that country.

According to Barry, Guinean women value the tendency of the grain to swell during cooking. This gives a generous helping of rice, making limited family grain supplies go further. As any left-overs from the evening meal are eaten for breakfast the next morning, keeping quality is also important. “Families will reject grain that ferments in the heat and humidity,” he says.

Jones believes the new interspecifics will pass the test of consumer acceptability. “Farmers often hold on to their old *glaberrima* types because they smell and taste sweet, as if they had butter with them,” he says. Some of those qualities have been retained in the new interspecifics. One, WAB 450-1-B-P-138, has already been selected for its grain quality, as well as its high yields. Jones comments: “For the first time, in the history of West African rice research, we have a high-yielding variety that also tastes good!”

Back for more

Fourteen technicians from Guinea made a second visit to Bouaké in early 1998. The purpose was to review the results of the 1997 season and prepare for the 1998 one.

The Guineans had experienced few problems in implementing the trials during 1997. One area had caused difficulty, however—recognizing pests and diseases and scoring for resistance to them. This theme received special emphasis during the second visit. Seed multiplication and statistical analysis of trial results were two more areas in which the team sought, and got, specialized advice from WARDA’s scientists.

“The Guineans feel confident in us because their farmers liked the new varieties,” notes Jones. “That’s why they keep coming back to us for more.”

Ingredients of success

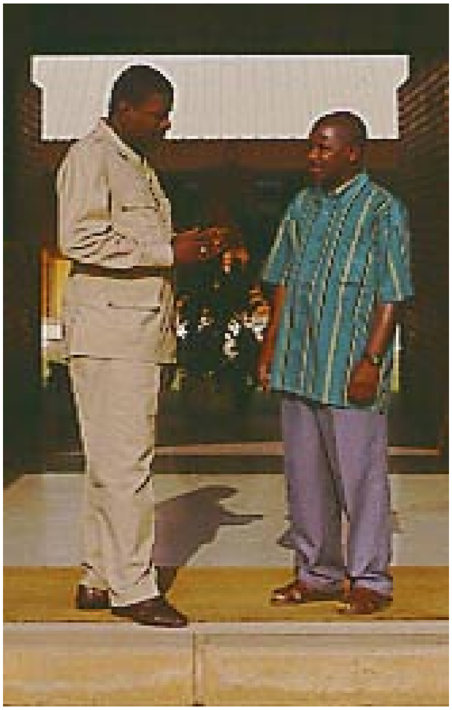
WARDA has spent many years training rice research and extension staff in West Africa. Why did Guinea not benefit from earlier training efforts, and what has made this project succeed where others failed?

The main reasons for success lie in the intensification of the training effort, its relevance to Guinea and the fact that it was linked to the introduction of new technology. The participatory approach to training, which parallels that to varietal selection, also helped.

“Guinea’s previous participation in WARDA training events was limited to sending two or three participants to courses held at the regional level, in Bouaké,” explains Jones. “Those courses were one-off affairs that did not deal with conditions specific to Guinea. And the number of Guinean participants was insufficient to breathe new life into the R&D process once they returned back home.

“This time it was different. We conducted no less than three courses, one of which was held in-country. All the

Aly Condé (left) and Billo Barry at WARDA’s Bouaké headquarters. Guinea’s research and extension services work closely together to ensure the success of Operation Upland Rice



participants were from Guinea and we focused sharply on Guinean problems and their solution. What's more, the courses weren't in the abstract: having learnt their lessons, the participants had to apply them for real during the next season."

WARDA's participatory approach to training ensured the relevance of training sessions. "We identified the course content ourselves," says Barry. "And because we were relatively few in number, each of us was able to participate more fully."

A classic case of spillover

The WARDA-SPAAR project with Guinea shows just how quickly improved technology can reach farmers' fields. In that respect it provides a useful model for others.

The project is also a classic case of spillover. Small countries such as Guinea often lag behind larger ones in agricultural R&D. But given the opportunity they can catch up fast, benefitting from progress made elsewhere. WARDA, like the other international research centers, can play an important part in making that happen.

A New Way with Legumes

UPLAND RICE farmers in West Africa need environmentally friendly technology to ward off weeds and replenish soil nitrogen. Introducing legumes is an obvious answer. WARDA scientists hope that, by adopting a participatory approach, they will succeed where others have failed.

Tuning in

"In the old days we used to clear only *grande forêt*," said one old man. "Now it's just *petite forêt*."

The farmers were sitting together in the village shelter, discussing their problems with WARDA scientists. As so often in such discussions, the older members of the group were able to throw valuable light on trends over time. The farmer's remark reflected awareness of how fallow periods in Côte d'Ivoire's forest zone had shortened over the past 25 years. The trees don't have time to grow as tall as they used to.

The talk moved to the topic of weeds, growing animated as the farmers vented their frustration. All expressed their hatred of *Chromolaena odorata,* a crawling shrubby species that invades rice fields, bringing the cropping cycle to an abrupt end and inhibiting forest regrowth. One described how the weed "falls from the air"—his way of denoting what the scientists call wind-borne seed transmission. Another called the weed by its local name of "Independence", a reference to 1960, the year in which Côte d'Ivoire became independent from French West Africa and in which *Chromolaena* first became widespread in the area. The name rings true: other records suggest that the weed probably entered West Africa with rubber planting materials imported from Southeast Asia during the late 1950s.

The farmers went on to display their detailed knowledge of a wide range of weeds. Some weeds are used as indicators of the state of the farming system, triggering certain responses. *Tridax*, for instance, is known to appear only when soil fertility starts to decline. When the farmers see this weed, they know it is time to abandon the land and clear new fields.

Chromolaena invades farmers' rice plots, forcing them to abandon their fields

When the scientists enquired about legumes as a possible solution to the weed problem, the group was unanimously dismissive. One farmer asked: "How do we know they won't take over, just like the weeds?" His question reflected the hard work he had had to put in only the previous season, when a twining legume had invaded his rice plot from a neighboring rubber plantation, obliging him to disentangle every stem of his crop. It went to the heart of the challenge facing the scientists: any new plant introduced to farmers' fields must be competitive enough to shut out weeds, without becoming a weed itself.

It is by tuning in to local knowledge and experience in this way that the scientists hope to succeed in an ambitious project—the introduction of legumes to rice-based upland farming systems in West Africa. Their softly-softly approach is dictated by the high failure rate of past attempts to persuade farmers in stressed production systems elsewhere on the continent to grow these valuable soil-enhancing plants. "Each location has different needs," says WARDA agronomist Mathias Becker. "It's essential to understand farmers' concerns and engage them in the research process before asking them to try something new."

Two birds, one stone

Two powerful forces drive slash-and-burn farming in the West African uplands—the buildup of weeds, and declining soil fertility. Both problems are becoming more acute as fallow periods shorten in response to the growing pressure on land.

The shortest fallows are recorded in the densely populated parts of the forest zone, where they have fallen to 2-6 years compared with 12-15 years in the early 1980s. Fallow periods in the savanna, at 12-15 years, are still relatively long, but the number of years of cultivation in each cycle has risen from 3 to 6-8. In neither zone are farmers adopting measures to replace soil nutrients, with the result that soils are being mined. As rice yields plummet, weeds that thrive on poor soils invade farmers' plots, forcing them to move on.

WARDA technicians sample weeds in farmers' rice fields. Understanding the dynamics of weed infestation is important in identifying the right solutions

To measure the relative importance of the two problems, Becker worked with weed scientist David Johnson to conduct yield gap studies at different locations in the forest and savanna zones. In plots superimposed on farmers' fields the scientists either added nitrogen or removed all weeds or else did both, comparing the resulting yields with those under farmer management in the surrounding field. They found that the share of weeds in explaining the difference in yields was higher in the forest, while nitrogen deficiency assumed more importance in the drier savanna zones. Together, the two problems explained over 60% of yield losses at all locations (Figure 4).

Johnson's studies have revealed some of the mechanisms underlying the worsening weed problem and its effects on soil fertility and crop production. As land use intensifies, changes occur in the pattern of weed infestation. "With longer cultivation cycles you get an increase in grasses, which are relatively difficult to control," he explains. "That pushes up the labor requirement, forcing farmers to work harder to maintain their yields." Savanna species such as *Digitaria* and *Euphorbia* are well adapted to farming systems, germinating only when the soil is tilled. And in the forest zone the ubiquitous *Chromolaena odorata* slows down the restoration of woody vegetation during the fallow phase.

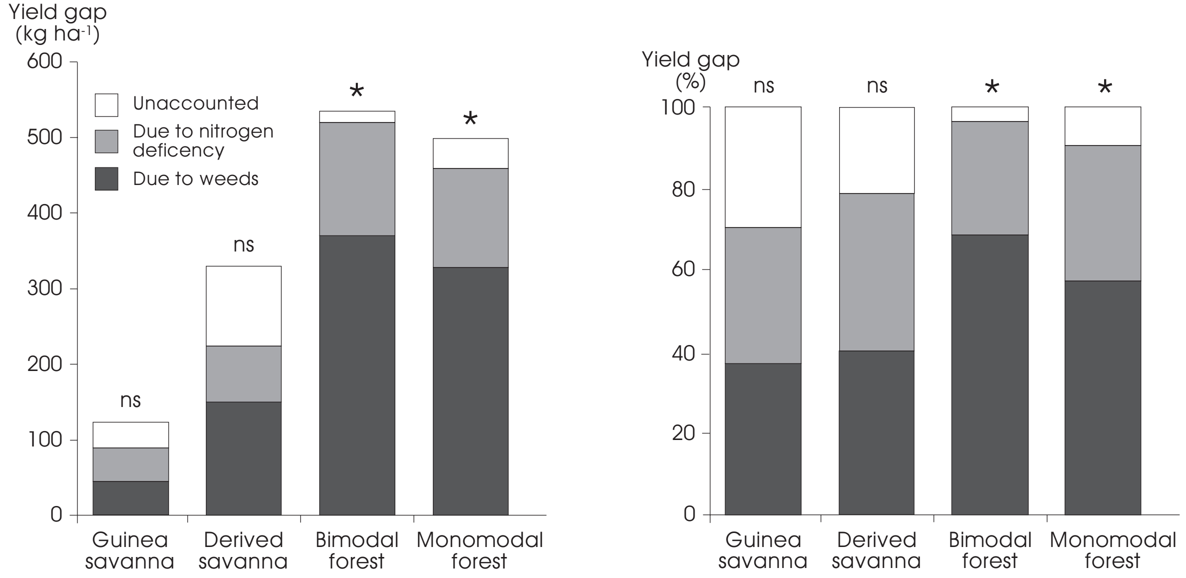
With herbicides and fertilizers unavailable or too expensive for most farmers, legumes seemed the appropriate low-cost solution. "The attraction of legumes is that they kill two birds with one stone," Becker says. "If we can identify species that produce sufficient biomass, they will occupy the land and hence keep out weeds at the same time as enriching the soil by fixing atmospheric nitrogen."

A valuable resource

Before research with farmers could begin, it was necessary to build a germplasm collection that would reflect the range of plant types available. Over a 2-year period the scientists assembled 95 accessions from 28 genera.

Most accessions were obtained from the genebanks of WARDA's sister institutes, the International Institute

Figure 4. Role of weeds, nitrogen deficiency and other factors in explaining intensification-related yield gaps in farmers' fields in different agro-ecological zones of Côte d'Ivoire



of Tropical Agriculture (IITA), the Centro Internacional de Agricultura Tropical (CIAT) and the International Rice Research Institute (IRRI). But around 20 are from local sources. Collecting the latter was a hit-and-miss experience, depending as much on luck and a sharp pair of eyes as on the expertise of farmers and others in the local community. "Some plants were under our noses," says Becker. "We even found one outside the WARDA guest-house in Bouaké." Others were spotted on field trips: "A flash of green amongst the brown dry-season vegetation, or a plant with no weeds growing near it—these were the signs we looked for." Still others came from local markets, where traditional healers or traders sold them as cures or for other specialized uses. A professor of botany from the University of Abidjan helped the scientists identify plants they were unsure about.

The collection is grown at Mbé and *in situ* on farmers' fields at different research sites in the forest and savanna zones. The aim is to provide not just a tool for research but a resource that will enrich local biodiversity.

The legume garden at Mbé, a highly diverse collection that now contains 95 accessions

Screening the collection

The next step was to explore the collection for traits important for adaptation to rice-based farming systems. For 54 accessions, the scientists had enough seed to get started in the 1995 season. To conduct an initial screening, they sowed all 54 at a range of village sites in the forest and savanna zones.

As expected, only a few of the legumes performed well at each site and very few performed well at all sites (Table 3). Biomass accumulation, however, was not the only important criterion by which to judge the plants. Survival through the dry season, the ability to keep out weeds, nitrogen fixation and seed production characteristics are equally important determinants of whether or not a plant will suit farmers' production systems.

Next came the crucial test—the effect of the legumes on the following rice crop. To gauge this as accurately as possible, the scientists simulated the traditional farming system by treating the legumes exactly as farmers would

Table 3. Biomass accumulation[1] by selected fallow legumes and associated weeds at various sites in Côte d'Ivoire, 1995-96 dry season

	Dry matter accumulation (t ha^{-1})							
	Guinea savanna		Derived savanna		Bimodal forest		Monomodal forest	
	Rice	Weeds	Rice	Weeds	Rice	Weeds	Rice	Weeds
Legume fallow								
Aeschynomene histrix	1.44 *	0.09 *	3.59 *	0.46	13.68 **	0.00 **	2.90 *	0.64 *
Arachis hypogaea	0.99 *	0.19	2.68	0.61	3.66	2.16	0.65	1.35
Cajanus cajan	1.39 *	0.28	6.69 **	0.21 *	21.11 **	0.00 **	0.00 (*)	1.76
Calopogonium mucunoides	0.65	0.10 *	4.55 *	0.41 *	3.94	0.92 *	0.17	0.89 *
Canavalia ensiformis	2.90 **	0.17	9.54 **	0.43	11.03 **	0.80 *	4.09 *	0.60 **
Canavalia rosea	1.72 *	0.18	6.79 **	0.47	4.35	1.31 *	3.11 *	0.98 *
Centrosema pubescens	0.39	0.13 *	3.02 *	0.45	3.59	0.29 **	0.22	1.55
Clitoria ternata	0.66	0.21	2.75	0.51	0.98	3.36	0.00 (*)	1.84
Crotalaria anagyroides	1.29 *	0.25	1.16	1.01	19.87 **	0.00 **	0.38	1.19
Crotalaria juncea	2.46 **	0.04 **	8.36 **	0.50	6.33 *	1.30 *	0.00 (*)	1.76
Crotalaria retusa	1.49 *	0.14 *	5.62 **	0.33 *	16.03 **	0.23 **	0.60	1.05 *
Dolichos lablab	1.28	0.14 *	3.88 *	0.56	3.42	1.10 *	0.11	2.08
Macroptilium latyroides	1.81 *	0.05 *	3.63 *	0.68	2.31	2.08	1.49	1.04 *
Macrotyloma geocarpum	0.69	0.36	0.83	0.97	0.83 *	3.72	2.00	1.43
Mucuna cochichinensis	2.98 **	0.07 *	5.14 **	0.35 *	11.72 *	0.00 **	1.77	1.14 *
Mucuna pruriens utilis	2.80 **	0.04 **	4.15 *	0.30 *	12.72 **	0.00 **	0.98	0.86 *
Pueraria phaseoloides	0.56	0.17	1.62	0.41 *	3.73	0.00 **	0.51	1.81
Stylosanthes guianensis	1.38 *	0.03 **	5.11 *	0.58	16.55 **	0.00 **	2.99 *	0.40 *
Tephrosia villosa	0.98	0.14 *	4.16 *	0.29 *	7.53 *	0.34 *	1.50	1.25
Vigna unguiculata	0.67	0.10 *	1.52	1.16	0.31 *	2.34	0.74	1.49
Voandzeia subterranea	1.27 *	0.22	1.44	1.39	0.38 *	2.95	0.42	1.28
Mean of legume plots	1.42	0.15	4.11	0.58	7.81	1.09	1.17	1.26
Weedy fallow control	0.29		1.12		3.59		1.70	
LSD (0.05)	0.49	0.08	1.29	0.70	3.58	1.56	0.54	0.81

Notes:
1 Maximum dry biomass during the 6-month growing period
*, ** Significantly more than weedy fallow control at 5 and 1% probability
(*) Significantly less than weedy fallow control at 5% probability

do when clearing a fallow. In other words, slashing was followed by burning in the forest zone, where the ash is used to fertilize the next crop, and by incorporation as green manure in the savanna zone. The scientists then planted rice and measured the impact of each legume on rice yield and weed biomass in the rice plot.

Average rice yields rose by about 25% across legumes and sites (Table 4). Some legumes gave disappointing results, leading to low rice yields and a weed biomass higher than that following a normal weedy fallow. A few produced "nuisance" regrowth in the rice plot, fulfilling farmers' fears of incurring fresh weed problems.

But along with these disappointments came some spectacular successes. The most exciting discovery was that of *Crotalaria anagyroides,* which in the bimodal forest zone gave a 50% increase in rice yields and a near total absence of weeds in the rice plot. This legume comes from Singapore, where its bright yellow flowers make it a popular ornamental around people's houses. Closely related to the more familiar Indian sunhemp, it is one of

Table 4. Rice grain yield and weed biomass[1] following different legume fallows at various sites in Côte d'Ivoire, 1996 wet season

	Rice grain yield and dry weed biomass (t ha^{-1})							
	Guinea savanna		Derived savanna		Bimodal forest		Monomodal forest	
	Rice	Weeds	Rice	Weeds	Rice	Weeds	Rice	Weeds [2]
Legume fallow								
Aeschynomene histrix	0.93 *	1.80 *	1.63	0.48	0.79 *	1.20	0.33	2.41 *
Arachis hypogaea	0.32	1.43 *	1.55	0.19 *	0.54	1.33	0.39	1.81
Cajanus cajan	0.77	1.39	1.91 *	0.36	0.57	0.83	0.38	1.63
Calopogonium mucunoides	0.75	1.41 * [3]	1.78	0.32	0.43	1.16	0.33	1.90
Canavalia ensiformis	0.72 *	1.87	1.73	0.48	0.96 *	0.91	0.51 *	1.72
Canavalia rosea	0.63	1.39	1.92 *	0.33	0.66 *	0.89	0.49 *	1.68
Centrosema pubescens	0.72	1.27	1.93 *	0.46	0.75 *	1.17	0.39	1.59
Clitoria ternata	0.42	1.23	1.84	0.50	0.43	1.01	0.49	1.81
Crotalaria anagyroides	0.48	1.00	1.94 *	0.65	1.00 *	0.53 *	0.39	1.55
Crotalaria juncea	0.40	1.51 *	1.48	0.54	0.83 *	0.93	0.32	1.60
Crotalaria retusa	0.56	1.20	1.70	0.41	0.87 *	0.91	0.30	1.48
Dolichos lablab	0.73	1.35	1.76	0.44	0.54	1.04	0.33	2.03
Macroptilium latyroides	0.86 *	1.49 *	1.23	1.01 *	0.66	1.26	0.29	1.97
Macrotyloma geocarpum	0.51	1.17	1.45	0.46	0.61	1.05	0.36	1.70
Mucuna cochichinensis	0.65	1.39	1.96 *	0.39	0.86 *	1.12	0.45	2.03
Mucuna pruriens utilis	1.07 *	1.45 *	1.55	0.79	0.78 *	1.04	0.49 *	1.33
Pueraria phaseoloides	0.87 *	1.51 * [3]	1.90 *	0.75	0.72 *	1.40 * [3]	0.48	1.73
Stylosanthes guianensis	0.49	1.06	2.18 *	0.36	0.99 *	1.25	0.55 *	2.83 *
Tephrosia villosa	0.92 *	1.67 *	2.41 *	0.50	0.80 *	1.08	0.42	1.97 *
Vigna unguiculata	0.47	1.92 *	1.38	0.40	0.64	1.67	0.44	1.89
Voandzeia subterranea	0.49	0.87	1.58	0.72	0.48	0.98	0.36	2.05
Mean of legume plots	0.66	1.40	1.75	0.50	0.71	1.08	0.41	1.84
Weedy fallow control	0.48	0.79	1.47	0.54	0.33	0.99	0.33	1.30
LSD (0.05)	0.39	0.63	0.44	0.31	0.33	0.40	0.15	0.56

Notes:
1 Cumulative dry weed biomass at 28 and 56 days after rice seeding
2 Weed biomass at rice harvest (no weeding at 56 days after sowing)
3 Mainly legume regrowth
* Significantly different from weedy fallow control (LSD 0.05)

several plants in the collection that are little known to scientists and have never previously been grown in West Africa. "Provided it doesn't attract too many pests and diseases, *Crotalaria* looks as if it could stabilize the farming system," says Becker.

Participatory legume selection

Given the low success rate of research on the introduction of legumes elsewhere in Africa, the scientists were keen to learn about farmers' likes and dislikes early in the research process. To do so, they adapted the techniques of participatory varietal selection already developed by WARDA for rice (see box p. 25).

At Gagnoa, in the forest zone, participating farmers made three visits to the trials. The first was during the fallow phase—while the legumes were growing, just before cutting and burning. The second and third visits were to the rice crop—at 65 days after sowing, when the effect on weeds was at its most visible, and again shortly before harvest, when yield differences could be seen. In each case the farmers were invited to walk round, ask questions and select the species they would like to test themselves.

The farmers were slow to take an interest in the legumes. During the first visit, several recognized some of the plants for which they had medicinal or other uses, but very few wanted to actually grow any of them.

Farmers' interest started to quicken when they saw the rice crop. At the end of the second visit, 43% expressed a wish to try out *Cajanus* and *Crotalaria* spp. And after the third visit the figure rose to around 60%, with *Tephrosia* joining the list of the most popular species.

The visits were a mine of useful information about farmers' preferences. The first thing the researchers learned is that plant habit is an important selection criterion. Creeping and twining plants such as *Mucuna, Pueraria* and *Centrosema* are anathema to farmers, who know them as damaging invaders that twine around the stems of their rice plants, making them extremely difficult to weed. *Crotalaria*, in contrast, was popular with farmers because it is an erect, single-stemmed plant that did not look as if it would get out of hand.

Secondly, legumes for the forest zone must be easy to slash and burn. *Mucuna* did not meet this criterion, according to farmers. Nor did *Cajanus*, which dried too slowly. *Crotalaria*, however, burned well—passing another crucial test on the way to adoption.

Thirdly, any legume must have multiple uses. Some uses are major, extending over wide areas. For example, throughout the Guinea savanna, where livestock are an important source of farm income, forage value is an important criterion. Other uses vary greatly from place to place, even from farmer to farmer. One farmer said he wanted a fallow species that would provide posts to build

Women farmers testing Crotalaria. Providing most of the labor for weeding, they especially appreciated this legume's ability to suppress weeds

Some legumes behave like weeds: Mucuna in a rice plot near Mbé

an *agouti* fence around his rice plot. The *agouti*, otherwise known as the bush rat, is a rodent pest of rice.

Lastly, it is important to conduct separate evaluations for men and women. The researchers found that, as in the case of rice, men and women valued similar traits in a legume, but ranked them differently. For both, the effect on subsequent rice yields came top of the list. Ability to suppress weeds was of more interest to women, who provide most of the labor for weeding. Men were more concerned with ease of slashing and burning.

A long haul

As the scientists expected, designing and introducing legume interventions for West African upland rice systems promises to be a slow, painstaking business. It will be made a lot easier when farmers start to show more enthusiasm for the technology.

That's what makes the women of Darakokaha so popular with the WARDA team. The women, who farm a cooperative near Bouaké, were first exposed to WARDA's legume germplasm collection when they visited the Mbé research station in September 1997. Since then they have put pressure on the researchers to supply seed of plants that will help them sustain the productivity and profitability of their market gardening enterprise. The women will soon be growing pigeonpea and other legumes in rotation with their crops of rice, groundnut and onions.

Enthusiastic early adopters of legume technology: the women of Darakokaha

The researchers believe that this is the shape of things to come. "The appetite for productivity-sustaining technology increases when land is in short supply," says Tim Dalton, economist with the team. "This is most likely to happen first in market-oriented systems near large urban centers, where incomes, not just the environment, are at stake."

Given time, legumes could yet prove to be the environmentally friendly technology needed to stabilize the region's upland rice systems. But it will be a long haul.

Salt of the Earth

SALINIZATION IS widely thought to threaten the sustainability of rice production in the Senegal River delta. How serious is the problem, what are its causes, and what can be done to solve it? WARDA's scientists and their partners have been finding out.

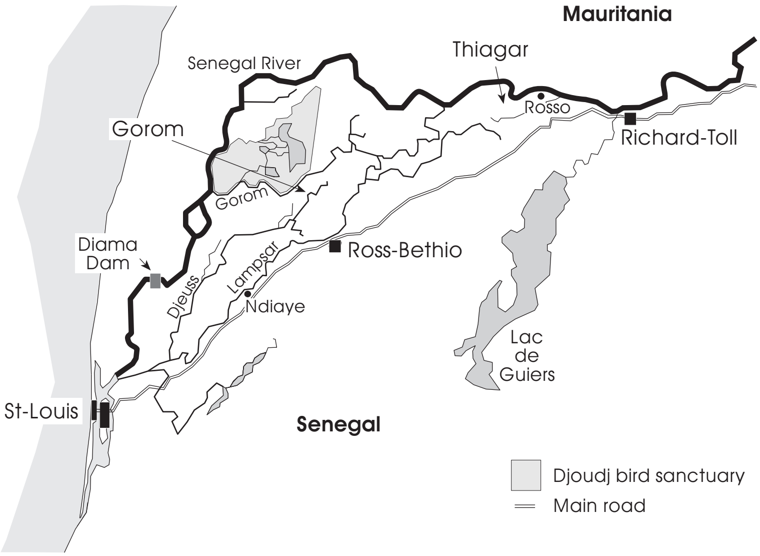
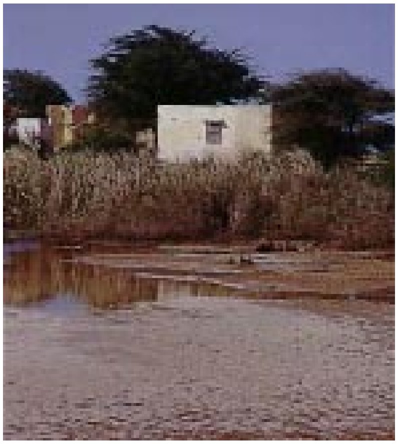


Figure 5. The Senegal River delta



Salt is never far from the surface in the delta

Senegal's salt cellar

Millennia ago, the Atlantic Ocean receded, then advanced, then receded again over the plains of what is now the Senegal River Valley. Each time it left behind it large deposits of salt that slowly found their way down the soil profile. Today, groundwater in the valley's subsoils can be three times more salty than sea-water.

That would not matter, if the groundwater were to stay put. But surface soil dries out rapidly in the hot air of the valley, and as it does so the groundwater rises by capillary action, bringing the salt up with it. The salt enters the root zone of growing crops and is drawn into plants by transpiration. Once there it eats away at plant tissue and impedes photosynthesis, with devastating consequences for yields.

Soil salinity is worst in the lower reaches of the valley, where groundwater levels tend to be higher. In large expanses of the delta (Figure 5) patches of salt lie on the soil surface, glistening under the sun. In the worst affected areas, cropping is no longer possible and the only plant that grows is a dreary grey-green shrub called tamarisk. The soil here has lost its structure, turning to a damp amorphous mass. Even the air smells brackish.

If salt is never far from the surface in the Senegal River delta, it is also uppermost in the minds of the people who work there. Malick Sarr is Head of Planning and Rural Development at the agency responsible for irrigated agriculture in the valley, the Société d'Aménagement et d'Exploitation des Terres du Delta du Fleuve Sénégal et des Vallées du Fleuve Sénégal et de la Falémé (SAED). He is in no doubt about the seriousness of the salinity problem, describing it as one of SAED's central concerns. "Our objective is sustainable crop production," he says.

"Salinization is a threat to that." And not only to that. The valley is home to one of the world's best known bird sanctuaries—a vast area of bush and swamp bounded on one side by the river and on the others by rice fields. "If the groundwater becomes too saline, the sanctuary's vegetation and fauna could change, destroying nesting areas and feed resources," Sarr warns. Worse still, domestic water supplies are also at risk. "Already, wells in many villages can no longer be used because the water has become too brackish."

The threefold threat posed by salinization—to crop production, the environment, and human health and living standards—warrants a strong collaborative research effort to combat the problem. WARDA's main research partners on salinization in the delta are SAED, the Institut Sénégalais de Recherches Agricoles (ISRA) and the Institut Français de Recherche Scientifique pour le Développement en Coopération (ORSTOM). Research in Senegal is linked through a networking arrangement to activities with national research and development organizations in Mauritania, Burkina Faso and Mali.

Shifting irrigation

In a survey conducted by Seydou Camara, sociologist with SAED, farmers mentioned salinization as the second most important factor explaining their low rice yields. Many claimed the problem had forced them to abandon their land.

How justified are such claims? It is true that farmers in the delta often leave their fields after 2 or 3 years cropping. Many move on to other fields, where they make a fresh start. The reasons for this "shifting irrigation" are not clear, but salt buildup is widely thought to be at least partly responsible. Certainly, many abandoned fields are extremely saline.

Irrigation schemes in the delta are of four kinds: large-scale publically managed perimeters, large-scale perimeters whose management has recently been transferred to farmers, village schemes managed by local cooperatives, and schemes that have always been managed privately. Village and private schemes tend to have higher rates of land abandonment than large-scale perimeters. These differing rates suggest that other factors

In parts of the delta, cropping is no longer possible

besides salinity may be involved, especially management and socio-economic factors.

Farmers get it wrong

It was to throw light on these issues that WARDA and SAED began their agronomic research on salinization. The catalyst for the research was Jean-Pierre N'Diaye, at the time head of ISRA's nearby research station and now the Institute's Director of Research. One day in 1995 he called on WARDA's agronomist Marco Wopereis and asked him to accompany him on a visit to a group of farmers in the village of Thiagar, in the northeastern part of the delta. He wanted Wopereis to hear for himself what the farmers were saying. The two men went to the village,

WARDA and SAED researchers work closely together

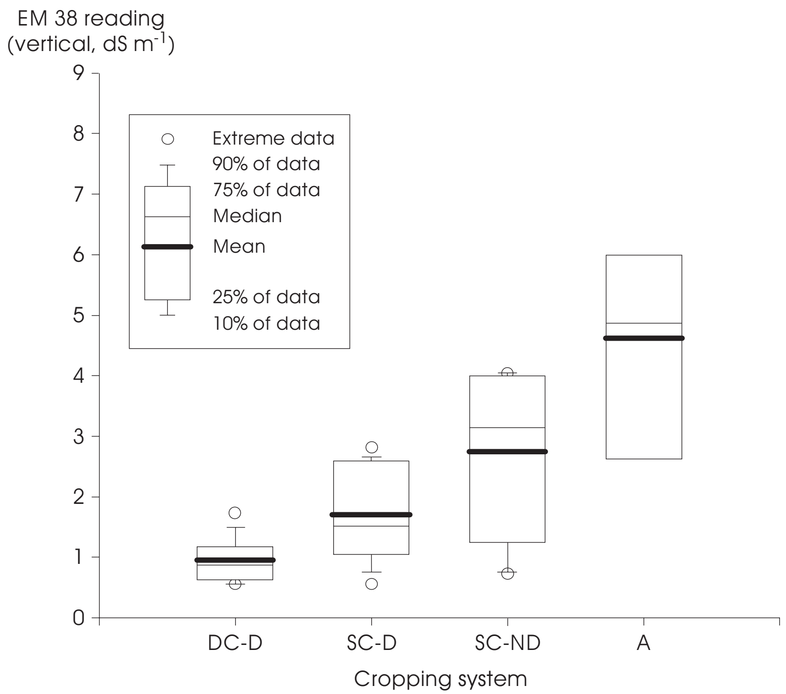
where they listened as a group of farmers repeated what they had earlier told N'Diaye: "Double cropping increases the salinity of our soils."

With N'Diaye's encouragement, Wopereis decided to find out whether the farmers were right. Working with Johan Ceuppens, SAED's expert on irrigation water management, he launched a survey in the Thiagar perimeter to assess the effects of production system and water management on soil salt content. The survey covered four types of field: double-cropped and surface-drained; single-cropped and surface-drained; single-cropped, but not drained; and abandoned fields. The scientists used an electromagnetic conductivity meter to measure soil salinity and verified their data with laboratory analyses.

The results (Figure 6) showed that production system had a strong positive effect. By far the least saline fields were those that had been double-cropped and drained. These fields are dry for only 3 to 4 months of the year, allowing less time for groundwater to rise than in single-cropped fields. The scientists concluded that, with good water management, salt levels in a double-cropped field should decline over time, or at least remain constant at a low level. In other words, the Thiagar farmers were wrong.

The effect of drainage was less marked, but undrained single-cropped fields did have higher salinity levels than drained fields. Besides drainage per se, the position of a field in the irrigation sequence was a factor. Many fields in the delta do not have their own canal and drainage facilities, with the result that up to four fields may be served by the same canal. Fields earlier in the sequence had less salt than later ones, which received dirty water drained from their neighbors.

Figure 6. Electrical conductivity of soil as a function of land use, Thiagar perimeter, Senegal River delta, 1995



DC-D: double-cropped, drained; SC-D: single-cropped, drained; SC-ND: single-cropped, not drained; A: abandoned

These results have positive implications for rice development on the heavy clay soils common throughout much of the delta. If double cropping on such soils has a beneficial effect on salinity, no harm can come by encouraging it. For once, a practice used to intensify production does not undermine its sustainability. Indeed, far from being unsustainable, rice is the *only* crop that can be produced in such areas over the long term. Attempts to grow crops that require less water, such as okra, maize, tomato or groundnut, are bound to fail.

However, the scientists emphasize that rice should not be promoted on the delta's light-textured soils. Because of their physical and chemical properties, irrigation on these soils leads to the rapid rise of saline groundwater.

Surprise finding

Wopereis and Ceuppens went on to conduct a second survey to verify the effect of single cropping without drainage on soil salinity over time. Using a combination of satellite imagery and SAED's geographical information system (GIS), they determined the previous cropping history of fields in a 2000-hectare area of the delta's Gorom region. They then measured salinity in the fields, again using a conductivity meter and verifying the results through laboratory analysis (see box).

The scientists expected to find that salinity increased over time, as salts accumulated in the topsoil. To their surprise, they found the opposite: whereas conductivity levels were 8.9 dS m^{-1} for fields in their first year of cropping, they fell to 2.2 dS m^{-1} for fields in their fourth year (Table 5). In other words, continuous rice cropping reduced salinity, even when conducted without drainage. Evidently, ponded water blocked the capillary rise of groundwater and leached salts down the soil profile as it percolated. This effect could be measured even within a single season, with EC values at the beginning of the season markedly higher than at the end of it.

Wopereis acknowledges that this finding is controversial. It needs to be verified and may turn out to be specific to the Gorom region and others like it. And it does not mean that drainage is never a worthwhile investment: if natural salinity levels are so high as to

EM 38: Not perfect, but a rough guide

At both Thiagar and Gorom, the scientists had an additional aim besides measuring soil salinity. They wished to test the accuracy of the EM 38 electrical conductivity meter—the instrument most widely used for this purpose. The EM 38 is popular in salinization research because it saves greatly on the time needed to conduct measurements.

The scientists used an EM 38 to measure salinity at over 8000 points in 158 fields at the two sites. To obtain readings from different depths, the meter was placed horizontally or vertically on the soil surface. In horizontal mode, EM 38 is mainly sensitive to salinity in the top 40 cm of the soil, whereas in vertical mode sensitivity peaks at 80 cm. The readings taken were compared with the results obtained from soil samples analysed in the laboratory.

In most situations, EM 38 measurements were comparable to the laboratory results. However, in fields with a dry topsoil the vertical readings were higher than the horizontal readings, suggesting that salinity increased with depth. Laboratory analysis showed that this was not true. Because the meter only detects salt in soil water, it gave inaccurate readings for the top 10 cm of soil.

The scientists concluded that EM 38 provides a good rough guide to soil salinity levels and is suitable for rapid, low-cost diagnosis. However, it should not be used to screen for salinity in the root zone when topsoil is very dry.

Table 5. Electrical conductivity (dS m^{-1}) of 1:5 soil extracts from plots cropped for differing numbers of years, Gorom region of Senegal River delta, 1992-95.

Sampling depth (cm)		No. of years cropped (1992-95)				
		0	1	2	3	4
0-10	Mean	8.85	2.49	2.45	2.05	2.15
	No.	12	68	92	52	23
	SD±	5.37	2.68	1.98	1.54	1.33
10-20	Mean	7.11	2.50	2.16	1.16	1.70
	No.	11	67	89	52	23
	SD±	2.93	2.62	2.09	0.96	1.14
20-30	Mean	7.73	2.34	1.77	1.16	1.70
	No.	12	67	90	51	24
	SD±	2.17	2.03	1.44	0.73	1.23

cause significant yield losses, surface drainage will be worthwhile, especially during the first few years of cropping.

Despite these qualifications, the survey results throw important new light on the salinity issue. Since abandoned fields are highly saline, it's tempting to conclude that salinization is the reason why they have been abandoned. But in fact the cause-and-effect relationship is more likely to work the other way round, with salinization occurring as fields dry out *after* they have been abandoned. In short, farmers' claims to have abandoned their land because of salinity should be taken with...um, a pinch of salt.

The real reasons

Wopereis and Ceuppens maintain that, although salinization may play a part, the real reasons why farmers abandon their fields have more to do with poor management. For a start, farmers do not prepare their fields well. Poor levelling results in uneven depths of water and hence in a crop that is quickly choked with weeds. Poor bunding leads to breakages of bunds and the escape of water. A host of other factors, such as delayed access to credit, mistimed fertilizer applications, breakdowns in pumping equipment and late weeding and harvesting may also intervene. The resulting harvest is scanty and unprofitable, the farmer finds he cannot repay loans—and decides to give up farming.

Farmers in private or village schemes are the ones most likely to fail. They habitually cut corners, skimping on the maintenance of irrigation and drainage canals, as well as land preparation. Many reduce the number of irrigations per season in order to save on pumping costs. Irrigation officials often describe management on these schemes as "sommaire", the French euphemism for downright inadequate. Such schemes compare unfavorably with those retained under SAED management, in which the rate of land abandonment is relatively low.

Piezometers: data from these could be crucial to the future of rice in the delta

Rising groundwater

One of the few vertical shapes to be seen in the largely treeless plains of the delta is the occasional metal pole, scattered at intervals across the rice fields. The poles, installed in the late 1980s under a project of the United States Agency for International Development (USAID), mark the sites of piezometers—the instruments used to measure the depth of groundwater.

Data on groundwater levels are available for 1988-91, the period covered by the USAID project. In 1997, Ceuppens asked a student and a SAED technician to take new readings at selected sites. These readings indicated that levels had risen by an average of 80 cm in just under a decade—an alarming rise that may threaten the future of irrigated agriculture in large parts of the lower delta.

Ceuppens had been prompted to investigate groundwater levels by another finding during the Gorom survey, namely that salinity levels appeared higher nearer the Gorom and Djeuss arms of the Senegal River. The most likely reason for this finding was rising groundwater tables near the watercourses. The new piezometer readings confirmed this impression, although the evidence here is maddeningly incomplete as only one transect of piezometers lies at right angles to the river.

Why are groundwater levels rising? Over-irrigation and lack of surface drainage are part of the answer. But the higher levels near watercourses mean that the other part probably lies with what has been happening at one of the delta's major bits of infrastructure—the Diama dam.

Completed in 1992, the dam spans the frontier between Mauritania and Senegal near the lower end of the delta. It was originally constructed to hold back sea-water, but is now being used to raise the level of the river. At inauguration the dam's height was set at 1 meter. It now stands at 1.80 meter, and there are plans to raise it still further. Each time the height is raised, that of the dykes that contain the river upstream must also be raised, incurring expensive earthworks.

The expense is worthwhile, say planners. Raising the level of the river opens up new areas for irrigation. It also enables farmers to irrigate by gravity instead of using diesel pumps, bringing an enormous saving in operating costs. The saving will help Senegal's beleaguered irrigation sector compete with cheap rice imports. But critics say the plan could backfire. As groundwater levels rise, the extra areas opened up could be cancelled out by the loss of currently productive rice fields. Eventually, large areas of the lower delta could lie permanently under water, including the bird sanctuary.

These risks underscore the importance of a second piece of infrastructure that has not yet been built, the much delayed *émissaire du delta* or main delta drainage channel. Currently on hold pending the outcome of negotiations with a donor, the channel is shown as a dotted line on the maps of the delta that hang on the office walls of SAED's irrigation officials. If it goes ahead, a deep trench will be cut southwestwards across several hundred kilometers of the delta, draining a vast area from Rosso in the north to the Diama dam in the south.

Like many others at SAED, Ceuppens feels building the channel is now urgent. "If groundwater levels continue to rise at their current rate, there could be a catastrophe," he warns. Already, more and more farmers in depressions are experiencing difficulty in draining their fields (see box overleaf). Raising the river level still further without building the channel could prove fatal.

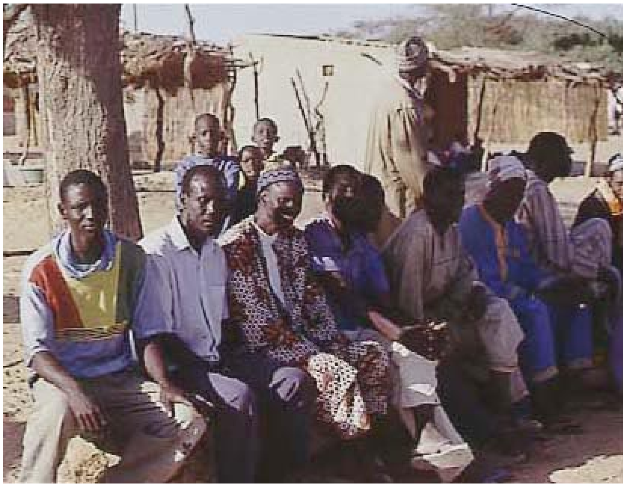
Towards tolerance

At the beginning of each cropping season, plant breeder Souleymane Gaye and his colleagues at WARDA's Ndiaye research station go out to local villages and buy sacks of cooking salt from traders. Back at the station, they sprinkle the salt into a pool of fresh water pumped from the nearby river. The scientists use the resulting *bassin salé* to irrigate the plots in which they screen rice varieties for their tolerance to salt.

Growing varieties that tolerate saline conditions is one way in which farmers can cope with the salinity problem. But the only variety of this kind available to

Raising the stakes: the Diama dam

Gravity irrigation makes delta rice production more efficient



Abdourahmane Diop (far left) with Diop Birahim and other farmers at Ndiaye

Still farming, but only just

"I'm still farming," says Abdourahmane Diop, "but I can only use one of my plots." Diop is from Ndiaye village, towards the lower end of the delta. A few years ago, he was granted two 1-hectare plots as part of a village cooperative. He describes how he and other farmers irrigated and sowed rice, then found they could not get rid of the water. "The soil is waterlogged and the water tastes salty," he says.

According to Diop Birahim, the president of Diop's cooperative, 8 out of 26 hectares around the village are in the same state. "Fields such as these can no longer be cropped in the wet season, and even in the dry, salt will attack the rice," Birahim says. "In the end, people abandon such land because cropping isn't worth the risk. You stand to lose the money you've invested in seed and inputs."

them at present is I Kong Pao, an Asian import that yields well but has poor grain quality and is only moderately tolerant. The aim of WARDA's screening exercise is to increase their choices. Since 1991, around 35 varieties have been screened each season. About half are selections from WARDA's breeding program, while the other half are from salt tolerance nurseries elsewhere in the world, notably Asia.

The exercise is complicated by the fact that each variety must be screened in both the delta's cropping seasons, since the effect of salt on yields is worse in the hot dry season, when transpiration rates are higher. Many varieties have shown a degree of tolerance in the wet season only to succumb during the dry. "Our conditions are more severe than Asia's, so most Asian materials billed as tolerant prove susceptible once they get here," says Gaye.

Despite these problems, the breeders have made some progress. Besides I Kong Pao, two other Asian sources of tolerance have been identified, namely IR 4630-22-2 and CSR-11. These have now been crossed with various high-yielding materials, including Sahel 108 and IR 31785-58-I-2-3-3, both originally from the Philippines-based International Rice Research Institute (IRRI). The progeny seem to perform reasonably well during the difficult dry season. An added advantage is their good grain quality, a characteristic difficult to combine with salt tolerance.

Building on nature

Another possible solution to the salinization problem—at least in areas where the groundwater is not already saturated with salts—would be to organize fallow years for specific plots while neighboring plots are cropped. These non-irrigated fallow plots would attract salt, which would rise into the dry area with groundwater (Figure 7). The salt would be flushed away by successive irrigations before cropping started again.

The men behind this idea are Claude Hammecker and Pascal Boivin, soil scientists with the Dakar-based branch of ORSTOM. The idea came to Hammecker during his field work, when he saw how salt accumulated on uncultivated plots next door to plots that were double-cropped during the dry season.

The strength of the idea is that it builds on what already happens in nature. But there are also snags. "It would take a lot of organization at local level," says Hammecker. "Farmers who agree not to crop would have to be compensated in some way. On profitable schemes such as Mali's Office du Niger, it might be difficult to secure that agreement." One way round these snags would be to shorten the fallow period to a single season, but would this be long enough to concentrate worthwhile quantities of salt? Hammecker hopes to find out soon, by testing his idea first on the research station and then directly with farmers at a range of locations in Mali, Mauritania and Senegal.

In the meantime, Hammecker and his colleagues are modelling the behavior of salt in soils using LEACHM, the leaching estimation and chemistry model developed at Cornell University in the USA. The aim of this work is to develop a predictive tool that will help irrigation managers and farmer groups decide how and when to intervene to deal with the salt problem. At present, LEACHM allows users to estimate the amount of salt precipitated on the soil surface, but it is not yet sufficiently sensitive to calculate the amount removed by flushing. "The problem is the extreme variability of salt distribution in the field," says Hammecker. "But we are doing field experiments that will help us build this factor into the model." Once that is done, LEACHM should prove useful in predicting the economic returns to fallowing and flushing in different situations.

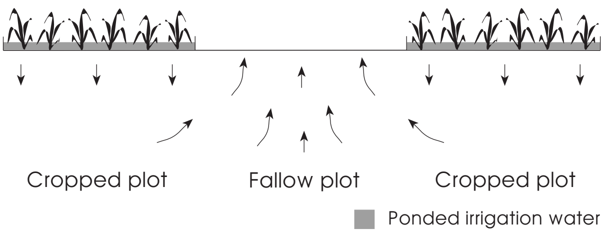
Stronger national research

Developing the skills of the next generation of national researchers is vital if Senegal is to find its own solutions to the problems posed by salinization in the longer term. Training in this complex area is closely integrated with the collaborative research effort.

No one knows this better than Rokhaya Samba Diène, a student at the University of Dakar who has just completed her PhD on salinization under the supervision of Wopereis, Hammecker, Boivin and others. Diène spent 2 years based at WARDA's Ndiaye station doing her field work in the delta and middle valley before retreating to ORSTOM's Dakar office, where she conducted laboratory studies and wrote up her results.

Through her studies, Diène has contributed to the research of ORSTOM and WARDA as well as honing her own skills as a researcher. For instance, her work with the EM 38 conductivity meter not only turned her into an expert in its use but also added to existing knowledge of salinity problems in farmers' fields. Diène also investigated the long-term threat to rice production posed by soil degradation in the Senegal River's middle valley.

Figure 7. How salt moves in irrigation systems



Getting the message across

As soon as they had completed their first survey, Wopereis and Ceuppens held a *journée de restitution*—a 1-day workshop—to present the results to the farmers of Thiagar. "The farmers now accept that they were wrong about double cropping," says Wopereis.

But that's not where the message making ends. Many more such workshops will be needed to disseminate the

A thesis nearing completion: Rokhaya Samba Diène (left) with Claude Hammecker at ORSTOM findings to all relevant parts of the delta. Both men are anxious to hammer home the fact that good management not only avoids sustainability problems but also increases the profitability of rice production. “We’ll only succeed by appealing to farmers’ self-interest,” says Wopereis, “not by preaching about the environment.”

Decision makers also have much to learn from the WARDA-SAED research. The most important message for them is that it is rising groundwater levels, not salinity per se, that most threatens the sustainability of irrigated agriculture in the delta. Building the main delta drainage channel will help solve this problem, but until this project is realized it may be advisable to hold the Diama dam at its current height or even to lower it. To keep tabs on the situation, groundwater levels need to be more closely monitored in future.

The combination of better management by farmers and appropriate infrastructural interventions by government should gradually improve both the efficiency and the sustainability of rice production in the Senegal River valley (see box). For Senegal, that’s a win-win prospect.

Saline solutions

What SAED can do:
- Build the main drainage channel
- Encourage farmers to improve their management
- Discourage “shifting irrigation”
- Discourage rice production on light-textured soils
- Monitor groundwater levels

What farmers can do:
- Prepare their land better
- Install surface drainage
- Flush their fields before and during the growing season
- Double crop on heavy clay soils
- Use a salt-tolerant rice variety

Defining the "D" in WARDA

IN PURSUIT of greater impact, WARDA has established a new program on technology transfer. A project with Winrock International is already operational and has achieved positive results.

Time to put our skates on

In the late 1980s, when WARDA became a fully fledged center in the Consultative Group on International Agricultural Research (CGIAR), its first priority was to build a strong collaborative research program. A decade later, that priority has been met and it's time for a shift in emphasis towards the development side of WARDA's mandate.

The rationale for this shift is simple. WARDA and its national research partners have increased the supply of productivity-enhancing technologies in West Africa. That means the potential for impact is now far greater than it was 10 years ago. But although some technologies have begun reaching farmers' fields, the process of technology transfer isn't happening fast enough. As a result, the actual impact of regional research lags way behind the potential.

West Africa has traditionally trailed behind the rest of the continent in disseminating agricultural technology. One of the reasons is the region's poor links between research and development. But that could be about to change: lack of resources and pressure from stakeholders are compelling previously reluctant partners to work together; non-government organizations (NGOs), weak or non-existent a decade ago, have recently proliferated in some countries; and new ways of overcoming seed shortages are being developed.

WARDA's decision to increase its emphasis on technology transfer came during its medium-term planning exercise of 1996. A new Information and Technology Transfer Program was launched later that year. Creating the program was "the right move at the right time", according to its acting head, Abdoulaye Adam. "Our donors and partners share our impatience to get things moving. Farmers too are putting new pressure on the sources of improved technology. Everyone agrees it's time we put our skates on."

New partnerships are emerging between government and non-government organizations

In 1997, in a series of seminars and workshops, WARDA's management and scientific staff developed a technology transfer strategy. This process culminated in a meeting with the directors of national research, held in early 1998, to discuss the strategy and its implementation.

What's new?

WARDA is already involved in some aspects of technology transfer. The new program will comprise a mix of old and new activities, falling into three main sets.

First is a set of existing activities geared mainly to the needs of WARDA's conventional partners, national research groups. These include the dissemination of germplasm, training in new research methods and various initiatives in information and communications.

The second set consists of activities to improve the packaging and promotion of new technology. Researchers typically lack both the experience and the motivation to turn their research results—which are often complex and presented for a specialized audience—into messages that can be used by farmers and extension services. They may also fall short in presenting their products and services to specific groups of users. WARDA's previous efforts in these areas have been sporadic and unsystematic. In the new program, researchers and information specialists will work together to improve the record.

Third is a new set of activities planned round the transfer of specific technologies. This will begin with diagnostic work to identify technologies that are ready for transfer and match them to target areas and user groups. Individual country-specific promotion activities will then be defined and implemented, in collaboration with appropriate institutions and individuals. WARDA will serve a dual role here, first as matchmaker and catalyst, bringing together potential partners and facilitating their collaboration, and secondly as a source of technical expertise, providing support in the design and implementation of activities. An innovative feature of these technology-specific pushes will be the formation of temporary "coalition groups" to champion the cause of the new technology (see box).

The strategy-making exercise identified seed multiplication and soil fertility management as the new program's two most urgent priorities. The first is a prerequisite if improved rice varieties are to reach farmers, while the second is essential if they are to perform well once they get there.

An expanded range of partners will be vital to the program's success. WARDA will aim to work directly with NGOs and the private sector, as well as its traditional partners, the national research programs and extension services. A basic premise of the program is that the old "assembly-line" model of technology transfer, in which new technology was developed by research then handed over to extension for dissemination to farmers, does not work. The aim is a new, more fluid model in which the participants interact continuously, each contributing according to its strengths. Central to the model will be the participatory approaches to research and development (R&D) that have emerged in the past decade.

The RADORT project

One component of the new program is already up and running. In 1996 WARDA and Winrock International formed a partnership to launch a new project entitled

WARDA's role

How can WARDA's new program on technology transfer maximize its impact without overextending itself? The answer lies in WARDA's role as catalyst and matchmaker.

This role is already much in evidence in WARDA's work. In Senegal, for example, the Association successfully introduced a threshing machine developed in the Philippines, not by doing all the research and development work itself but by creating a coalition of partners, each of whom contributed to the task according to its strengths. While national research and extension groups conducted trials on farmers' fields, village blacksmiths made the first Senegalese models. These were then further refined and tested, with support from a private-sector company interested in manufacturing and marketing the machine. An early task of the new program will be to replicate this success in other countries of the region. And the coalition approach will be a central strategy of the program.

Seed multiplication is another area in which WARDA can act in this role. Some organizations have funds for seed multiplication, but lack the necessary training and facilities. Others have technical expertise, but few resources. By bringing the two together, WARDA can achieve impact at low cost to its own slender resources.

Research on Accelerated Diffusion of Rice Technology (RADORT). Supported by the International Fund for Agricultural Development (IFAD), the project aims to increase on-farm rice yields by promoting seed multiplication and soil fertility technologies through multi-agency partnerships. It builds on the success of an earlier Winrock activity, the On-farm Productivity Enhancement Project (OFPEP).

As its name suggests, RADORT has a dual focus, being directly involved in technology transfer yet also standing back from the process in an attempt to identify the best ways of doing it. "It's a creative tension," says project coordinator Niels Hanssens. "WARDA has neither the resources nor the mandate to devote itself entirely to development activities. But we can't derive lessons except from experience. Lecturing others without being involved ourselves would be a pointless academic exercise."

The project already operates in three countries—Côte d'Ivoire, Senegal and The Gambia—and has just been initiated in a fourth, Nigeria. Activities in each have begun with a workshop bringing together representatives of potential partner organizations. The workshop leads on to specific technology transfer activities on the ground.

Initial experiences

It is too early yet to assess the impact of RADORT, but the project's initial experiences raise several interesting issues and allow some tentative conclusions to be drawn.

The strength of the NGO movement is highly variable in the different countries in which RADORT is working. In countries such as Nigeria, NGOs have mushroomed in recent years, whereas in Côte d'Ivoire they are still few in number and relatively weak.

Despite this variability, exciting new partnerships are emerging. Several NGOs have developed strong collaborative relationships with national research institutes in areas such as seed multiplication and participatory on-farm research. Often, these relationships are formed to solve an immediate problem but lead on to more permanent activities. In The Gambia, the Agency for the Development of Women and Children (ADWAC) approached the National Agricultural Research Institute (NARI) when it needed improved rice varieties and support in implementing on-farm trials in the mangrove swamps. It has now signalled its long-term commitment to collaboration with NARI by signing a memorandum of understanding. In Nigeria, a fully fledged research project has grown out of what was originally intended as a short-term partnership with two local NGOs in the search for varieties tolerant to African rice gall midge (ARGM). The NGOs are now multiplying and disseminating seed of Cisadane, a tolerant variety introduced from Indonesia.

Such projects demonstrate the potential unleashed by bringing together the technical expertise of research institutes with the local knowledge and commitment to grass-roots development typical of the NGO. Some NGOs are now a major force in disseminating new technology. In northern Senegal, for example, the Union des Jeunes Agriculteurs de Koyli Wirndé (UJAK) has achieved high adoption rates of the new high-yielding variety, Sahel 108. A study in the mangrove swamps of The Gambia showed that, in areas where ADWAC and other NGOs had been active, improved varieties covered 90% of the area cultivated.

But it's not all white wine and roses. Such partnerships often run into difficulties that reflect a clash of institutional cultures. Some NGOs are still highly

Thanks to NGO activity, new varieties have been widely adopted in The Gambia's mangrove swamps

UJAK: a dynamic NGO with members in 22 villages of northern Senegal

mistrustful of government and all its works, preferring their traditional role of confrontation to the risks of collaboration. Others are prone to frequent changes in priorities, laying them open to the accusation that they make "unfaithful" partners. In one country a new dam remains unfinished because the NGO responsible for building it pulled out half way through. An on-farm research program launched with the same NGO was also abruptly broken off.

Government institutions may also be unwilling to collaborate, either despising NGOs for their lack of professionalism or feeling threatened by their demand for an equal partnership. One country's researchers had, until recently, not regarded NGOs as part of the national research system and had therefore left them out when breeders' seed was circulated.

Other problems are technical rather than institutional. NGOs often find it difficult to control seed quality when seed is multiplied by small-scale farmers. In The Gambia, the problems are so serious that most NGOs have abandoned seed multiplication altogether and switched instead to helping farmers improve their seed storage facilities. In Senegal, a comparison of seed of Sahel 108 from different sources revealed deteriorating quality owing to poor land preparation and weeding.

These problems are amenable to training—an area in which RADORT can help. In Côte d'Ivoire, the project organized a highly successful workshop on seed multiplication in the farming community. There are plans to replicate the workshop in Senegal and The Gambia. In Senegal, RADORT also plans on-farm demonstrations and training seminars.

Focus on seed quality: participants at the workshop on seed multiplcation held in Côte d'Ivoire

While collaboration with NGOs has progressed in leaps and bounds in recent years, that with the private sector remains limited. "It's harder to find common cause with the private sector," comments Hanssens. Nevertheless, RADORT does have one activity with a commercial company. This involves the testing of Roundup to control weeds on irrigation schemes in Senegal. The trials are partially funded by Monsanto, the multinational that manufactures the herbicide.

RADORT has frequently served as a catalyst, getting things to happen faster than they might otherwise have done. Activities in Côte d'Ivoire have centered round a push to revitalize the country's languishing seed sector. After a decade in which no new varieties at all were released, a reconstituted national release committee approved no less than 17 in 1997, nine of them developed by WARDA.

The matchmaking role has also been much in evidence. At Saioua, in western Côte d'Ivoire, an NGO conducting participatory varietal selection with women farmers needed assistance in implementing field trials. Thanks to a request from RADORT, the Ministère de la Famille et de la Promotion de la Femme assigned an *animatrice rurale* to work with the NGO. *Animatrices rurales* are young women volunteers who receive 5 years of basic training from the Ministry before being posted to rural areas.

RADORT can also help coordinate activities. This can be especially useful in countries such as The Gambia, where NGO activity is plentiful but fragmentary and sometimes competitive.

Lastly, RADORT's early experiences have revealed plenty of scope for research. "The aim of our research is simple," says Hanssens. "It's to find out what works and what doesn't." Of the four countries in which RADORT operates, Nigeria has the most diverse institutional landscape. Under a project with the UK's Overseas Development Institute (ODI), Hanssens plans a study of that country's successes and failures in multi-agency partnerships. Meanwhile, in The Gambia, a national PhD student at the USA's Cornell University is assessing the impact of the previous OFPEP program. And Hanssens hopes to create plenty of similar opportunities for gifted young national researchers in the future.

Looking ahead

For WARDA, RADORT's experiences provide a fascinating preview of the issues likely to arise as the Association engages with the NGO community and other partners in its new drive to transfer technology.

"Our role as catalyst and matchmaker will be critical for success," says Adam. "That's the role that determines how much impact you can achieve from limited resources. As a small institute we can't afford to get directly involved in too many activities. And we certainly shouldn't substitute for national development organizations."

Despite those caveats, exciting times lie ahead. West Africa's changing institutional landscape is opening up new opportunities for impact. WARDA's new program will play a valuable part in realizing those opportunities. Watch this space!

Rice or Semiconductors?

A WARDA economist has introduced national policy analysts in West Africa to a powerful tool for assessing the profitability of producing different commodities.

Amadou Diouf: "PAM is a valuable decision-making tool for Senegal"

A new direction

"It was very intensive," says Amadou Diouf. He grins as he recalls the workshop, 2 years ago now, that launched him in a new professional direction. Then he adds: "But it was fascinating. I knew I had come across something really useful."

Diouf is a policy analyst at the Unité de Politique Agricole (UPA) of the Senegalese Ministry of Agriculture. His cramped fourth-floor office, high above a street market in crowded down-town Dakar, is a far cry from the world of the small-scale farmer. Yet his work has important implications for that world. Diouf is using a new computer-based tool, the policy analysis matrix or PAM for short, to assess his country's comparative advantage in producing rice and other commodities.

Diouf first came across PAM in February 1996, when he attended a national workshop at which a WARDA economist, Thomas Randolph, demonstrated the tool and trained participants in its use. Following the workshop, Randolph invited Diouf to collaborate with him in using PAM to analyse the economic viability of Senegal's rice sector. Diouf was also asked to head up a national team of economists charged with a separate analysis of this strategically important commodity.

In September 1996 the Senegalese economists came to Bouaké for a further 2 weeks intensive training in PAM. Throughout the following year they worked hard with Randolph and others to gather the data and complete their study. Diouf has now drafted a policy memorandum on the national rice sector, which he will shortly present to senior policy makers.

The experience has convinced Diouf and his colleagues that PAM is a valuable decision-making tool for Senegal. So much so that Diouf's boss has put him in charge of a whole set of similar studies on other commodities, including cotton, tomato, meat and groundnut. These studies are being conducted by around 20 professionals divided into small teams. To launch the exercise, Diouf organized a workshop at which he trained the teams in the use of PAM, passing on to others the expertise acquired through his work with WARDA.

The teams are due to present their findings at a national seminar planned for February 1998. It'll be the third big meeting in Senegal devoted to PAM in the space of 3 years—a measure of the country's growing enthusiasm for the tool.

Getting at the truth

PAM was developed in the 1980s by economists Scott Pearson and Eric Monke at Stanford University in the USA. The idea arose out of the first ever study of comparative advantage, which they had conducted in the late 1970s. The subject of that study, commissioned by WARDA, was rice production in West Africa.

In most countries of the region, the economists found a sector riddled with distortions induced by government policy. Only when these distortions were stripped away was the sector's underlying profitability—or lack of it—revealed. The extent of government intervention and its often contradictory nature complicated the analytical task, making it difficult to reach conclusions. On return to California, Pearson and Monke set about developing a tool that would make the task easier.

The result is a precision instrument that enables users to assess the competitiveness of different commodities in different situations. The precision comes through the use of a concept known as the commodity system. Put simply, a commodity system is the route taken by a commodity from production to consumption, along which costs are incurred by different operators. Most major commodities have many systems, which may be grouped into sets according to production system. In Senegal, for instance, rainfed rice grown in the Casamance has a different set of commodity systems from irrigated rice grown in the large-scale irrigation schemes of the north (Table 6). Within the set of systems associated with irrigated rice, there is one in which rice is pounded and eaten on the farm, a second in which it is processed by large-scale mills and sold to urban consumers, a third in which processing is done by small-scale mills, and so on.

Users of PAM can assess the comparative advantage of a system by tracing the actual costs incurred by each operator, starting with the purchase of seed and other inputs by growers, passing through the costs met by millers and traders and ending with the price paid by the consumer—whether farmer, urban housewife or restauranteur. A correction is then made to convert actual costs into the real costs met by society. For example, in the case of public-sector irrigation systems in Senegal or Mali, the costs of irrigation need to be factored in. These costs are not fully met by producers, as the irrigation schemes were constructed by government. Society pays what is known as an "opportunity cost", since the money spent on building the schemes could have been spent on building hospitals or schools instead.

The kinds of distortion that must be corrected in this way range from artificially high exchange rates or import tariffs, through subsidies on inputs such as water or fertilizer, to attempts to control prices so as to lower the cost of food for urban consumers. Once the analysis has been corrected for these distortions, the true profitability of different commodity systems is revealed.

The policy debate

"Take Singapore," says Randolph. "They don't have any agriculture, yet incomes there are higher than anywhere in tropical Africa."

Singapore is, of course, an extreme case. But apologists for the doctrine of comparative advantage often cite the tiny Southeast Asian city state as the perfect example of a country that has achieved food security without producing food itself. "Having no natural resources hasn't put Singapore at a disadvantage," says Randoph. "The country has found out what it's good at and specialized in that. It uses the profits from its electronics industries to finance food imports."

African countries, which generally have more plentiful natural resources, are not obliged to take Singapore as their model for economic development. Nevertheless, many developed-world economists have argued that they need not pursue 100% self-sufficiency in their major food commodities. Such an objective could, these economists say, be seen not merely as unrealistic but also as unwise, if in so doing these countries miss out on more profitable production opportunities.

African economists and policy makers tend to be more cautious. They cite the risks of depending on the global market for food supplies when wars or natural catastrophes could block supply routes or drive up prices. There are also strong internal reasons why developing countries should seek to stimulate domestic agriculture, including the need to provide rural employment and stem the drift to the cities. These factors are not captured in conventional PAM analyses.

In Africa, as in post-World War II Europe, the pursuit of self-sufficiency owes much to recent history. "It's a

Table 6. Domestic rice commodity systems included in the PAM exercise for Senegal

Commodity system no.	Paddy production area and system	Post-harvest system: Milling technique	Post-harvest system: Destination	Share of national rice production (%)
Casamance:				
1	Traditional mangrove, manual	Hand pounding	On-farm consumption	4
2	Traditional inland valley swamp, manual			14
3		Small-scale huller		3
4	Traditional upland, manual	Hand pounding		4
Senegal River valley:				
5	Large-scale public scheme in the lower valley, direct seeding, mechanized harvesting	Small-scale huller	St-Louis market	12
6		Mini-rice mill		5
7		Industrial rice mill		3
8	Private scheme in the lower valley, direct seeding, mechanized harvesting	Small-scale huller		12
9		Mini-rice mill		10
10		Industrial rice mill		3
11	Large-scale public scheme in the middle valley, transplanting, manual harvesting	Small-scale huller	Matam market	7
12		Industrial rice mill	St-Louis market	2
13	Private scheme in the middle valley, direct seeding, manual harvesting	Small-scale huller	Podor market	2
14		Industrial rice mill	St-Louis market	2
15	Small-scale village scheme in the middle valley, transplanting, manual harvesting	Small-scale huller	Matam market	12

knee-jerk reaction," says Randolph. "It goes back to the world food crisis of 1974-75, when grain prices doubled, then tripled, in the space of a few months. That, coupled with famine across much of East and West Africa, scared people. Self-sufficiency became the prevailing dogma, in both national governments and the donor community."

In West Africa, the drive for self-sufficiency led to heavy investment in irrigation to open up the Sahel for rice production. But in the late 1980s came a reaction, as donors realized how inefficiently some schemes were performing. The emphasis switched to the rehabilitation of existing schemes rather than the construction of new ones, the pursuit of greater efficiency through yield increases and double cropping, and the liberalization of markets.

Now the pendulum has begun to swing back again. Currency devaluations and rising world prices for rice have started to make West African production look more competitive. That impression is heightened by some impressive gains in efficiency, reflected in substantial yield increases. In recognition, donors and governments are once again talking about expanding irrigation schemes.

In this context PAM comes into its own, conferring objectivity and subtlety on the policy debate. "It puts a dollar figure on the opportunity costs of continuing to protect inefficient domestic production," says Randolph. "But it also shows you what is truly profitable. It's not all black-and-white: a country may find it should produce rice under one commodity system, but not under another."

A tale of two sectors

PAM studies of the contrasting rice sectors of Senegal and Mali illustrate the way in which the tool adds clarity to the policy debate.

Of the two countries, Mali has by far the easier time producing rice profitably. It is landlocked, with the result that high transport costs keep the price of imported rice high. Most Malians prefer higher value whole rice to broken rice, so low-grade qualities cannot be dumped on the market and farmers can earn a premium by supplying high-quality grain. In the once much maligned Office du Niger the country now has one of Africa's more efficient irrigation schemes. The scheme is gravitational, requiring no pumping, so it is relatively cheap to operate. Yields here have nearly quadrupled over the past decade in response to a combination of rehabilitation and policy reforms. The most important reforms have been improved security of tenure for farmers and the liberalization of markets, so that farmers are free to sell rice where they wish and at the price the market will pay. Liberalization has led to the demise of the huge state-operated rice mills that once dominated the schemes both physically and financially. In their place small-scale village mills have mushroomed, as farmers choose the prompt payment and higher prices offered by the private sector or the added value achieved by milling themselves.

Senegal faces much more difficult conditions. The country's Atlantic seaboard means that competitors can deliver imports quickly and cheaply. The Senegalese national dish is cooked with broken rice, attracting massive imports at knock-down prices of what most other producer countries regard as a byproduct. And the major irrigation schemes on the Senegal River still operate mainly by pump, requiring users to meet high operating and replacement costs. Under these circumstances, irrigated rice production is still not economically efficient in Senegal. Domestic production in this system persists, the study concludes, only because of welfare transfers to operators totalling a staggering US$ 21 million a year.

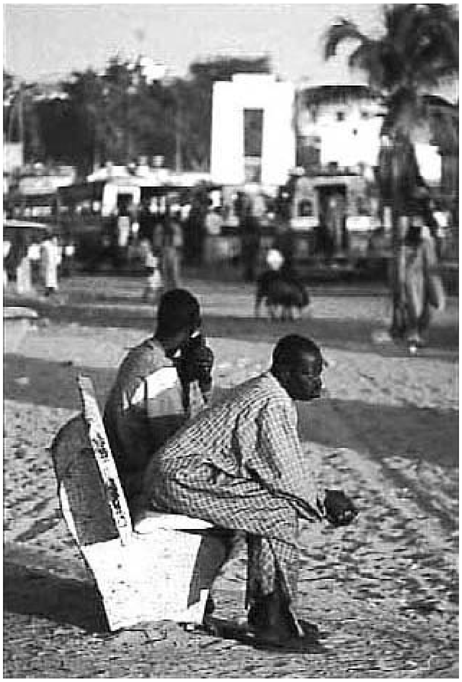
Should they give up?

Does this mean that Senegalese policy makers should decide to abandon rice production in the Senegal River valley? "Certainly not," says Randolph.

For a start, there have been efficiency gains in recent years, and all the signs are that these gains will continue. Despite a chequered record in policy reform, the Senegalese rice market has now been fully liberalized. Inefficient producers have been shaken out of the sector and, with the closure of large-scale mills, there has been a shift towards more efficient commodity systems. Yields are rising as farmers learn the business of irrigated rice production, and double cropping is gradually coming in. A new market for higher value whole grain is emerging.

Secondly, Randolph accepts the strength of the Senegalese argument for developing irrigated agriculture to keep people on the land. Cities such as Dakar and St-Louis are crowded enough already without adding fresh waves of jobless migrants from the rural areas. The social costs saved by preventing migration and avoiding periodic relief efforts are difficult to quantify but are probably so high that they alone are enough to offset the purely economic losses associated with rice production.

Open to the Atlantic, open to cheap imports: despite recent improvements in performance, producing rice efficiently is difficult for Senegal



No room and no jobs in the cities...big arguments for continued investment in irrigation

Finally, there is an environmental argument for continuing rice production in the Senegalese River delta. As we report on p. 31, irrigated rice may be the only sustainable production system under the delta's saline conditions. The option of switching to other crops, such as groundnut or vegetables, does not appear viable.

Stronger national capacity

From WARDA's point of view, the most exciting thing about PAM is the way the tool has become a means of strengthening national analytical capacity.

Partly this is due to the nature of the tool itself. PAM is versatile, serving an array of purposes such as analysing policy, deciding on research priorities and examining regional trade issues. It is also simple to use and easy to grasp for people who are not economists. Minimal training is needed to give a wide range of people access. The tool relies on data from micro-economic studies—normally a strength of national research institutes—but it also demands macro-economic inputs, encouraging collaboration with central policy units.

WARDA's unique institutional status as research institute and intergovernmental association, as well as its links with donors and development organizations, have also helped prevent PAM studies from degenerating into a sterile academic exercise. Six West African countries have now benefited from training workshops of the kind given in Senegal. In each case, Randolph has worked with a local collaborator to conduct a preliminary study, the results of which have been presented at the workshop and used in the training program. The workshop has helped identify more national collaborators and strengthen contacts with key policy makers. In both Senegal and Mali, national policy units subsequently conducted their own PAM studies. In several countries the World Bank's Economic Development Institute (EDI) and the United States Agency for International Development (USAID) have funded the workshops and/or the subsequent studies.

"The PAM studies have helped national policy units establish their credibility," claims Randolph. "And they have allowed WARDA to contribute to the national policy debate, through support to the quality of the analysis."

Regional implications

PAM can play a part in strengthening the policy dialogue at the regional as well as the national level. The tool enables different countries to forge a common analytical approach, facilitating the comparison of data and the discussion of issues.

The next step in this direction will be to hold a seminar on PAM at regional level. “West Africa’s PAM users can learn a lot from each other,” says Randolph. “They now have a basis for analysing comparative advantage and the cross-border effects of policy changes within the region. For example, if country x changes its tariff on rice imports, PAM can tell them how that will affect producers in exporting country y.” To support regional policy analysis, WARDA is developing a regional rice statistics data bank in collaboration with the Centre de Coopération Internationale en Recherche Agronomique pour le Développement (CIRAD).

Such initiatives take on heightened significance in view of recent attempts to inject new life into the stalled process of regional economic integration. At the behest of the World Bank, tariff structures are being simplified and harmonized across countries, a move that could mean a new lease of life for the region’s ailing trading bloc, the Economic Community of West African States (ECOWAS).

Financial Statement

1. Position for the year ended 31 December 1997 (in US $)

ASSETS	1997	1996
Current Assets		
Cash and Bank Balances	1 600 884	1 201 134
Accounts Receivable:		
Donors	1 786 232	1 713 412
Employees	387 961	237 600
Others	1 720 858	1 948 584
Inventories	875 754	716 279
Prepaid Expenses	147 701	138 026
Other Current Assets	0	228 217
Total Current Assets	6 519 389	6 183 252
Fixed Assets		
Property, Plant and Equipment	18 025 237	17 100 112
Less: Accumulated Depreciation	(4 316 385)	(3 599 738)
Total Fixed Assets (Net)	13 708 852	13 500 374
TOTAL ASSETS	**20 228 241**	**19 683 626**

LIABILITIES AND FUND BALANCES		
Current Liabilities		
Cash and Bank Balances (Overdraft)	174 084	763 419
Accounts Payable:		
Donors	2 584 062	2 703 203
Employees	206 085	195 874
Others	2 243 600	1 838 276
Provisions and Accruals	1 245 583	787 475
Total Current Liabilities	**6 453 414**	**6 288 247**
Total Liabilities	**6 453 414**	**6 288 247**
Net Assets		
Capital Invested in Fixed Assets		
Center-owned	13 708 852	13 500 374
Capital Fund	(783 756)	(182 850)
Operating Fund	(717 781)	77 855
Total Net Assets	**13 774 827**	**13 395 379**
TOTAL LIABILITIES AND NET ASSETS	**20 228 241**	**19 683 626**

2. Statement of activities by funding for the years ended 31 December 1997 and 1996 (in US $)

	Unrestricted	Restricted	Total 1997	Total 1996
REVENUE				
Grants	4 862 215	4 153 020	9 015 235	9 146 090
Member States' Contributions	382 739		382 739	379 675
Other Income	140 636		140 636	82 851
TOTAL REVENUE	**5 385 590**	**4 153 020**	**9 538 610**	**9 608 616**
OPERATING EXPENSES				
Research Programs	2 517 450	3 750 804	6 268 254	6 230 427
Training and Communications			0	926 883
Administration and General Operations	3 251 606		3 251 606	2 052 671
Depreciation	738 663		738 663	694 655
Gross Operating Expenses	6 507 719	3 750 804	10 258 523	9 904 637
Recovery of Indirect Costs	(359 582)		(359 582)	(342 819)
OPERATING EXPENSES (NET)	6 148 137	3 750 804	9 898 941	9 561 818
EXCESS/(DEFICIT) OF REVENUE OVER EXPENSES	**(762 547)**	**402 217**	**(360 330)**	**46 798**
Allocated as Follows:				
Operating Funds	762 547		762 547	444 287
Capital Funds		(402 217)	(402 217)	(491 085)

MEMO ITEM

Operating Expenses by Natural Classification

	Unrestricted	Restricted	Total 1997	Total 1996
Personnel Costs	*3 516 352*	*1 408 378*	*4 924 730*	*4 679 668*
Supplies and Services	*1 840 423*	*1 882 474*	*3 722 897*	*3 982 076*
Operational Travel	*412 281*	*459 952*	*872 233*	*548 238*
Depreciation	*738 663*	*0*	*738 663*	*694 655*
Gross Operating Expenses	***6 507 719***	***3 750 804***	***10 258 523***	***9 904 637***

3. Grants for the year ended 31 December 1997 (in US $)

Unrestricted research agenda

	1997	1996
Canada	546 275	612 423
Côte d'Ivoire	152 652	304 616
Denmark	231 932	
France	71 526	105 508
Germany	341 214	397 921
Japan	1 284 245	1 497 116
Korea	49 980	49 980
Netherlands	256 057	295 299
Norway	160 560	170 121
Spain		30 000
Sweden	470 396	551 116
United Kingdom	197 378	187 890
United States of America	200 000	150 000
World Bank	900 000	605 000
Total unrestricted grants	**4 862 215**	**4 956 990**

Restricted research agenda

African Development Bank (Institutional Support)	275 468	447 345
Canada (Laval University Project)	3 543	
Canada (Vector-borne Diseases Project)	327 651	249 665
Denmark (Phytosanitary and Seed Health Project)	163 644	16 348
Denmark (Vector-borne Diseases Project)	139 605	68 074
Denmark (Inland Valley Consortium Project)		151 759
European Union (Crop and Resource Management Project)	301 268	725 328
France (Agrophysiology Project)	63 387	85 351
France (Inland Valley Consortium Project)	99 950	156 693
Gatsby Foundation (Containment Facility)	1 740	
Germany (GTZ) (Temperature Stress Project)	143 223	170 215
Germany (GTZ) (Salinity Project)		27 876
Germany (GTZ) (Pesticides Project)	52 471	37 109
Germany (GTZ) (Peri-urban Project)	2 912	
Germany (GTZ) (Soil Nitrogen Project)	200 588	36 642
IFAD (RADORT Project)	189 334	129 421
Japan (Post-doctoral Studies)	25 125	
Japan (Grain Quality Studies)	72 593	70 000
Japan/UNDP (TCDC Project)	262 338	
Netherlands (Inland Valley Consortium Project)	722 453	393 010
Norway (Vector-borne Diseases Project)	138 603	84 925
Norway (Training Project)	124 054	
Rockefeller Foundation (Anther Culture Project)	103 722	103 055
United Nations Development Programme (Training and Communications)		252 147
United Kingdom (INGER Project)		245 011
United Kingdom (Weeds Project)	2 612	12 321
United Kingdom (Weeds/Insect Interaction Project)	6 693	12 401

Restricted research agenda (continued)

	1997	1996
United Kingdom (Nematology Project)	44 560	28 886
United Kingdom (Gall Midge Project)		11 803
United Kingdom (RYMV Project)	21 764	
United Kingdom (Blast Project)	23 850	
United Kingdom (RYMV Holdback Project)	18 630	
United Kingdom (Soil Degradation Holdback Project)	11 714	
United States of America (USAID) (Arkansas Linkage Grant)	3 089	
United States of America (USAID) (Network Project)	330 071	473 186
United States of America (USAID) (Technology Dissemination Project)	83 971	163 012
United States of America (USAID) (Africa Link Project)	192 394	4 139
Miscellaneous		33 378
Total restricted grants	**4 153 020**	**4 189 100**
Total Grants	**9 015 235**	**9 146 090**

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Soil Scientist	Sitapha Diatta
Soil Scientist	Kanwar Sahrawat
Ecophysiologist	Koichi Futakuchi*

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Agronomist (St-Louis, Senegal)	Marco Wopereis
Economist (St-Louis, Senegal)	Cynthia Donovan

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Grain Quality Specialist (JICA)	Hideo Watanabe
Human Health Project Coordinator	Thomas Teuscher
Inland Valley Consortium (IVC) Regional Coordinator	Jean-Yves Jamin
Inland Valley Consortium (IVC) Research Coordinator	Peter Windmeijer
Nematologist (NRI)	Daniel Coyne
Physiologist (CIRAD)	Alain Audebert
Weed Scientist (NRI)	David Johnson

* Joined in 1997
** Left in 1997

Training

Courses Given in 1997

Title and dates	Location	Language	Participants		
			Male	Female	Total
Lowland Rice Improvement and Production, 28 April-16 May	Ibadan, Nigeria (IITA)	English, French	21	2	23
Research Farm Management, 16 June-15 July	Mbé, Côte d'Ivoire (WARDA)	French	13	0	13
Use of RIDEV Software for Sahel Rice Production, 28-30 July	St-Louis, Senegal (WARDA)	French	13	0	13
Nematology Methodologies for Rice-based Production Systems, 25-30 August	Mbé, Côte d'Ivoire (WARDA)	French	10	2	12
Micro-computer Use for Agricultural Information Management, 6-24 October	Mbé, Côte d'Ivoire (WARDA)	French	6	10	16
Multiplication and Certification of Rice Seeds, 17-21 November	Mbé, Côte d'Ivoire (WARDA)	French	21	2	23
Total					100

Individual Trainees in 1997

Name and thesis topic	Institution	Sponsor	Degree
Attiogbévi, Somado Eklou Enhancing nutrient cycling in rice legume rotations through phosphate rock in acid soils	University of Göttingen	DAAD	PhD
Akanvou, René Optimizing rice-legumes intercropping in inland valleys in West Africa: A systems approach to interspecific competition	Wageningen Agricultural University	WARDA	PhD
Jalloh, Alpha Bella Genetics of iron toxicity tolerance in *indica* rice	University of Sierra Leone	AFDB	MPhil
Masiyandima, Mutsa Impact of land use on recharge to shallow groundwater	Cornell University	Rockefeller Foundation	PhD
Ouassa, Anne-Marie Control of mosquito populations in Gambian rice fields	University of Abidjan/Institut Pierre Richet	AFDB/ WARDA	PhD

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Acronyms

ADWAC	Agency for the Development of Women and Children (The Gambia)
AFDB	African Development Bank
ANADER	Agence Nationale pour l'Appui au Développement Rural (Côte d'Ivoire)
ARGM	African rice gall midge
CGIAR	Consultative Group on International Agricultural Research
CIAT	Centro Internacional de Agricultura Tropical
DAAD	Deutscher Akademischer Austauschdienst
EC	Electrical conductivity
ECOWAS	Economic Community of West African States
EDI	Economic Development Institute
FAO	Food and Agriculture Organization of the United Nations
GIS	Geographical information system
IFAD	International Fund for Agricultural Development
IITA	International Institute of Tropical Agriculture
INGER	International Network for the Genetic Evaluation of Rice
IPM	Integrated pest management
IRAG	Institut de Recherche Agronomique de Guinée
IRRI	International Rice Research Institute
ISRA	Institut Sénégalais de Recherches Agricoles
IVC	Inland Valley Consortium
JICA	Japanese International Cooperation Agency
LEACHM	Leaching estimation and chemistry model
NARI	National Agricultural Research Institute (The Gambia)
NCRI	National Cereals Research Institute (Nigeria)
NGO	Non-government organization
NRI	Natural Resources Institute (UK)
OFPEP	On-farm Productivity Enhancement Project (Winrock International)
ORSTOM	Institut Français de Recherche Scientifique pour le Développement en Coopération
PAM	Policy analysis matrix
RADORT	Research on Accelerated Diffusion of Rice Technology (Winrock-WARDA project)
R&D	Research and development
RYMV	Rice yellow mottle virus
SAED	Société d'Aménagement et d'Exploitation des Terres du Delta du Fleuve Sénégal et des Vallées du Fleuve Sénégal et de la Falémé (Senegal)
SNPRV	Service National de la Promotion Rurale et de la Vulgarisation Agricole
SPAAR	Special Program for African Agricultural Research (World Bank)
UJAK	Union des Jeunes Agriculteurs de Koyli Wirndé (Senegal)
UPA	Unité de Politique Agricole (Senegal)
USAID	United States Agency for International Development
WARDA	West Africa Rice Development Association

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Photos:
Front cover: WARDA
Text: opposite p. 1, p. 2, p. 3, p. 4, p. 8, p. 11, p. 12, p. 27, p. 36, p. 37 (upper and lower), p. 40, p. 41 (left and right), p. 42, p. 43, p. 50, p. 54 (upper and lower), p. 56: Simon Chater; p. 9, p. 13 (upper and lower), p. 14, p. 16 (upper and lower), p. 19, p. 20 (upper and lower), p. 22, p. 23, p. 24, p. 25, p. 26, p. 29, p. 30, p. 31, p. 34 (left and right), p. 35, p. 45, p. 47, p. 48 (upper and lower): WARDA

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Tables:
p. 21, p. 22, p. 32, p. 33, p. 39, p. 52: WARDA

Printed and bound by:
Ebenezer Baylis & Son Ltd
The Trinity Press
London Road
Worcester WR5 2JH
United Kingdom

Phone: +44-1905-357979
Fax: +44-1905-354919