

CIRAD
2001



CIRAD

Cirad 2001

The Centre de coopération internationale en recherche agronomique pour le développement (CIRAD) is a French scientific organization specializing in agricultural research for development for the tropics and subtropics. It is a State-owned body, which was established in 1984 following the consolidation of French agricultural, veterinary, forestry, and food technology research organizations for the tropics and subtropics.

CIRAD's mission is to contribute to the economic development of these regions through research, experiments, training, and dissemination of scientific and technical information.

The Centre employs 1800 people, including 900 senior staff, who work in more than 50 countries. Its budget amounts to approximately French francs 1 billion (euros 152 million), more than half of which is derived from public funds.

CIRAD is organized into seven departments: CIRAD-CA (annual crops), CIRAD-CP (tree crops), CIRAD-FLHOR (fruit and horticultural crops), CIRAD-EMVT (animal production and veterinary medicine), CIRAD-FORÊT (forestry), CIRAD-TERA (territories, environment and people), and CIRAD-AMIS (advanced methods for innovation in science). CIRAD operates through its own research centres, national agricultural research systems, or development projects.

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Message from the President

CIRAD's strategic project was adopted by the Board of Trustees in March 2002. I would like to underline the quality and importance of this document, which defines CIRAD's major objectives and which reflects our ambition to develop new impetus and to open our doors to the outside world.

This project is the culmination of many months of internal preparation, including an in-depth review of the areas of excellence that CIRAD should seek to develop and the lines of action it should follow.

It takes account of the views expressed by the Scientific Advisory Committee, and the Scientific Visiting Committee, consulted in April 2001. It also provides a synthesis of the numerous excellent discussions on CIRAD's strategic options held over the last two years by the Board of Trustees.

The strategic project points the ways towards a new form of development-oriented research, focusing on joint knowledge building and sharing in the quest for sustainable development, notably through partnership centres of excellence. This is a key challenge to be addressed. Development-oriented research has a critical role to play in a world where globalization is affecting not only international trade, but also the exchange of knowledge and ideas.

The strategic project also affirms CIRAD's ambition to establish stronger roots in the French system of research and higher education and to play an active role in the European Research Area. CIRAD is engaged in a process of scientific modernization. The recognized role of our research teams—the basic units of scientific endeavour—the implementation of an assessment policy on four levels—the organization, the department and its programmes, the team and the individual—coordination through horizontal thematic projects, scientific information monitoring and strategic planning will all contribute to progress in this area. Last but not least, an ethics committee will be set up to illuminate our choices from a different angle, notably those made in partnership with the private sector and with developing countries.

The strategic project must now be brought to life. It offers a broad and ambitious framework enabling all staff members, at both individual and collective levels, to see clearly where their actions are leading. It also provides CIRAD's partners, both public and private, in North and South, with a structure upon which to build future synergies.



Daniel Nahon
President, CIRAD Board of Trustees



Towards fair and equitable globalization

CIRAD's strategic project for the next ten years is underpinned by two key ambitions: firstly, to ensure that the reduction of inequalities becomes a priority objective in international relations and, secondly, to establish a concept of fair globalization through joint knowledge building and sharing. Initiated at the end of 1999 and approved by the Board of Trustees in March 2002, this project will provide a framework for all of CIRAD's missions—research, support for development and for public policy making, training and information dissemination—to address the needs of developing-country partners more effectively.



CIRAD's strategic project

Our world is changing fast. Globalization and the liberalization of trade, progress in biology and computing, new information and communication technologies are sweeping away our traditional customs and practices.

The planet is now a global village that we must learn to manage together.

As we enter the third millennium, the fight against poverty and malnutrition, progress in food safety and quality, the reduction of inequalities and environmental protection are the key challenges facing countries of both North and South.

A scientific organization dedicated to agricultural research for development, CIRAD is closely involved in these international issues and a key player in the changes now transforming our planet.

How should we adapt to this changing environment? How should we orient our research priorities to contribute to a more equitable world? On what foundations should we build our future? To answer these questions, in the autumn of 1999, CIRAD began an in-depth review of its strategy for the coming ten years.

Sustainable development as a driving force for progress

In developing countries today, agricultural products are not always available in sufficient quantities, malnutrition is an ongoing problem, and rural societies struggle to achieve the living standards to which they aspire. Farming productivity in these countries must be increased rapidly, through higher yields and lower production costs, while decreasing pressure on land and protecting the environment. CIRAD will be an active player in this doubly green revolution, working with its partners to develop sustainable agriculture, not only on the scale of individual cropping, livestock breeding or forestry systems, but also at national and regional levels.

In response to this immense challenge, CIRAD has adopted an ecological and environmental approach to agriculture. Sustainable development in the South is the driving force that powers its actions. The environmental dimension is built into all its research projects, giving them new shape and direction.

In line with this strategy, it will contribute more decisively to the objectives expressed in major international agreements, such as those on biodiversity, the fight against desertification and on climate change. This means that CIRAD will need to act quickly to strengthen its research capacities in the fields of water, erosion, pollution, emerging diseases, forests and carbon sequestration—to mention just a few examples. It will also focus on food quality and the nutritional, and cultural, impact of changes in dietary habits in developing countries.

Over the coming years, alongside its traditional know-how in biology and agriculture, and in its quest to further the cause of sustainable development, CIRAD will harness expertise in wide-ranging complementary disciplines: ecology, epidemiology, engineering, social and legal sciences, management and information, and applied mathematics.



Joint knowledge building and sharing

Access to knowledge and information is a key factor in economic development and developing countries are now fully aware of this fact. As part of its role in training and information dissemination, CIRAD shares its knowledge with its partners. It provides research facilities and guidance to guest students and interns, it publishes and disseminates research results, and it offers documentary support to research scientists.

The strategic project affirms CIRAD's vital role in this area and gives it a new dimension. CIRAD will make use of new information and communication technologies to simplify information access and to work jointly with its partners in knowledge building and sharing. The new research facilities now being set up—common research units, partnership centres of excellence, European and international research networks—will serve as a framework for students and researchers seeking to acquire and share knowledge. These structures will also offer innovative systems for information retrieval, publication and dissemination.



At the heart of the European Research Area

One of CIRAD's roles is to contribute to French policy making in its specific areas of expertise. Today, in an international context marked by globalization and market liberalization, this role is taking on a new dimension. Indeed, the very purpose of public policies is to regulate the markets, to combat inequalities and to preserve the environment. With its in-depth knowledge of tropical societies and ecosystems, CIRAD, in association with other leading French organizations in this area, can help decision makers to devise and implement effective policies in the fields of development, agriculture and the environment.

In agreement with its supervisory ministries, CIRAD is now seeking to deploy its expertise at European level by contributing actively to European research and development policy. In more general terms, it intends to work at the very heart of the European Research Area. Its specific knowledge and experience will offer valuable input to the "development-oriented research" activity of this area, notably through research conducted in the French overseas departments and territories, on the outer fringes of Europe.

Foundations for the future

Over the years, CIRAD has developed solid foundations upon which to build its future.

Through its strong tradition of cooperation, CIRAD is now familiar with a mode of partnership based on common interests and shared experience. In some 50 countries of Africa, Asia, Latin America and the Pacific, and in the French overseas departments and territories, CIRAD has built ties with players in wide-ranging areas of endeavour: research, universities, agriculture, industry, associations, and so on. The centres of excellence that it has founded in partnership with developing countries are a key component of this system, providing a means for CIRAD and its partners to establish the scientific and technical bases for sustainable agriculture.

In France, CIRAD has always worked closely with the world of university research and teaching. Its expertise in key fields such as biology, biotechnologies, agronomy, food technology, economics, socio-economics and computing is now widely recognized. CIRAD will strengthen its ties with the French scientific community by taking part in combined research units and in the joint research institutes that are now emerging. It is through such ties that CIRAD will maintain its standards of excellence.



CIRAD is a targeted research organization with a multi-disciplinary approach. From the gene to the variety, from the plant or animal to the final product, from analysis to decision, from the plot to the region, it organizes its skills on the basis of methodological continuums, a principle that it understands and promotes.

Alongside its research activities, CIRAD contributes actively to the practical dissemination and application of research results, provides consulting services and works on development projects, all of which favour knowledge integration. CIRAD is one of the few institutions in the world capable of applying an integrated approach to the research questions of international importance raised by the farming and food systems of developing countries. It intends to reinforce its capacities in this area.

New management methods

CIRAD will introduce new management methods to implement its strategy. The research team, now recognized as the basic structure of all scientific endeavour, will play a more decisive role. The assessment system, reinforced to attain global scope and consistency, will cover four levels: the organization, the department and its programmes, the team, and the individual. CIRAD will place particular emphasis on scientific information monitoring, strategic planning and impact analysis. It will implement a quality assurance system applicable to all research, training, information and management processes. It will define criteria for collaboration with the private sector while reserving the right to transfer the knowledge thus acquired to developing countries. Lastly, against a background of cultural diversity and economic disparity between North and South, it will pay closer attention to ethical issues in its collaborative research activities.



Collaboration and scientific excellence

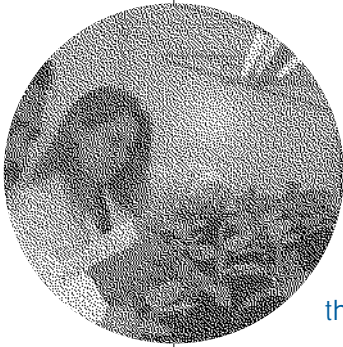
To address the global challenges now facing mankind, institutions are pooling their financial and human resources and rethinking their traditional modes of cooperation. Likewise, a wind of change is sweeping through the national and international scientific community. Faced with the threats of exclusion and growing inequality, CIRAD is opening new areas of cooperation for scientists involved in research for development. It is working closely with its partners to build and coordinate new modes of organization for collaborative scientific research.

Since 1999, CIRAD has focused its efforts on the construction of a balanced, durable system, underpinned by the continuous presence of research teams in tropical and subtropical regions.

It has also set up facilities in the French overseas departments and territories, in collaboration with other research centres. Outside France, CIRAD research teams are working in an ever wider range of national and international research structures.

The creation of new partnership centres of excellence is an example of this changing environment. CIRAD is also building closer ties with universities and other higher education institutions through its involvement in joint research units and is implementing its project for an international research platform in Montpellier.

With a new structure based around centres of excellence, the French scientific community now has a more coordinated framework for its activities. CIRAD is enhancing its potential for cooperation with European, North American and developing-country systems. Its close relations with the world of higher education and the creation of partnership centres of excellence outside France will offer numerous benefits to developing-country researchers, provided that appropriate hosting and training facilities are made available.



New forms of partnership

A series of major initiatives have been launched in recent years to enhance the organization of research, be it for the production, transfer or practical application of knowledge. Whatever their origin or their scale, these initiatives all converge towards the creation of centres of excellence based around major themes, such as the link between research and training, or the organization

of international cooperation.

It was against this changing background that CIRAD decided to rethink the organization of its research activities.

In France, it is contributing actively to the creation of a national development-oriented research system. More generally, it is helping to develop new cooperation opportunities for scientists from North and South working in development-oriented research and is closely involved in the creation and coordination of new forms of partnership. At the same time, CIRAD is seeking to refocus its activities and to build new alliances to develop a research infrastructure that is evenly balanced in both scientific and geographical terms.

Closer integration with French research

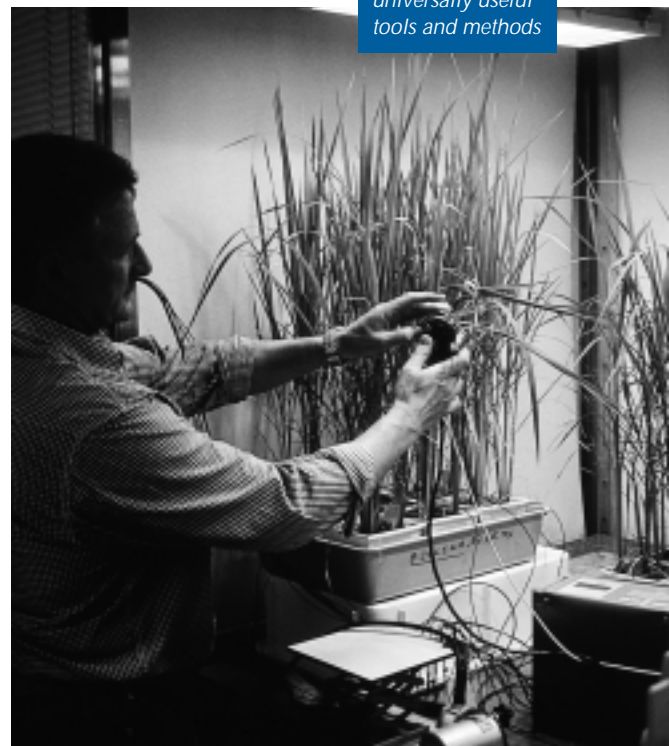
In France, CIRAD has established closer ties with its main partners—INRA, IRD and universities—each working in a complementary area of research. A national system of agricultural research for development is progressively taking shape in the form of jointly run projects, research units and laboratories.

Joint research units to harness new synergies

The joint research units bring together research centres, universities and institutes of higher education. Through these alliances, CIRAD will enhance its research potential by working with high-level teams to define new concepts, tools and methods that address development issues and serve the entire research community. They also enable CIRAD to play a more active role in French higher education.

By taking part in joint research units, one of CIRAD's key objectives is to open the French research and higher education system to scientific cooperation with developing countries. There are two ways to achieve this goal. The first is to mobilize research teams around problems specific to tropical and subtropical regions and to encourage research organizations to focus on questions of planetary importance. The second is to provide more research and study opportunities for developing-country students and scientists, giving them easier access to training and qualification. The joint research units provide a means to pool financial and human resources on a contractual basis for an initial period of four years. The aim is to harness new synergies by bringing together teams of researchers from different backgrounds to work together on a single theme. Joint research units are created on the initiative of groups of scientists who submit their projects for examination and approval by the partner institutes. At the end of four years, each joint

*Developing
universally useful
tools and methods*



Joint research units of which CIRAD is a member

- Agrarian systems, sustainable management of resources and of tropical and Mediterranean zones. Signatories: CIRAD, CNEARC, ENGREF. Director: Philippe Jouve (CNEARC)
- Agropolymer engineering and emerging technologies. Signatories: Agro Montpellier, CIRAD, ENSIA, INRA, University of Montpellier II. Director: Stéphane Guilbert (university)
- Biology and plant-parasite interaction genetics for integrated production. Signatories: Agro Montpellier, CIRAD, INRA. Director: Jean-Loup Notteghem (Agro Montpellier)
- Biology of the development of perennial cultivated plants. Signatories: Agro Montpellier, CIRAD, INRA, IRD. Director: Françoise Dosba (Agro Montpellier)
- Botany and bioinformatics of plant architecture. Signatories: CIRAD, CNRS, INRA, IRD, University of Montpellier II. Director: François Houllier (INRA)
- Centre for biology and population management. Signatories: Agro Montpellier, CIRAD, INRA, IRD. Director: Yves Gillon (IRD)
- Diversity and genome of cultivated plants. Signatories: Agro Montpellier, CIRAD, INRA, IRD. Director: Serge Hamon (IRD)
- Forest ecology in French Guiana. Signatories: CIRAD, ENGREF, INRA. Director: Meriem Fournier (INRA)
- Functional and evolutionary ecology centre. Signatories: Agro Montpellier, CIRAD, CNRS, IRD, Universities of Montpellier I, Montpellier II, Montpellier III. Director: Bernard Delay (CNRS)
- Genomics applied to agronomic traits. Signatories: Agro Montpellier, CIRAD, INRA. Director: Jean-Christophe Glaszmann (CIRAD)
- Innovation, technical change, learning and coordination in agriculture and agribusiness. Signatories: Agro Montpellier, CIRAD, CNEARC, IAM, INRA. Director: Fabrice Dreyfus (Agro Montpellier)
- Laboratory of Mediterranean and tropical symbioses. Signatories: Agro Montpellier, CIRAD, INRA, IRD. Director: Bernard Dreyfus (IRD)
- Operation and management of tropical and Mediterranean cropping systems. Signatories: Agro Montpellier, CIRAD, INRA. Director: Jacques Wéry (Agro Montpellier)
- Plant populations and biological stressors in the tropical environment. Signatories: CIRAD, University of Reunion. Director: Jacques Figier (university)
- Process engineering, bio-product manufacturing. Signatories: CIRAD, ENSIA, Universities of Montpellier I and Montpellier II. Director: Alain Grasmick (university)
- Ruminant production in tropical and subtropical regions. Signatories: Agro Montpellier, CIRAD, INRA. Director: François Bocquier (Agro Montpellier)
- Wood rheology laboratory. Signatories: CIRAD, CNRS, INRA, University of Bordeaux. Director: Patrick Castera (INRA)

research unit is assessed by the partner members and, if justified, its existence may be prolonged. CIRAD's main partners are INRA, Agro Montpellier and the universities of Montpellier, along with IRD, CNRS, CNEARC and IAM. CIRAD is already a member of 17 joint research units.



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A reference centre for citrus fruits in Corsica

Reference centres

Other forms of collaboration are being developed to provide backup to existing structures or to create new ones. Joint units, federated research institutes and scientific interest groups provide a framework for coordination and information exchange between research networks, thereby serving as reference centres.

For example, an interdisciplinary unit run jointly by INRA and CIRAD has been set up at the San Giuliano station in Corsica to study citrus and Mediterranean fruit species and is now an international reference centre on citrus genetic resources. Bringing together scientists from both organizations, the unit's role is to define scientific and technical methods for creating new varieties, monitoring food safety, improving quality and optimizing production costs.

CIRAD scientists are working with university researchers and with teams from CEDIMES, CIREC (a CNRS and EHESS joint research unit), IEDES (University of Paris I), Solagral and INRA at the Jardin Tropical de Paris. Their aim is to become an international reference centre on globalization and the economics of sustainable development, open to researchers from developing countries.

CIRAD also hosts and manages the Institut du Développement Durable et des Relations Internationales, a scientific interest group that brings together ADEME, CIRAD, CNRS, IFEN, INRA and IRD. It was set up to develop information exchange and consultation between scientists, decision makers, the private sector and NGOs with a view to identifying and analysing the challenges of sustainable development and defining the corresponding research priorities.

Last but not least, l'Institut français de la Biodiversité, set up on the initiative of the public authorities and research organizations, is a scientific interest group with 17 members. Its role is to coordinate research and disseminate research findings in the field of biodiversity, in response to the needs of scientists, managers and society as a whole.

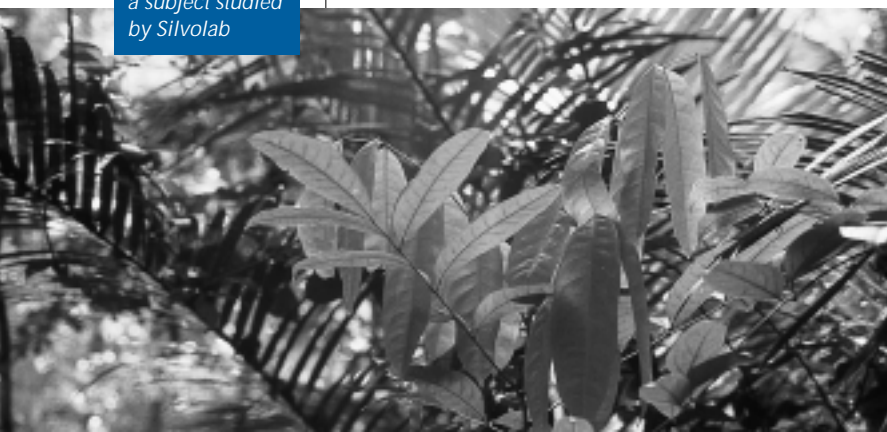
Overseas research hubs with a regional vocation

The French overseas departments are a key component of the French agricultural research system while forming part of a broader regional system. They are also the most outlying regions of the European Union. The research teams based there are attentive to the needs of local decision makers and farmers' groups and their functions are defined jointly with the local communities that support their work. The challenge is now to give these facilities a more direct role to play at European level and hence to favour their integration into the global system.

CIRAD also aims to enhance the quality of the facilities already present in the French overseas departments and territories, in order to bring them up to international standards. This will be achieved by building closer ties with other research and higher education centres present locally—INRA, CEMAGREF, IRD, ENGREF, universities—but also through substantial investments and a change in the status of these facilities to encourage exchanges between research teams. Over the longer term, these bases will form a network of well-equipped scientific platforms conducting work of international significance and providing access to know-how of both local and regional interest. Their influence will extend from Réunion towards southern Africa, Madagascar and Mozambique, from French Guiana towards Amazonia and the Guyana plateau, from Martinique and Guadeloupe towards the West Indies, South and Central America.

Research programming follows a theme-based approach. New studies focusing on production

The Amazonian rainforest, a subject studied by Silvolab



© A. Ferment



Study of rusa deer rearing in Réunion

and cropping systems and on industrial crop diversification provide a complement to long-standing research projects on industrial commodity sub-sectors, such as banana and sugarcane, and on animal production. Their objective is to obtain healthy products in a healthy environment. In Réunion for example, six research centres have been created—sustainable agriculture, environment and forests; livestock production; sugarcane; fruit, vegetables and aromatic plants; plant protection; agribusiness—with the support of local authorities and the European Union, and in collaboration with farmers' associations. In Guadeloupe, a centre on the theme of biodiversity is being set up to group the expertise of l'université des Antilles et de la Guyane (French West Indies and French Guiana), INRA and several CIRAD departments. In Martinique, an agricultural research centre is being formed under a multi-institutional partnership with INRA, IRD and CEMAGREF. In French Guiana, the research centre on the tropical rainforest ecosystem brings together CIRAD and several French scientific entities via the Silvolab scientific interest group. This centre, which includes a joint research unit (ENGREF, CIRAD, INRA) studying forest ecology in French Guiana, has created new ties with the universities of the French West Indies and French Guiana, Montpellier II, Nancy I, with the union of Amazonian universities and with universities in Germany, Belgium and Scotland. In New Caledonia, CIRAD and l'Institut agricole néo-calédonien, the agricultural institute of New Caledonia, have signed a framework agreement in line with the Matignon and Nouméa agreements. CIRAD provides organizational and scientific back-up to the research conducted by IAC, notably in the fields of animal production, fruit and vegetables, forests and rural development in the northern province.

In French Polynesia, CIRAD is actively involved in research conducted at the vanilla virology laboratory at Raiatea, while in Mayotte CIRAD is providing support for the institutional changes now under way. CIRAD is involved in collaborative research with farmers and is setting up a resources centre in association with the Coconi agricultural school.



Poultry farming,
the core activity
at a centre
in Vietnam

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Rethinking our partnership with the South

Partnership centres of excellence are the cornerstone of CIRAD's new policy of cooperation with Southern countries. Offering all the facilities required for high-level scientific research, they place emphasis on joint research and training. They address development issues identified with local partners and cover one or more related scientific themes. The partnership centres of excellence work together with research institutes, local organizations—farmers' associations, NGOs—and universities, enabling scientists to work in multidisciplinary teams on a single site, outside France. The research conducted in these centres must have a tangible impact on the living conditions of Southern populations, by improving agricultural product supply and raising farmer incomes.

The activities of the partnership centres of excellence will be managed by a team representing different scientific disciplines and different organizations, established on a contractual basis and with a long-term remit. Results will be assessed at regular intervals to see whether the partners are successfully consolidating their scientific expertise and disseminating the products of research among rural communities and in the agricultural and food sectors concerned. Their economic, social and ecological impact will also be taken into account.

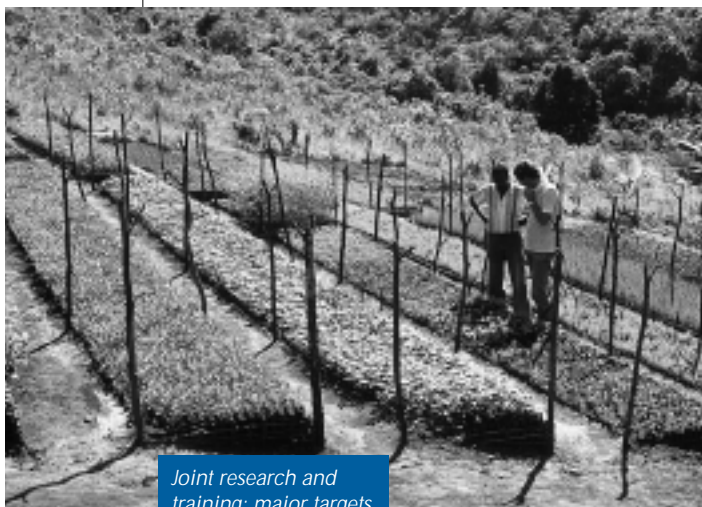
Eight partnership centres of excellence have been set up or are currently undergoing validation. In 2003, centres focusing on tree crops, agroforestry and ecosystem management will be set up in wet tropical regions. These centres will enable CIRAD and its partners to understand and analyse the environmental, economic and

Partnership centres of excellence created or undergoing validation in 2001-2002

- Consumption economics and urban food supply. In Vietnam, a centre is being set up to group together the research and training activities initiated by CIRAD (CIRAD-FLHOR, CIRAD-EMVT, CIRAD-AMIS) with its partners (IOS, RIFAV, VASI) on the question of urban food supply.
- Physiological and genetic mechanisms for drought adaptation. Based in Senegal, this centre brings together ISRA, ENSA in Thiès, UCAD, the university of Paris-Créteil, the university of Hohenheim in Germany, the university of Greenwich in the UK and CIRAD (CIRAD-CA, CIRAD-AMIS).
- Research centre on intensive livestock production. This centre was created in Vietnam in 2002. It brings together CIRAD (CIRAD-EMVT) and Vietnamese partners (NIAH).
- Sustainable cropping and rice growing systems. Based in Madagascar, this centre will focus on the problem of ecologically, economically and socially sustainable management of small-scale rice growing systems. It brings together FOFIFA, the university of Antananarivo (Essa) and CIRAD (CIRAD-CA, CIRAD-TERA).
- Sustainable forest management and biodiversity protection. Based in Madagascar, this centre will bring together FOFIFA, the university of Antananarivo (ESSA and law faculty), CNRE and CIRAD (CIRAD-FORÊT, CIRAD-TERA).
- Sustainable management of savannah ecosystems in Western Africa. Based in Mali, this centre brings together IER, the Institut polytechnique of Kati-bougou, the university of Bamako and CIRAD (CIRAD-CA, CIRAD-EMVT, CIRAD-FORÊT, CIRAD-TERA).
- The fight against desertification and agrosylvo-pastoralism. Based in Senegal, the agrosylvo-pastoral centre for Western African arid zones brings together ISRA, the universities of Dakar and Saint-Louis and CIRAD (CIRAD-EMVT, CIRAD-FORÊT, CIRAD-TERA).
- Tropical plant genomics and agribusiness. In Brazil, a centre is being created under framework agreements signed by CIRAD with Unicamp and USP, two universities of the state of São Paulo.

social challenges facing tropical and subtropical regions.

The complete transformation of our existing collaborative research infrastructure will take several years. Each centre must be set up in association with local partners and will call for progressive redeployment of our human and financial resources.



Joint research and training: major targets for partnerships

© F. Besse

These new modes of cooperation provide a complement to the wide range of research infrastructures working with stakeholders at local and regional levels and which bring together national institutes, international centres and Northern research teams. CIRAD is a member of research groups which do not, as yet, have the status of partnership centres of excellence, but which are based on the same principles of scientific production and partnership. For example, CIRAD is associated with PRASAC, a regional centre for applied research in the development of the savannas of Central Africa, based in Chad, and CIRDES, an international research and development centre for animal production in subhumid zones, based in Burkina Faso. In the forestry area, CIRAD is associated with a research unit on industrial plantation productivity in the Republic of Congo. It also works with CATIE, a regional research and teaching centre on tropical agronomy in Costa Rica, and with the Franco-Chinese laboratory for applied computing and mathematics in China.

Towards a global research platform

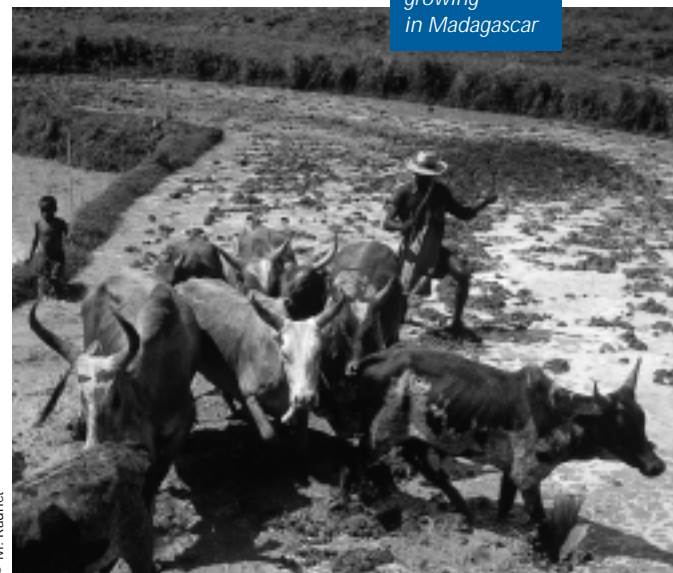
CIRAD has now achieved its aim of making the Montpellier research centre into a world platform of agricultural research for development.

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Moreover, by building up its Agropolis platform, CIRAD and its partners—including some twenty research and education institutions, local authorities and private companies—have developed the international status of the scientific community in the field of tropical agronomy. Joint programmes have been implemented with the centres of the Consultative Group on International Agricultural Research and scientists from these centres are now working in Montpellier. An agreement has been signed with Embrapa, the Brazilian Agricultural Research Corporation, and an Embrapa laboratory, called Labex, has been set up in Montpellier. Negotiations are in progress to open Agropolis to other Southern partners, notably ICAR in India and consortiums of Thai and South African universities.

Thanks to these new tools, to the extension of the Agropolis platform, the coordination of research through joint research units and the creation of partnership centres of excellence, CIRAD is pursuing its missions of development-oriented research and training provision to Southern scientific communities. Today, almost one-third of CIRAD researchers are working in these new structures.

A centre for sustainable rice growing in Madagascar



Annual crops

Research projects undertaken by CIRAD's Annual Crops Department in 2001 were designed to improve cropping systems and involved scientists from a range of disciplines. Research teams implementing the new cotton cropping strategy in Benin, Cameroon and Mali were reinforced. A project on preserving smallholder sorghum varieties was initiated in Mali and Burkina Faso. In Madagascar, the rice research team merged with the agrosystems team that is developing no-till cropping systems. The initial results of research under way in Senegal on edible groundnut quality are now being assessed within functional cropping systems.

The overall thrust of these projects has shifted from conventional agronomic strategies—hinged on yield, crop quality and soil fertility—to a more ecosystem-oriented approach to cropping systems.

In essence, crop plant biodiversity, soil biology, erosion, and water flows are taken into account, along with the effects of crop sequences and improved varieties on pests and diseases and on the environment, as well as the response of cropping environments to recycled waste inputs.

These environment-friendly approaches pool scientists from various disciplines to focus on research themes that are broad in scope, specific topics and joint development projects. Hubs of expertise have been formed in partnership with scientists and academic stakeholders in Mali on the management of savanna ecosystems, and in Madagascar on sustainable cropping systems for rice and other crops—this work has fostered the development of new cooperative programmes. These hubs, and various sites in the French overseas departments and Brazil, are now focal points of major research and innovation development.



Sugarcane

The sugarcane programme is focusing its research on increasing yields while reducing production costs. In-depth studies on sugarcane breeding, cost-effective crop management and sustainable water resource use were undertaken. Collaborations were strengthened with foreign partners through new initiatives: accompanying sugar producers in West and Central Africa, improving the productivity of small sugarcane farms in South Africa, using new genotyping tools in Brazil, and assessing the impact of soilborne pests in Louisiana.

Crop modelling

CIRAD developed a dynamic and functional sugarcane growth model (MOSICAS) in Réunion. It is currently valid for cv. R570 ratoons with 12-14 month growth cycles under limiting water and nonlimiting nitrogen supply conditions. It can simulate all biomass and water status components. It should soon be possible, on the basis of the results of experiments under way in Réunion and Guadeloupe since 2000, to supplement the model with data on plant cane and six other commercial varieties, while also adding specific functions such as water balance on vertisols.

The model already has many decision-support applications: estimating production for entire sugarcane-growing areas, optimizing water resource use, and adjusting crop cycles for Guadeloupe and the higher altitude regions in Réunion.

The model could also help sugarcane breeders in characterizing target environments, analysing multilocation test results, and deciding on suitable varieties for given environments. Geographical information systems (GIS)—CASSIS (georeferenced database for the sugarcane growing area in Guadeloupe), MAPIRRIC (georeferenced display of field parameters concerning water management) and MAPCANNE (mapped cane potentials)—can be linked with the growth model to generate information on cane potential and crop field management.

Environmental protection

Intensive mechanized banana monocultures in the Capesterre region of Guadeloupe are responsible for serious physicochemical soil degradation (plough pan, compaction, anoxia) and the proliferation of soilborne pests (nematodes, weevils), leading to declines in banana yield and limiting the lifespan of banana plantations. Pressure from environmentalists, however, has forced growers to reduce their standard pesticide treatments. The banana industry in Guadeloupe has been weak-



© P. Todoroff

ened by this turn of events, within a competitive environment that is not very conducive to investment.

Sugarcane was introduced into this banana cropping system in the hope that it would be an agroeconomically interesting way to offset this problem in Guadeloupe. Sugarcane-banana crop rotations are being tested in almost 200 ha of banana plantations, and the initial results are promising.



Banana-sugarcane
crop rotation

It has already been found that a short sugarcane cycle enables growers to reduce hazardous polluting pesticide treatments by about 25%, while also clearing the soil of soilborne pests. It has not yet been determined whether this rotation scheme improves the soil structure. This practice should be more economically viable than systems with grass fallows because the climatic conditions are suitable for cane production to supply distilleries, the sugar industry and even for high quality cuttings.

Genome mapping

CIRAD began collaborating with the University of Campinas, Brazil, in a sugarcane gene sequencing project (SUCEST) with the aim of finding new genotyping tools. Around 250 000 partial sequences of sugarcane genes culled from databases have been obtained. This is one of the largest sequencing projects ever undertaken on any plant species. Research is also under way on sequence polymorphism since sugarcane is polyploid and highly heterozygotic.

A preliminary study was conducted on two multigenic families, ie 6-phosphogluconate dehydrogenases and alcohol dehydrogenases. This led to a detailed analysis of sequence polymorphism in five genes from these families. The results highlighted many variations, ranging from simple base substitutions to the deletion of fragments of up to 20 bases long. These analyses documented high sequence polymorphism in elite sugarcane varieties and indicated that the SUCEST database should prove to be an efficient tool for detecting this phenomenon.

Organizing supplies to sugar factories

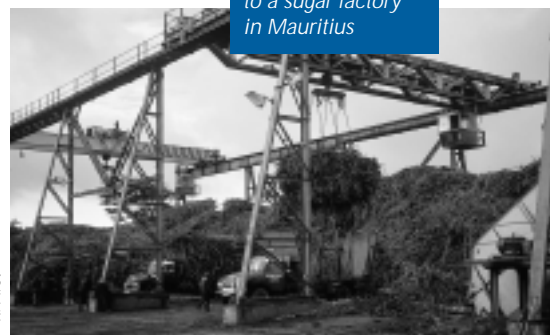
The main concern of sugar manufacturers is to reduce production costs by centralizing milling units, continuing to use some sugarcane reception sites or factories, and modernizing their industrial equipment. This includes reorienting cane flows and resizing existing equipment.

A project focused on the structural and functional reorganization of a whole supply system was carried out in collaboration with INRA, the French agricultural research institute, the Mauritius Sugar Producers' Association, and three sugar industry groups in Mauritius. Two software models were developed to determine efficient ways of reorganizing sugarcane deliveries to sugar factories, including a global model that generates simulations for whole sugarcane-growing areas supplying one or several sugar factories, and a logistic model that is designed to assess the impact of different scenarios in terms of resizing agro-industrial equipment.

The mid-term objective is to determine the impact of different proposed scenarios, from both logistic and strategic standpoints. New delivery quota allocation strategies could be assessed in terms of the sucrose content of cane and also relative to agroindustrial equipment use.

© C. Poser

Delivering cane
to a sugar factory
in Mauritius



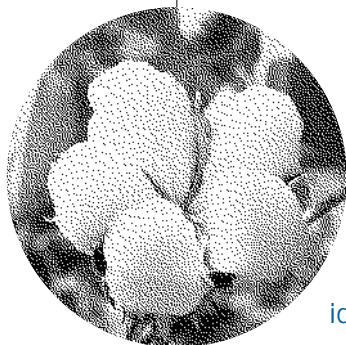
© R. Pirot

Yellow leaf syndrome

A study was undertaken to determine the impact of yellow leaf syndrome, caused by sugarcane yellow leaf virus, on the main sugarcane varieties grown in Réunion and to assess the dynamics of this disease throughout the island. The results showed that virus infection reduced sugarcane yield volumes by 23% and sucrose contents by 11% in cv R577, while having no impact on cvs R570 and R579.

An epidemiological survey revealed that: there are differences between cultivars in disease resistance; sugarcane stubble does not recover from the disease after harvest; and the virus is mainly, but not exclusively, disseminated by planting contaminated cuttings, not via insect vectors. All but two

of the sugarcane yellow leaf virus isolates from Réunion were found to differ from isolates of other origins, suggesting that the virus was introduced from another country and a unique genotype subsequently developed that became endemic on the island. ■



Cotton

The cotton programme initiated scientific projects to address current challenges in the cotton subsector and to fulfil other research priorities. The first project, a new cotton cropping strategy, is aimed at developing new crop management sequences dealing with major constraints that have been identified in several cotton-growing areas. Two workshops were held in 2001,

with the participation of scientists, extension agents and cotton growers. Three networks to promote joint development of cotton crop management sequences were launched on the basis of these workshops: a global network, a regional network in West Africa, and a local network in Cameroon.

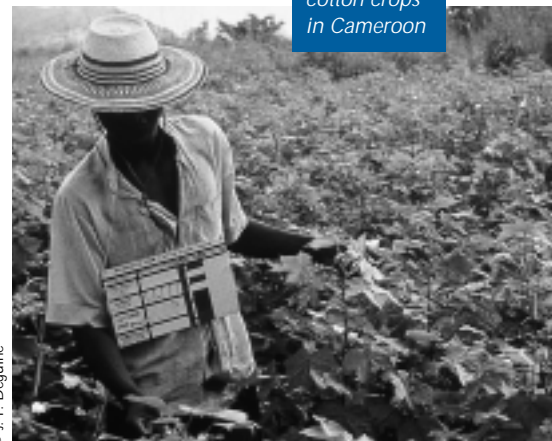
The second project is devoted to transgenic cotton, with the aim of gaining experience on assessing the environmental impact of this new plant material and developing effective sustainable management strategies. The third project deals with cotton quality geared to tapping the full potential of cotton products and by-products.

Modelling cotton bollworm damage

Pesticides are generally applied according to a preset treatment schedule within the framework of current cotton bollworm management programmes. Sustainable integrated control strategies should be adopted whereby pesticides are only used when pest outbreaks represent a real economic risk for the crop. By this approach, an economic tolerance threshold is set, beyond which the pest population would cause greater economic damage than the cost of the pesticide treatment. Cotton plants have an indeterminate growth pattern and are able to offset the loss of fruiting organs, which makes it hard to determine an economic tolerance threshold for this crop. A given pest insect population can, for instance, cause various degrees of yield loss depending on whether or not the plants are able to compensate for the damage incurred. Tolerance thresholds are now being viewed under a new light as a result of recent progress in the modelling of cotton growth and development via the COTONS® model, combined with modelling of insect population development.

In this perspective, the SIMBAD model was developed in collaboration with IRAD, the Cameroonian agricultural research institute, within the framework of PRASAC, a regional research initiative for savanna development in Central Africa. SIMBAD simulates the population dynamics and feeding behaviour of the four main African cotton bollworm species: *Helicoverpa armigera*, *Diparopsis watersi*, *Earias* spp. and *Spodoptera littoralis*.

Counting
bollworms on
cotton crops
in Cameroon



By combining the COTONS® and SIMBAD models, cotton production losses caused by a bollworm population can be assessed according to certain parameters, such as the population size, its faunistic composition, the date of infestation, the crop yield potential, etc. The ultimate goal is to draw up guidelines to help growers decide when to initiate pesticide treatments according to the targeted yield, to the production potential, or to climatic conditions. These decision-making guidelines should then be validated in the field.

Pesticide resistance

The worsening of the pest situation in cotton-growing areas of West Africa, due especially to the development of pesticide resistance in some polyphagous insects, such as the cotton bollworm *Helicoverpa armigera*, is a serious blow to this booming sector. In 1994, laboratory monitoring tests began to show a marked reduction in pest susceptibility to pyrethroids, a trend that was subsequently confirmed by the failure of pesticide sprays conducted in cotton fields in Benin and Burkina Faso in 1996.

Cotton-producing companies and national agricultural research services acted very quickly by setting up a regional project designed to prevent the spread of this phenomenon. The three main thrusts of this project are to reduce selection pressure by excluding pyrethroid sprays associated with organophosphates at the beginning of the crop season, later

reusing these compounds in binary blends, and with weekly monitoring of bollworm populations. Pest infestation levels were very low during the last two crop seasons, suggesting that the measures taken had an immediate impact on bollworm populations. The proportion of resistant bollworms did not, however, decline. In addition, studies were carried out (in Benin and Côte d'Ivoire) to determine the mechanisms of resistance involved. The results indicated that the active ingredient could be metabolized by oxidases, thus giving rise to resistance.

A similar trend is suspected in aphid *Aphis gossypii* and whitefly *Bemisia tabaci* populations, and CIRAD has initiated research to assess this situation. Perhaps the most significant finding so far is the discovery that some Cameroonian aphid strains are resistant to dimethoate.

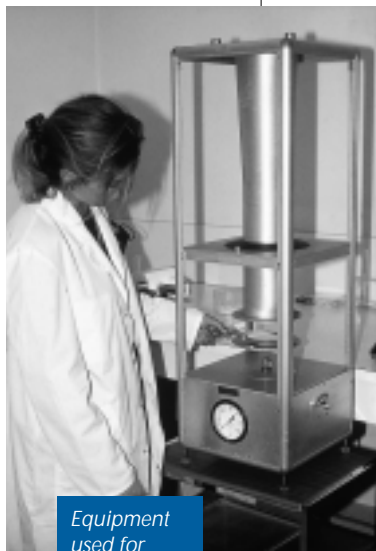
GERICO is another project that was launched in late 2001 and is funded by the French Ministry

of Foreign Affairs. It aims to document gene flows between pest insect populations, especially those linked with pesticide resistance, and to determine how this resistance spreads in West Africa. The essence of this project is both scientific and pedagogical—to characterize pest populations and investigate resistance mechanisms, while training scientists from developing countries on biochemical and biomolecular techniques required to conduct this research.

Research in Benin

The cotton component of PARAB, the Benin agricultural research support project, terminated in 2000. A cotton-breeding programme was initiated, with the joint involvement of CIRAD and INRAB, the Benin agricultural research institute, to enhance ginning yields and the technological quality of cotton fibre. A breeding team was formed and has already developed hundreds of lines of new promising genetic material, and set up a participatory breeding initiative in partnership with cotton growers' organizations in Benin.

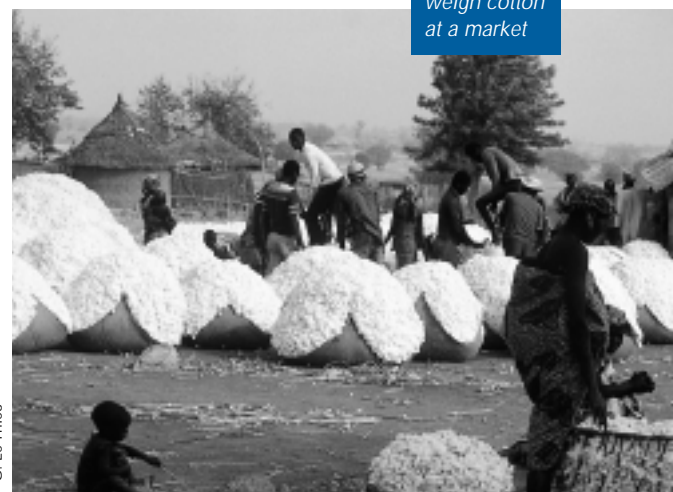
The new PARCOB project (2002-2005) will underpin the PARAB project results. It will enable scientists to adapt to the institutional and technical changes under way and find ways to boost the Beninese cotton industry's competitive edge on world markets, while enhancing the sustainability of cotton-based cropping systems. A cotton subsector observatory was set up to assess the strategies of a broad spectrum of farmers and different stakeholders under evolving environmental conditions so as to be able to deal with them more effectively in a research context.



Equipment used for insecticide bioassays

© T. Erwin

Waiting to weigh cotton at a market



© G. Le Thiec

Based on current diagnostic criteria, several factors could account for decreases in cotton yield recorded in the field: low yields of some imported varieties, a drop in the efficacy of some pesticide active ingredients, late sowing, and delayed fertilizer application and weeding. These factors will be the main focus of a participatory research initiative to ensure that the resulting innovations will be applied in sustainable cropping systems.

Research programmes must strive to create an environment that will induce stakeholders to benefit from its innovations. Hence, the team scientists should be involved in the quality control of products, training of supervisory staff and especially farming community representatives, in stakeholder awareness campaigns, and in setting up experimental structures and decision support tools within farmers' organizations. ■



Food crops

The food crops programme undertakes research on smallholder crops and technical food processing innovations for small-scale applications with the aim of developing local commodity systems geared to supplying nearby, as well as international, markets and meeting rural food security needs.

A further thrust of the programme is to improve the competitiveness and

sustainability of rice production subsectors that are world market oriented and based on industrial-scale mechanized farming or on smallholdings within the same region. Research is therefore carried out on plant biology, and on interactions with the cropping environment, plant breeding, and developing efficient crop management sequences.

Dried *Aklui*

Aklui is a traditional porridge based on fermented maize flour. It is very popular among urban consumers in Benin. It is generally prepared daily on a small scale, sold fresh and eaten on the seller's premises. As this product has no shelf life, CERNA, the Beninese regional centre for nutrition and food, with the support of CIRAD, developed an instant breakfast porridge in the form of dried, ready-to-cook granules, which has a long shelf life.

A semi-industrial unit to manufacture dried *aklui* was set up at CERNA. This new product, which is more expensive than the traditional porridge, is now being marketed to meet the current urban consumer demand. The manufacturing conditions were recently improved and standardized with the financial support of the French Ministry of Foreign Affairs.

Maize flour is now produced mechanically using a germ separator and fermentation tanks that are available locally. This has substantially facilitated the operation. The dried *aklui* product is then packaged in pouches. Consumers have clearly accepted this product, which they readily buy despite its high price.

This semi-industrial production unit has been manufacturing and marketing dried *aklui* in Cotonou for six years. It is already generating profits. Meanwhile, six competing units have been set up to fulfil the needs of this new market—some



© J. Hounhouigan

of them received technical support on the manufacturing process from the team running the pilot unit.

Rice blast

CIRAD has assembled the most important *Magnaporthe grisea* collection in the world. It currently hosts more than 2 000 strains from 55 countries. Fertile strains of this fungus, which is the causal agent of rice blast disease, were identified, and the genetic basis of the host-pathogen interaction studied.

In collaboration with CNRS, the French scientific research institute, three avirulence genes of this fungus were mapped and one of them (*ACE1*) was cloned and sequenced. It is a very large gene and differs markedly from all other avirulence genes cloned to date. A genetic analysis revealed very early and targeted expression for this gene.

The rice resistance gene *Pi33* corresponding to *ACE1* was mapped on chromosome 8. Markers flanking this gene were also obtained. Locus *Pi33* was physically mapped in Nipponbare, a cultivar whose genome sequence is known but which does not possess the allele of the *Pi33* gene that confers resistance. Physical mapping is under way in a variety that has the resistance gene and, if the results are favourable, it will then be cloned.

These studies should help to understand problems of resistance durability in the hosts and evolutionary

trends in the pathogen populations. The results could also be applied in marker-assisted selection schemes. The *Pi33* gene occurs in several varieties grown on large surface areas, and, when combined with another resistance gene (*Pi1*), it could confer efficient durable resistance to a broad range of *M. grisea* strains.

Effect of avirulent and virulent *M. grisea* strains on the same rice variety



© D. Tharreau

Genetic diversity in taro

Colocasia esculenta is cultivated on an area of about 2 million ha throughout the humid tropics. No international research centres are focusing seriously on preserving or improving local taro cultivars, despite the importance of this crop for many of the poorest farmers in the world. CIRAD, with EU funding, thus participated in setting up the Taro Network for Southeast Asia and Oceania (TANSAO), which involves scientists from Indonesia, Malaysia, Papua New Guinea, the Philippines, Thailand and Vietnam.

From 1998 to 2001, this network collected and characterized nearly 2 300 local taro varieties and screened more than 2 000 of them with six enzymatic systems to assess the genetic diversity within



© V. Lebot

A taro plot within a rice field in North Vietnam

this broad spectrum of plant material. Moreover, 170 elite cultivars were placed under in-vitro conditions and released to research institutions in participating countries for subsequent propagation. A study was undertaken with amplified fragment length polymorphism (AFLP) markers to analyse 235 accessions and the findings confirmed the presence of two distinct gene pools in Southeast Asia and in the Pacific region, corresponding to separate domestication areas. Taro cultivars have a very narrow genetic base within each country.

In the light of these results, and considering the high genetic variability of the main pathogen of taro, ie *Phytophthora colocasiae*, parent plants for breeding should be exchanged through a transit centre in order to broaden the genetic base for breeding purposes. The high variability in terms of dry matter and starch content also highlights the importance of choosing the right varieties for breeding.

Edible groundnut

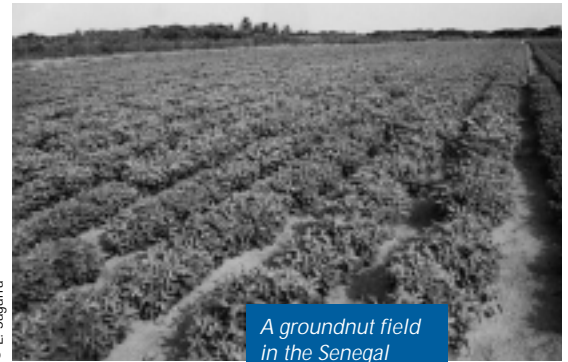
Senegal should revitalize edible groundnut production for export by guaranteeing the physical and sanitary quality of the products, especially by ensuring that they are free of aflatoxins, which are detrimental to human health. A joint French-Senegalese project is developing an integrated strategy to improve quality at each production stage from the field to the consumer.

Irrigation management tools were developed and a study on the impact of farmers' practices and leaf diseases on edible groundnut quality was carried out during the first year of the project.

In 2001, the initial results were applied in the field and the irrigation management tool was validated with new varieties under various irrigation schemes. A study on the impact of postharvest activities on edible groundnut quality was conducted in order to optimize tools and practices. Government discussions are under way on amending the regulations applied to edible groundnut in Senegal.

Qualitative constraints associated with each edible groundnut production and processing stage have now been pinpointed and quantified with respect to potential risks of quality degradation. Preventive and corrective measures were proposed

and a pilot groundnut production programme will implement all of these recommendations to assess the technical and economic feasibility of producing edible groundnut for export. ■



A groundnut field
in the Senegal
River valley

© L. Sagarra



Agrosystems

The agrosystems programme integrates explanatory research in genetics, environmental physiology and geochemistry, in addition to geography, sociology, economics and process engineering.

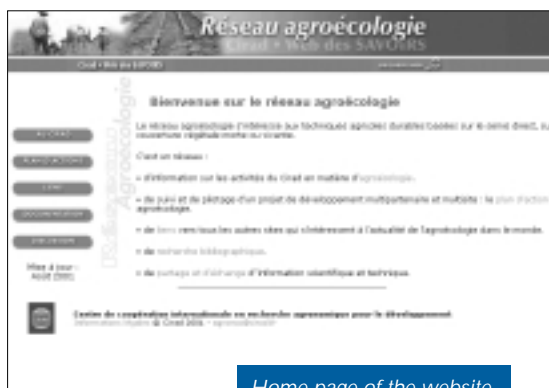
The team that develops no-till cropping systems with permanent mulch cover trained four recently recruited agronomists, held a training workshop in Madagascar and initiated projects in Cameroon and Tunisia. The team that deals with waste processing adopted an observatory-oriented strategy, based in Réunion, and two biogeochemists were recruited. A preliminary assessment of the potential of flooded cropping systems stressed that research is needed to develop agricultural innovations for irrigated farming systems.

Soil biology laboratory

Soil macrofauna, especially earthworms, ants and termites, have an impact on the soil ecology. The roles of these organisms in pedological processes—such as the regulation of biomass dynamics, the release of bioavailable nutrients required by plants, the maintenance of the physical structure of the soil and the genesis of some soils—have been widely discussed and illustrated. It is now known that this macrofauna is involved in regulating microbial activity in the soil, and can also alter the abundance and structure of other invertebrate populations. A direct correlation between earthworm activity and plant growth was recently documented. Moreover, earthworms affect plant pest and parasite population levels positively.

CIRAD, with the financial support of the European Union and the Regional Council of Réunion, decided to create a tropical soil biology laboratory in Réunion to assess the impact of soil macrofauna.

This laboratory conducts quantitative studies on the activity of fauna and effects on soil function in agrosystems. It also aims to gain a thorough understanding of the yet unclear mechanisms involved and to train students at all academic levels. Scientists from surrounding countries (Comoros, Madagascar, Mayotte, South Africa, Zimbabwe) can be hosted by the laboratory in a regional cooperation context.



Home page of the website
<http://agroecologie.cirad.fr>

Agroecology website

CIRAD developed a website to showcase the activities of its agroecology network, which is accessible via: <http://agroecologie.cirad.fr>

The agroecology network is devoted to sustainable agricultural techniques based on direct seeding on live, dead, or mixed mulch cover. It fosters the exchange of information on CIRAD's agroecological activities. Moreover, it is the driving force behind a multipartner and multilocation development project, the agroecology action plan. This initiative pools the expertise and operational resources of the main French development aid stakeholders. The aim is to develop means to transfer and develop agroecological techniques in five countries within a priority solidarity zone

encompassing a broad range of agroclimatic conditions (Cameroon, Laos, Madagascar, Mali and Tunisia). There are links to other agroecology-oriented sites worldwide, eg networks, NGOs, thematic sites, etc.

A bibliographical list, of works on cropping techniques involving direct seeding on mulch cover and on the ecology of the soil profile and the air-plant-soil continuum, is provided.

Through a free public discussion forum, users can discuss technical aspects of agroecology, share their know-how, exchange contacts and bibliographical references and receive news about the agroecology situation throughout the world.

Conservation agriculture

In March 2001, CIRAD organized an international workshop in Madagascar concerning cropping systems on mulch cover. Some 50 scientists and other agents involved with cropping systems on mulch cover, and from a variety of backgrounds, were trained. The workshop led to interdisciplinary scientific discussions and paved the way for potential network-based cooperations.

Participants exchanged their experiences, which were multiple and wide ranging, since they came from countries and regions as different as Benin, Brazil, Cameroon, Ethiopia, France, Indonesia, Laos, Mali, Mayotte, Mexico, Mozambique, Réunion, South Africa, Tunisia, Vietnam, and of course Madagascar. A range of topics was discussed, such as crop farming-livestock production associations and plant resource management and

Training on direct seeding
 equipment under draught
 cultivation conditions
 in Madagascar



allocation. Farmers and technicians worked together in the field, and this experience highlighted the need to hold further in-depth workshops on this topic.

CIRAD was highly involved in the first World Congress on Conservation Agriculture that was held in Madrid in October 2001, with 12 scientific contributions regarding DMC (direct-seeding, mulch-based conservation tillage). There were some 800 participants from 50 different developed and developing countries. The sheer number of participants and their geographical and institutional diversity was evidence of a shared belief that productivity, sustainability and environmental protection should be considered as one concern, and not separately. This congress helped to boost public awareness on the importance of conservation agriculture.

Carbon sequestration



Root system
of the cover
plant *Eleusine
coracana*

© L. Seguy

The agroecology action plan is a series of development projects jointly implemented by AFD, the French development agency, the French Ministry of Foreign Affairs, FFEM, the French fund for the world environment, and CIRAD. The FFEM project research council and the main scientific stakeholders (CIRAD, INRA, and IRD, the French development-oriented research institute) met in Montpellier in 2001. Working sessions were geared to assessing methods for comparing greenhouse gas emission and sequestration in no-till cropping systems

with mulch cover, and in conventional cropping systems.

Four target areas for funded experimental research were identified—Laos, Mali and Madagascar, countries designated to host pilot projects for the agroecology action plan, and Brazil, the most advanced tropical country in terms of DMC—and their future experimental activities were discussed. Papers were presented on the scientific and economic aspects of carbon sequestration that could have an impact in the different experimental zones. Project participants defined a common methodological strategy for setting up controlled agricultural tests, soil sampling and analysis techniques. It was stressed that problems on sampling and measuring soil carbon reserves have to be clearly identified in terms of the different investigated conditions.

Regional agronomic diagnosis

A thesis entitled “Crop modelling and regional agronomic diagnosis—Development of a method and its application to maize crops on smallholdings in central Brazil” presented a novel diagnostic method based on a field survey and the use of a crop simulation model. This approach facilitates the detection of constraints and classifies them objectively. It can also verify—for a series of crop seasons representative of local climatic conditions—the diagnostic procedure developed for the survey.

In this case study, the STICS model was modified to improve water balance simulations and to introduce the effects of aluminium toxicity, waterlogging and crop-weed competition for light, water and nitrogen. The diagnostic results highlighted problems faced by farmers’ associations concerning tractor and seeder management. ■

Tree crops

In the current atmosphere of liberalization and globalization, and the emergence of new issues for the sustainable management of land and resources, CIRAD is thinking hard about the medium- and long-term maintenance of the present economic, social and environmental functions of tree crops in the humid tropics. In November 2001, its reflections led it to link up with BNETD, the national technical and development studies organization in Côte d'Ivoire, and the Free University of Amsterdam to hold an international conference on "The future of perennial crops: investment and sustainability in the humid tropics" in Yamoussoukro.

The conference enabled development players, national and international decision-makers, nongovernmental organizations and researchers to discuss the prospects in a number of areas: prospects for demand and its determining factors; market dynamics for each sector; models of decision-making and risk assessment; changes in the political and institutional setting; environmental impact of perennial crops; producers and prospects for innovation.

Over and above assessing the crisis in the sector, the aim was to inventory the political, economic, social and technical means of developing new market operations that favour investment, ensure a fair deal for all the players involved and take account of environmental constraints.

The participants from the 26 countries represented produced a declaration to draw the attention of global public opinion and politicians to their concerns. Their statement confirmed the significant role of perennial crops in the economic, social and environmental balance of the tropics. It stressed the need to ensure that smallholders benefit from programmes aimed at alleviating poverty, and it called for the strengthening of international exchanges, based on the interdependence of economic and political stakeholders.



Cocoa

In addition to obtaining major scientific results through working with researchers and cocoa sector professionals in France and producing countries, the Cocoa Programme's year was marked by the launch of two major multi-year projects on the sustainability of cocoa farming systems in West Africa. The first, on the rehabilitation and replanting of older, deteriorated cocoa plantations, headed by CIRAD and CNRA, the national agricultural research centre in Côte d'Ivoire, is supported by funding from the French Ministry of Foreign Affairs,

and has led to the secondment of a CIRAD farming systems specialist.

The second, which is regional—Cameroon, Côte d'Ivoire, Ghana and Nigeria—and funded by the French Ministry of Foreign Affairs, set out to identify competitive and sustainable cocoa farming systems for Africa. An agronomist based in Ghana is in charge of scientific coordination. Both projects are contributing to the global cocoa programme currently being established under the Global Forum for Agricultural Research (GFAR).

QTL mapping

Cocoa genetic improvement programmes set out to combine alleles favouring productivity and quality within a given genotype. The first genome map was obtained by CIRAD, and has been followed by several mapping studies that have identified quantitative trait loci (QTL) linked to yield components, resistance to *Phytophthora*, and to bean characteristics. These QTL are spread over cocoa's ten chromosomes, although concentrated on chromosome 4.

Of the progenies studied, the three planted at CNRA in Côte d'Ivoire have now been analysed over a period of about ten years. QTL have been identified in two groups of cocoa trees: Trinitario and Upper Amazon Forastero. Some genotypes, belonging to the same group or to both groups, share colocations of QTL linked to a given set of characters, such as those involved in bean size. Colocations of QTL for different characters have also been identified in the same region of the genome, for instance that revealed in chromosome 4, involving QTL linked to pod weight, vigour and resistance to *Phytophthora*. These results pave the way for breeding strategies using molecular markers (Marker Assisted Selection).

Ochratoxin A in beans

Ochratoxin triggering and development are being studied in conjunction with the European Association of Chocolate Manufacturers (Caobisco), with a view to identifying the critical factors favouring mould development and ochratoxin A (OTA) production.

The results obtained in the first year showed that appropriate postharvest practices—rapid pod opening, box fermentation, solar or artificial drying with frequent turnings—ensure beans with little or no OTA, but such techniques are not widely used by small-scale producers. They also demonstrated that OTA content increases



© D. Paulin

towards the end of the main crop, in February–March.

The programme's objective for its second year is to understand the links between OTA formation and smallholder postharvest practices on the one hand, and the behaviour of buyers on the other. After analysing the results, recommendations will be drawn up concerning postharvest techniques.



Drying
Criollo cocoa
on concrete

© E. Cros

Venezuelan Criollo cocoa

Venezuela produces fine cocoas, particularly the Criollo type, with strongly marked aromatic properties. However, the farmers who produce such cocoas use a wide range of postharvest processing techniques that are not always appropriate.

CIRAD and CONICIT, the Venezuelan national scientific and technological research council, are conducting a four-year research programme involving four doctoral students. The first aim is to recommend Criollo cocoa postharvest processing techniques that producers will accept, and which will guarantee good commercial cocoa quality, and to determine how the flavour of this type of cocoa develops. The second is to identify the genetic structures that most favour the expression of certain quality characteristics. To this end, a systematic study has been undertaken on the effect of fermentation conditions—pod opening time, fermentation times and turning frequency—on flavour quality, which is measured by organoleptic and chemical analyses of the flavour-related compounds, especially volatile compounds.

The factors studied have a significant effect on cocoa organoleptic characteristics. The interactions between these factors were also seen to affect acidity and flavour intensity. However, cocoas fermented for three or four days were consistently more aromatic, irrespective of other processing conditions.

Black pod disease epidemiology

Of the *Phytophthora* species that affect cocoa, *P. megakarya* is considered the most dangerous in the field. Potential yield losses can reach 80% in Cameroon. The main way of controlling the disease to date has been to breed varieties with at least partial resistance to the disease. However, genetic improvement programmes have been hindered at the planting material evaluation stage by a lack of knowledge of the genetic structure and degree of aggressiveness of the various *P. megakarya* strains.

Work has been done in Cameroon on the genetic diversity and varying aggressiveness of different strains, in conjunction with IRAD, the development-oriented agricultural research organization of Cameroon, to pinpoint the effects of the different strains during such evaluations. The aim is to evaluate the efficacy of a strategy based on cocoa tree resistance to *P. megakarya* and to predict the sustainability of such resistance depending on the diversity and adaptability of the pathogen.

The spatio-temporal, genetic and pathogenic diversity of strains from an experimental plot have been studied so as to gain a clearer understanding of how the different development factors—mutation, recombination, genetic drift, migration and selection by the host—act. The novelty of the study lies in the fact that it combines epidemiological analyses with research on pathogen population structure. ■

Epidemiological
assessment
of cocoa trees
in Cameroon



© M. Ducamp



Coffee

The coffee quality concept refers to a set of physical, biochemical, organoleptic and sanitary characteristics governed by genetic, ecological, cultural and technological factors such as postharvest processing, roasting and beverage preparation. For some considerable time, researchers studied these factors without truly realizing how interdependent they were.

As a result of the current global coffee price slump, many coffee growers can no longer cover their production costs. Moving into the luxury coffee market

by promoting specific geographic origins therefore looks like a promising way forward for producing countries. However, the only way to satisfy the increasing number of producing countries wanting to develop such operations is to adopt a multidisciplinary approach to quality, taking account of the whole range of different factors.

Coffee ochratoxins

CIRAD has embarked upon a project aimed at preventing the development of the moulds that cause ochratoxins. In 2001, it demonstrated the omnipresence of fungi of the genus *Aspergillus* in coffee. An in-vitro study of the toxigenicity of different strains revealed substantial variations in ochratoxin production. The correlation between the ochratoxin content of coffee batches and the toxigenicity of the sampled strains has yet to be determined.

The origin of contamination by moulds caused by *Aspergillus* between harvesting and postharvest processing remains to be studied. Preliminary observations suggest that drying coffee on specially prepared surfaces should limit mould contamination, and that toxin content is generally high in poorly dried coffees. The prevailing conditions during the several weeks spent in storage also apparently have a significant impact on ochratoxin production.

An analysis of national commodity chains has shown that traders and buyers are among the weak links: the coffee they buy is sometimes not sufficiently dry and they do not take the precaution of drying it quickly before storing and processing it. Paying a bonus for well-dried coffee should help to reduce contamination rates, particularly when prices are very low.

Somatic embryogenesis

Coffee varietal improvement is now shifting towards the selection of vigorous, high-yielding hybrids that produce quality coffee and are resistant to the main pests and diseases. To propagate these hybrids on a large scale, CIRAD has developed an efficient and novel in-vitro propagation procedure using somatic embryogenesis. The method consists of mass-producing embryos in bioreactors and then planting them directly. It combines automatic embryo production in the

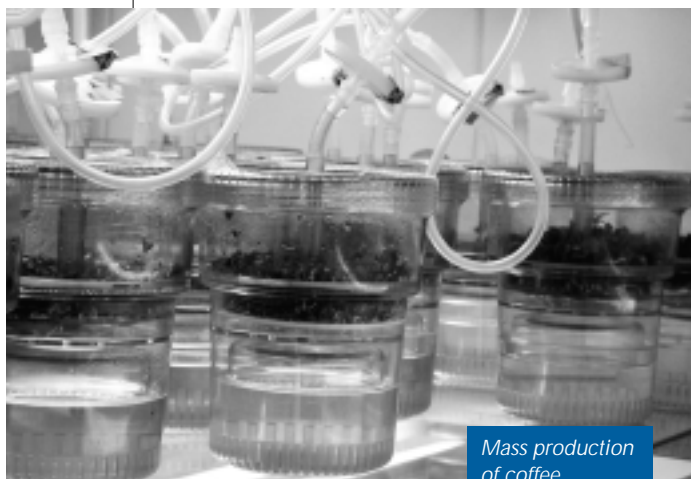


Drying Arabica coffee on tables in Burundi

© P. SNOECK

laboratory with the simplicity of conducting the entire plant regeneration stage in the nursery. About 100 000 plants have already been put in place in Central America and Tanzania to assess the agronomic performance and genetic conformity of material regenerated using this technique. The low production costs and the initial agronomic data are very promising, and suggest that it should now be possible to move up to industrial-scale production.

In order to satisfy the demand for new varieties and promote this technique in producing countries, CIRAD has linked up with Vitropic, a private laboratory specializing in the propagation of in-vitro banana plantlets, in order to adapt the technique on an industrial scale. Transfer of the technology to Vitropic is now almost complete, and propagation of varieties selected by CIRAD is under way.



Mass production of coffee somatic embryos in bioreactors

© H. Etienne

Ecophysiology

Since 1999, CIRAD, CATIE, a tropical agricultural studies and training centre, and the coffee research institute in Costa Rica have been studying the physiological responses—photosynthesis and transpiration—of coffee leaves in various production systems and under different microclimatic conditions. Moreover, sap flow and light interception measurements have enabled more accurate characterization of water and light partitioning between coffee trees and shade trees. These measurements have confirmed the importance of branch position on the tree, cherry load, water status of the coffee tree, and shading intensity for coffee productivity and physical, biochemical and organoleptic quality.

In 2001, a preliminary version of a model of carbon allocation within a coffee tree branch was developed in conjunction with INRA, the French agricultural research institute. The model simulates the effects of shading, cherry load and coffee tree water status on the production of assimilates and on their distribution among coffee cherries and the vegetative part of the growing branch. This ecophysiological work is due to be stepped up over the next four years, through a European project launched at the end of 2001.

© D. Duris

Quality in Laos

On the Bolovens Plateau in southern Laos, straddling the provinces of Champassak and Saravane, 30 000 hectares of good volcanic soils between 800 and 1 200 m above sea level have been planted with Robusta, Arabica and Excelsa coffee, primarily by smallholders. Favourable agronomic conditions on the Bolovens Plateau enable high quality Arabica production, and for this reason a research and development operation has been launched to prove that growers can work together to produce coffee with a high added value. This operation fits in with the move to develop commodity chains that combine the concepts of fair trade and quality, bringing together stakeholders and researchers, whose role is to come up with the necessary methods in terms of genetics, ecology, technology and organizational support.

The project, which was launched in 1999 with funds from AFD, the French development body, enabled smallholders to work with an exporter to prepare 9 200 kilos of parchment coffee beans (before the dry skin has been removed mechanically) that were subsequently exported to Malaysia as green coffee beans. In 2000, samples were shown to a French buyer with access to a specialized market. Numerous growers have expressed an interest in the operation and the opportunities it offers.

In 2001, 16 200 kilos of green coffee were purchased at a farm-gate price of 12 000 kips (US\$1.90) per kilo. If smallholders keep up their hard work, Laotian Arabica coffee should soon be able to rebuild its lost reputation. ■

Removing coffee pulp in Laos





Coconut

The main partners in the coconut sector are preparing to launch a global, development-oriented, coconut research programme. Five main research topics have been chosen: genetic resources management and varieties improvement; pest and disease control; coconut-based farming system productivity and sustainability; end-products and processing; and socio-economic issues. From the outset, CIRAD has played an active part in this initiative, which fits in with the approach of the Global Forum on Agricultural

Research (GFAR). It has contributed its long-term view of the sector, in-depth knowledge of the people and places involved, and high-level scientific and technical expertise. CIRAD has also made a substantial contribution in several fields, including carbon balance in the farming system, integrated pest and disease control, and coconut in-vitro culture.

A groundbreaking global research programme on coconut lethal yellowing, which is likely to be supported by the Common Fund for Commodities (CFC), has been announced.

Carbon sequestration

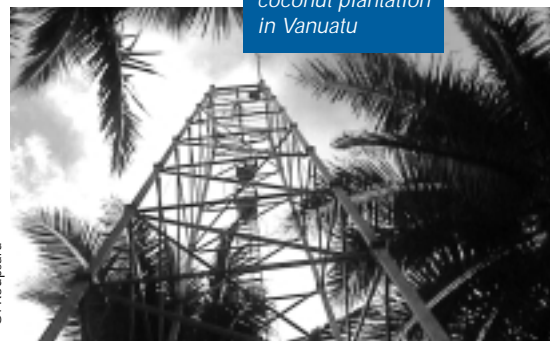
Carbon sequestration in coconut plantations is currently being studied in Vanuatu under a project involving CIRAD, VARTC, INRA, the French development-oriented research organization IRD, the French scientific research centre CNRS, and the University of Franche-Comté. Total energy, water and carbon flows in plantations are being measured continuously using the turbulent flows method. The total annual carbon flow has been compared with variations in reserves for various age categories. The initial results have revealed very rapid growth and high photosynthesis, but also high ecosystem respiration. Daily carbon sequestration is therefore moderate. On an annual scale, it could nevertheless reach the exceptional figure of seven tonnes of carbon per hectare per year, if climatic conditions are relatively stable, water stress is limited and given the fact that coconut palm growth is continuous.

Assuming a figure of US\$10 per tonne of carbon, an average yield of one tonne of copra per hectare per year, and a farm-gate price of US\$ 171 per tonne of copra, the income from carbon sequestration could thus provide an additional 40% in income compared to that obtained from copra production alone, although the figure would be lower if only the real certifiable share of carbon sequestration were taken into account. Coconut oil can also be used as a biofuel, to replace diesel: it takes about five hectares of coconut to produce enough oil to run a car for 20 000 kilometres a year.

Coconut micropropagation

CIRAD is working with IRD on coconut in-vitro micropropagation techniques, since cloning should enable the distribution of high-yielding genotypes resistant to the main diseases. However, despite the progress made, further work needs to be done on somatic embryo germination and in-vitro plantlet vigour before the technique can be applied on a large scale.

Carbon and water flow measurement tower in an adult coconut plantation in Vanuatu



© O. Roupsard

In an attempt to overcome these difficulties, CIRAD is working with recently acquired data on model plants. Genes known to control cell division and cauline meristem establishment, and functioning in *Arabidopsis*, have been isolated in coconut, and how they express themselves in varying culture conditions is currently being studied. In 2001, work was done in the programme in collaboration with CICY, the Mexican scientific research centre: this included the hosting of a post-doctoral student and a researcher.

Cryopreservation of genetic resources

Coconut is primarily conserved in regional field collections, which means there is a high risk of genetic erosion. This conservation method makes germplasm exchanges between producing countries extremely complicated. The joint IRD-CIRAD team is currently working with CNRA in Côte d'Ivoire on cryopreservation techniques, in the hope of overcoming these difficulties. The work aims to optimize the embryo plumule encapsulation and drying procedure. In view of the growing threat of eradication of regional collections such as the one in Côte d'Ivoire, studies will be carried out on the risks of transmission, via embryos, of the phytoplasm responsible for lethal yellowing. The French Genetic Resources Bureau (BRG) has provided funding for the programme. ■



Coconut plumule germination after cryopreservation

© B. Malaurie



Rubber

Against the backdrop of the current rubber crisis, CIRAD organized a seminar during the International Rubber Research and Development Board (IRRDB) annual meeting on what biotechnologies have to offer the crop. Eighty people from ten producing countries participated. The 23 papers presented gave an overview of global research on biotechnologies applied to rubber. Significant progress has been made on developing somatic embryogenesis and genome study tools. Several possibilities for collaboration were

discussed, particularly with Malaysia. A biotechnology group has now been set up under IRRDB, to be coordinated by CIRAD. The Rubber Programme has stepped up its operations in Thailand by seconding a third physiology and biochemistry researcher to Kasetsart University, to work with the Rubber Research Institute of Thailand (RRIT) on rubber quality variability.

Water and carbon functioning

The plant components of rubber-based farming systems store and recycle carbon, water and minerals. A global ecophysiological approach needs to be taken to optimize resource use, prevent competition and increase farming system profitability.

To successfully market wood from rubber trees necessitates developing crop management sequences that ensure a better balance between tree growth and latex production, since tapping rubber trees creates a new metabolic sink and results in competition for hydrocarbon assimilates and water, thus slowing growth.

The first stage of the research launched in Thailand in 1999, in conjunction with INRA, RRIT and Kasetsart University, and with the support of the French Ministry of Foreign Affairs, set out to quantify carbon and water flows within rubber trees, with a view to developing an explanatory model

of how tapped rubber trees function. The water supply to young potted rubber plants was controlled, to determine the effect of water stress on carbon assimilation and to estimate the consequences for growth during the non-tapped juvenile phase, using two clones with different structures.

To understand the relationship between tapping and overall functioning, carbon consumption through respiration at trunk level on adult trees is being measured using scientific apparatus developed by INRA.

In addition, metabolic activity and sucrose mobilization in the latex vessels, and starch storage and reserve mobilization in the wood as a function of varying degrees of tapping intensity are being monitored at an RRIT station. The initial results suggest that sucrose accumulates outside the area directly drained by tapping, and that the latex tissue metabolism is activated over a large area of the trunk.

These data should enable an analysis of production variations depending on tapping panel management. Removal of entire trees, aimed at quantifying total biomass increase, at different points of the tree, showed that the usual methods underestimate the biomass of the most commonly grown clone in Thailand, and

that the clonal types most suitable for wood production are not necessarily those that produce the most biomass.

Specific promoters

A start has been made on cloning the promoters specific to latex tissue or that may be induced by biotic and abiotic stress, with a view to optimizing the expression of the genes due to be introduced into rubber by genetic modification. Selecting the right specific promoters for the intended application helps to control the spatio-temporal expression of transgenes more effectively than constitutive promoters, which are often criticized. Two types of promoters have now been cloned from genes expressed in the latex cells of producing trees: glutamine synthetase genes, which are induced prematurely by ethylene, and hevein genes, which are potentially specific to latex cells and are over-expressed as a result of opening of cuts and ethylene. A promoter specific to latex cells would optimize transgene expression in latex without disrupting the plant as a

whole. Promoters induced by ethylene are useful in optimizing transgene expression under intense tapping conditions, since latex production is often stimulated using ethylene treatments.

The promoters isolated and cloned upstream of the GUS reporter gene are to be analysed in rubber, initially using transgenic callus lines until modified plantlets can be regenerated. They are currently being analysed in model plants: rice and *Arabidopsis*. The initial results have confirmed that the promoters are functional in rice, which could make it possible to extend their application to plants other than rubber.

Modified callus lines

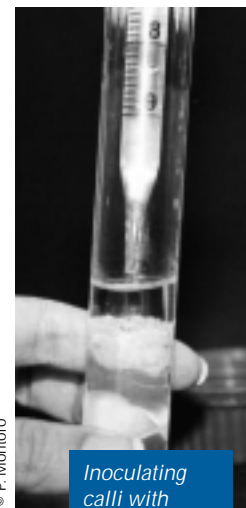
A *Hevea brasiliensis* genetic modification technique is currently being developed to provide a way of studying latex cell functioning by modifying the expression of genes involved in latex production. This work will help to identify target genes for improving commercial clones by genetic modification.

The genetic modification procedure consists of an initial stage leading to the establishment of modified friable callus lines, followed by transgenic plant regeneration through the somatic embryogenesis technique. The work done in conjunction with Kasetsart University and RRIT in Thailand identified the necessary conditions for obtaining friable callus lines modified by *Agrobacterium tumefaciens*. The technique is currently being tested at CIRAD, with the aim of regularly obtaining lines to be used to regenerate transgenic plants. Also being used are new transformation vectors, which include worthwhile promoters enabling either specific expression at latex tissue level, or expression that can be induced by ethylene. Furthermore, maintained callus lines modified using various candidate genes are being created with a view to an early study of the regulation of gene expression and the metabolic impact of these modifications. This will make it easier to identify target genes for improving rubber productivity. ■



Measuring respiration and microvariations in diameter on a rubber tree trunk

© E. Gohet



© P. Monnier

Inoculating calli with *Agrobacterium tumefaciens*



Oil palm

The Oil Palm Programme is now working to establish contract-based links with public- and private-sector partners throughout the commodity chain. Such a move has increased awareness of the programme's activities outside CIRAD and has stabilized its partnerships by placing them within a 20- to 30-year time frame. Research operations thus now have access to large-scale experimental networks with long-term guarantees.

These renewed partnerships are based on contractual tools that are crucial in ensuring competitive commercial activities. As regards seed production and sales, such agreements class CIRAD as co-breeder of the plant material, a status warranted by its substantial intellectual and financial investment.

They also clearly define how income is to be shared fairly between partners, through a system of royalties due to the co-breeders and of sharing the profits from improved planting material sales.

Commodity chain liberalization

The oil palm sector in Côte d'Ivoire was privatized in 1997 after 30 years of State management. The operation culminated in a buyout of the State-run management company by three private groups, and in a clearly expressed wish on the part of the government to promote professional growers' organizations.

This overhaul of how the different players are coordinated, combined with the world price slump, has resulted in conflict between growers and millers, particularly over the oil palm bunch price-fixing mechanism and the transfer to growers of services for which agro-industrialists are still responsible for the time being. It is now essential to clarify the new commodity chain management rules and set up new negotiating forums, in order to reach new compromises.

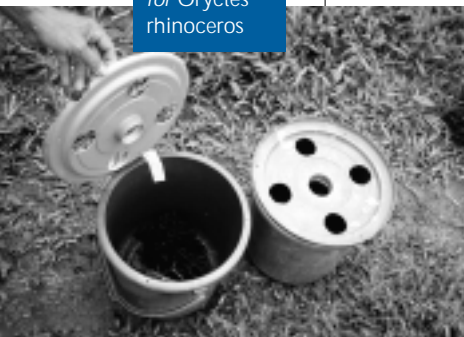
CIRAD and the University of Bouaké are working to organize the commodity chain following privatization, with a view to investigating research topics such as: the consequences of the new types of contract-based operations for smallholder production management; the interface between local markets and processing industries; stepping up cooperative operations; and economic and sociological analyses of the mechanisms for negotiating and establishing rules and regulating the sector.

Affected palms are colonized in isolation, by either male or female pests. Studies of old wood and rotting plant debris confirmed that the insects arrive on this plant matter and then group together to mate and lay eggs. The pheromone released by the males encourages colonization. These observations were used to improve pest trapping by combining the pheromone with rotting empty bunches from palm oil mills. The resulting synergy doubled or even trebled captures compared to the pheromone alone. Pending the development of an entirely synthetic attractant, which is currently being researched, this result has boosted the usefulness of mass trapping. Spatio-temporal studies are to be conducted with a view to understanding the effect of attractants on plot colonization and assessing the efficacy of trapping in reducing attacks on young palms.

Oryctes rhinoceros trapping

Oryctes rhinoceros is the most serious pest in oil palm and coconut plantations. Adults mine galleries at the base of the central leaves, resulting in slower growth and sometimes even killing young palms. Research has recently been conducted under a European project to attempt to reduce pest population levels by mass olfactory trapping using a pheromone and plant odours.

Trap used
in Indonesia
for *Oryctes*
rhinoceros



© J.-P. Morin

Ganoderma resistance

Oil palm basal stem rot, which is caused by *Ganoderma* sp., results in increasingly severe yield losses over successive crop cycles in Southeast Asia. The field results obtained suggest that there are significant differences in performance from one genetic origin to another. Deli material is generally susceptible, while the La Mé and Yangambi origins have a degree of resistance. *Elaeis oleifera* x *E. guineensis* interspecific



Oil palm
with basal
stem rot

© H. de Franqueville

hybrids show few symptoms, even in highly contaminated zones. These results are due to be used to rule out sources of high susceptibility, establish a breeding strategy and supply the range of reference crosses required to develop an early susceptibility test.

CIRAD has embarked upon a joint research programme with two private planting companies in Sumatra. One, Pt Socfindo, is now beginning its fourth crop cycle, and is facing phytosanitary problems that foreshadow those likely to be seen through Southeast Asian palm plantations in the next ten to twenty years. The Pt London Sumatra planting company is already heavily involved

with research on *Ganoderma*, through Bah Lias Research Station.

Clone conformity

The scaling-up of micropropagation by somatic embryogenesis is currently hindered by the occurrence during in-vitro culture of a somaclonal variation known as the mantled abnormality. Such plants have an abnormal floral architecture that can result in reduced oil yields. As the mantled character is reversible and is passed on in a non-Mendelian way, molecular studies have been conducted of genome expression in cells produced in vitro, with a view to identifying markers of true-to-type and abnormal tissues.

Under a project co-funded by the Malaysian Palm Oil Board (MPOB), the RT-PCR differential display technique has been used to identify several genes whose expression is modified in relation to clone conformity status. One of these genes, EGAD1, codes for a protein from the plant defensin family. Excess accumulation of transcribed RNA of gene EGAD1 has been observed in variant in-vitro cultures at the callus stage, compared to true-to-type cultures. CIRAD and MPOB recently took out a patent on these promising results, which are due to be used to develop an early clone conformity test, so as to eliminate variant plants before field planting, and to perfect the micropropagation procedure.

Byproduct composting

Milling oil palm bunches results in large quantities of byproducts, including one tonne of empty bunches and three tonnes of effluent per tonne of oil. CIRAD has been working for several years now, in conjunction with PT SMART in Indonesia, on using these mineral-rich organic byproducts in plantations to ensure more efficient, environment-friendly, oil palm growing operations. Composting is an attractive alternative if growing conditions prevent direct use of fresh products in the field. It reduces empty bunch volume by 80% and their initial weight by 55%, which makes for easier transport and handling.

Experiments conducted on various scales have helped to identify the optimum conditions for composting: initial inoculation with ripe compost and regular watering with effluent to maintain a 60% moisture content. These two compounds also provide nitrogen-rich matter that stimulates the microorganisms responsible for composting. Application doses and frequencies have been determined for every stage of the procedure. Watering reinforces the effect of regular turning to control windrow temperature.

Compost is an excellent substitute for the inorganic fertilizers generally used at every stage of oil palm cultivation. Depending on how long the plant matter is left to compost, the end product can be used for various purposes: very ripe compost in the nursery for rapid uptake and less rotted compost in the field, where a slower, more sustained effect is required. ■

Small-scale
compost
production



© J.-P. Calliman

New or strengthened strategies have been adopted by the department in several priority areas to meet changing market demand and consumers' needs, while it addresses environmental issues and adjusts its programme to the ever-evolving fruit and vegetable sector in both the North and the South.

Portraying the nutritive value, sensory and aromatic properties of fruit and vegetables, and preserving the quality of this produce by conservation and transformation processes is also a top priority.

The aim is to respond effectively to the rising concern of consumers in developed and developing countries to benefit from a healthy balanced diet. Macronutrients are essential for human health, and nutrition specialists are now, to an increasing extent, stressing the importance of micronutrients. Fruit and vegetables that contain these vital elements, however, still do not sufficiently fulfil food security needs in the developing world.

Structural and functional genomics research is another key priority of the department, focusing specifically on disease resistance, enhancing fruit quality, and understanding the pathogenic mechanisms of viruses in the banana genome.

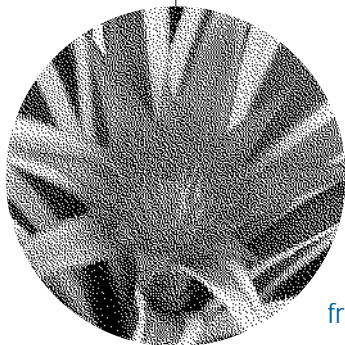
The department's teams have established a world reputation in this research field.

Many field teams are also striving to promote sustainable agriculture in order to strike a balance between agri-environmental concerns and market requirements in terms of product quality and competitiveness.

Users should be able to benefit directly from the research innovations by adopting, sustainably integrating and using these research products in their traditional systems. This is the thrust of meetings that are organized regularly with stakeholders of the different subsectors.

For instance, the September 2001 professional meeting provided an opportunity to present the department's research results to its agricultural processing industry partners, and to promote interaction between its scientists and those who use the innovations.

Fruit and horticultural crops



Banana, plantain and pineapple

Bananas, plantains and pineapples are chiefly produced by smallholders for domestic and regional markets and home consumption, with only around 10% cropped intensively for export. In the West Indies and Africa, the banana, plantain and pineapple programme is developing environment-friendly cropping systems that will enable export-oriented stakeholders to meet the market demand for healthy top quality produce.

Dissemination of hybrid pineapples

Hybrid pineapples—several ornamental varieties and one fruit variety—are now being distributed to private growers. This hybrid bears attractive firm-fleshed fruit that ripens uniformly and is very sweet, with a pleasant taste and a high vitamin C content. The first harvests of these pineapples should be marketed in 2003. The ornamental varieties are cherished for their beautiful flowers, and are already being marketed, chiefly in northern Europe.

Pineapple production and food security

Recent crises that upset various agricultural sectors prompted high consumer demand for safe foods and, at the same time, the adoption of strict European Union (EU) regulations limiting pesticide residue levels in foods. Most residue levels for several tropical food products were hastily set at the detection threshold due to a lack of available scientific data.

This decision will limit the export potential for many fruit and vegetable products. The pineapple subsector is seriously affected by this situation because of the widespread application of ethephon treatments to enhance fruit colour. A research project, funded by the Central Pineapple and Banana Producers and Exporters Organisation (OCAB) in Côte d'Ivoire, has been set up to assess this issue. The experimental results highlighted the complexity of this problem. It is important to offset treatment efficacy—climatic conditions, input application techniques, manuring, and individual fruit weight are crucial factors that determine treatment success—with taste quality and minimal chemical residue concerns. The studies revealed major problems that the EU legislation overlooks, especially with respect to the validity of treatment dosages, individual variability, and analysis methods.

The results will help to draw up a code of good agricultural practice and new EU standards

In West and Central Africa, the programme has a partnership with CARBAP, the regional African centre for research on bananas and plantains based in Cameroon, to meet the needs of a growing local urban population and to help boost the income of small-scale growers. The programme is also involved in cooperative projects with some countries in East Africa, the Indian Ocean region, Latin America and the West Indies.

Luciana
pineapple
flower



© C. Teisson

that should address the interests of both pineapple growers and consumers. The experience gained on this specific topic could ultimately be applied to other produce.

Pineapple germplasm

CIRAD's pineapple germplasm collection has been based in Martinique since 1985 and currently hosts more than 600 accessions. There is a substantial quantity of collected data that have been underused because they are recorded in a variety of forms. CIRAD compiled a pineapple genetic resource database to counterbalance this situation, and an evaluation version of the database was released in late 2001.

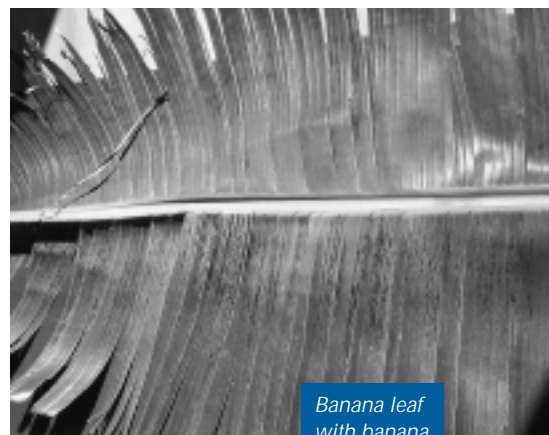
Each accession in the database can be identified by its passport (origin, collection location), a unique number, its name and botanical classification. Highly heritable qualitative traits, which are easy to observe and relatively unsusceptible to environmental conditions, are recorded individually. Quantitative yield traits and biochemical characteristics of fruit can be altered by environmental conditions. A series of points are thus recorded during each measurement cycle. An observation reliability indicator is tagged to each trait and can serve as a search filter.

Database users have various display options: a condensed or extended inventory, per-accession description files, and photographs. These can be selected according to the field of interest, eg genetics, breeding, development and training. The software also offers a wide range of search options. In addition, the International Plant Genetic Resources Institute (IPGRI) is building a database with information derived from all pineapple germplasm collections worldwide. It will be possible to exchange standardized information on pineapple accessions between databases.

Dissemination of badnavirus-free banana varieties

Symptoms induced by the banana streak virus, the badnavirus responsible for banana streak virus disease, can ultimately lead to complete plant dieback. The *Planococcus* scale insect is the natural vector of this badnavirus. Several research teams, including two virology teams from CIRAD (CIRAD-AMIS and CIRAD-FLHOR), recently discovered that badnavirus sequences are contained within the genome of banana varieties with *Musa balbisiana* chromosomes. These varieties can develop the disease simply when stressed, without coming into direct contact with the virus.

CIRAD decided to avoid the risk of widely disseminating the disease by halting the release of *Musa acuminata* x *Musa balbisiana* hybrids with integrated sequences of the virus. A multidisciplinary research programme was also set up with the aim of investigating genetic and molecular



Banana leaf with banana streak virus

© T. Lescot

factors controlling the activation of these integrated sequences and assessing the risks associated with releasing plants containing virus sequences.

In addition, new hybridization schemes using only diploid *M. acuminata* parents that do not contain virus sequences are being investigated. CIRAD should benefit from the results of this programme, thus enabling it to release certified disease-free hybrids that have shown resistance to leaf streak diseases, considerable agricultural potential, and high postharvest fruit quality.

This was a highly commendable CIRAD research operation: baseline upstream research was undertaken to address the need for disseminating new hybrids.

Banana quality

A molecular physiology study on banana was initiated in Guadeloupe in early 2000 to gain a thorough understanding of the molecular mechanisms involved in fruit ripening in association with quality.

CDNA proteins are implicated in key ripening processes. They can be detected and characterized through analyses of gene expression and complexity. They are then validated as candidates to screen for molecular markers of fruit quality. These more targeted markers will supplement the existing set of random markers.

Current research is geared to assessing aspects of the biosynthesis and transduction of the signal for ethylene, ie the hormone that initiates and controls certain banana ripening and quality buildup mechanisms. cDNAs encoding two key enzymes involved in ethylene biosynthesis, and two new cDNAs encoding ethylene receptors were isolated and registered with the numbers AF445195 and AF445196 in the genebank. ■

Environment-friendly banana production

A major goal of commercial banana industry stakeholders is to address their economic and environmental challenges as effectively as possible. Scientists and growers are working hand-in-hand to come up with technical solutions adapted to specific environmental conditions. Studies are under way on reducing tillage to control erosion, on the use of yield and pollution indicators to optimize fertilizer applications and pest control treatments, on water resource management, and on promoting an early warning system to control fungal diseases of banana leaves in support of banana growers. Pineapple-banana and sugarcane-banana rotations are being evaluated, especially with respect to their capacity to cleanse soil of banana nematodes and to their impact on restoring organic soil fertility.

Chemical control can be adjusted to pest infection levels in banana plantations by monitoring numbers of weevil pests caught in pheromone traps. New biological control strategies are being assessed that combine trapping and application of nematodes and entomopathogenic fungi.

Projects have been set up with the aim of executing agri-environmental measures via sustainable practices: development and monitoring of *contrats territoriaux d'exploitation* for mountain bananas in Guadeloupe, technical specifications for organic agriculture, fostering a quality assurance label for fair-trade bananas, etc. All stakeholders in this subsector are promoting these new practices and striving to make efficient commercial use of the innovations.

Collecting runoff water in a banana plantation in Guadeloupe



© M. Dorel



© M. Dorel

Erosion caused by intensive cropping techniques in banana plantations in Guadeloupe

Tillage

In Guadeloupe, soils in banana plantations are being destructured as a result of intensive cultivation practices. The programme assessed the impact of mechanized practices on the physical characteristics of recent volcanic soils. The soil profile was characterized by highly contrasting horizons: compact structures with low macroporosity and hydraulic conductance, next to loose fragmented structures with high conductance.

For nonmechanized tree cropping, the soil profile seems to be favourable for lateral rooting without any sharp structural discontinuities. Running machinery through the rows during cultivation will compact the interrow soil, thus hampering lateral root growth. Soil compactness was measured under controlled conditions and the results indicated a marked reduction in banana plant biomass, root density and the length of primary roots. Also studied were banana rooting patterns and soil water use at two tillage depths. Based on experimental data, a simulation model was used to assess the effect of the physical soil status on banana crop functioning.

Technical guidelines were drawn up that take into consideration differences in soil-climate conditions in banana plantations throughout Guadeloupe. They recommend limiting or even halting tillage in banana plantations, especially for highland andosols. The guidelines seek to optimize banana root system functioning while sustainably preserving soil fertility. ■



Fruit trees

Fruit is an essential source of nutrients for consumers in both developed and developing countries. The fruit trees programme conducts research on citrus fruit, mango and fruit diversification based on a thorough understanding of cropping systems, market trends and consumer preferences. Citrus and mango account for 80% of all fruit produced in hot regions, so they are major

components in the fresh and processed fruit subsectors.

Research on fruit diversification is geared to the replacement of major cash crops and to tapping the full potential of new products. The programme's research is organized around hubs of expertise and networks, while focusing on the integrated development of fruit subsectors, matching supply and demand, and developing innovative end products that can be readily adopted by industrial stakeholders.

Citrus greening in Vietnam

Citrus greening (Huanglongbing) is a highly destructive bacterial disease of citrus that is spread by grafting or via psyllid insect vectors. In Asia, the lifespan of citrus trees is sharply reduced to just 6-8 years by this disease, which means they only bear harvestable fruit twice or thrice at most. Citrus greening management is complex. Some preventive techniques are recommended: isolating sites where citrus orchards are planted or being rehabilitated, and destroying infected trees as early as possible. Moreover, growers should only plant healthy citrus trees, while efficiently controlling the psyllid vectors.

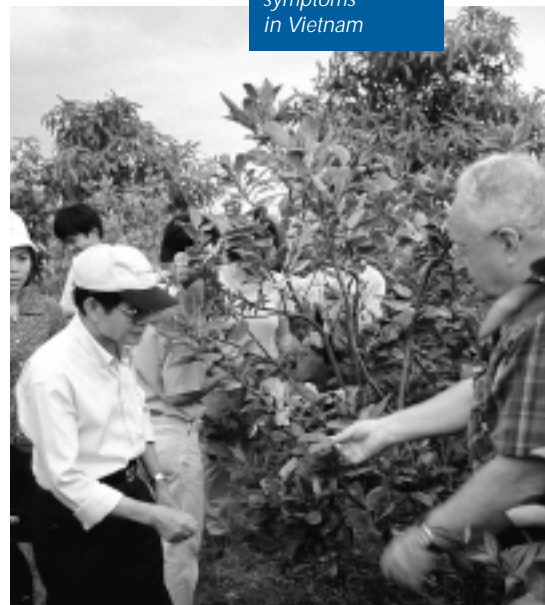
Citrus greening is a serious problem in Vietnam. The Vietnam Agricultural Science Institute (VASI) and the National Institute of Plant Protection (NIPP) are thus collaborating directly with CIRAD in a citrus greening research project, with the involvement of the Australian Centre for International Agricultural Research (ACIAR).

Three main citrus greening management strategies have been developed. Currently, the most important one is to crop citrus in regions where conditions are unsuitable for the disease. Management strategies rely chiefly on preventing spread of the disease into uninfected areas, especially by supplying growers with healthy plant material while implementing preventive control measures throughout the crop cycle. Research is also under way to determine efficient ways of controlling the psyllid insect vector and focusing citrus breeding programmes on obtaining greening-resistant varieties.

Research in Brazil

Consumers worldwide are seeking safer foods. In Brazil, various aspects of this problem are being investigated: improving fruit processing technologies, ensuring the sensory and nutritional quality of fruit products, and assessing the effects of current processing techniques on end-product quality. A large-scale project is under way with the collaboration of several Brazilian

*Training
in Huanglongbing
symptoms
in Vietnam*



© P. Cao Van

R&D institutions (EMBRAPA, FRUTHOTEC, IEM, UNICAMP), as well as CIRAD, the Technical Centre for Agricultural and Rural Cooperation (CTA), CNRS, the French scientific research institute, Brazilian and French universities, and private stakeholders.

In 2001, a research project was initiated in Nordeste state, in collaboration with EMBRAPA, the Brazilian agricultural research institution, to find effective ways of preserving mango quality. Postharvest mango physiology is being investigated, especially in conjunction with modified atmosphere studies.

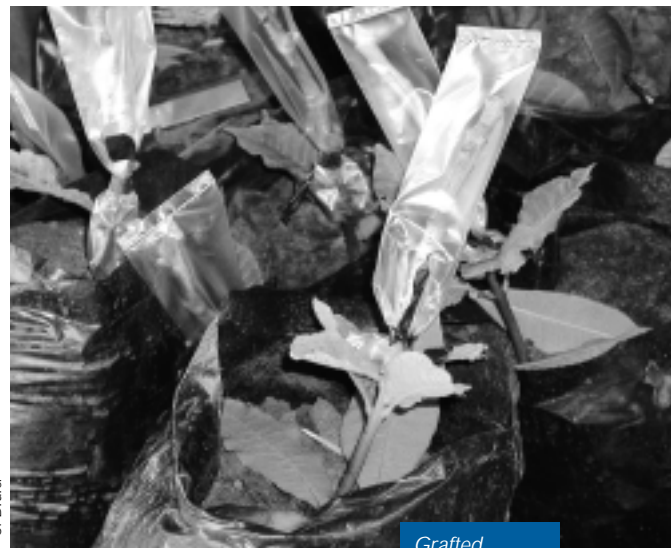
Another study, which brings together several Brazilian institutions (EMBRAPA, CENARGEN, CPAAF, INPA, FUNAI) and universities, IPGRI and CIRAD, is under way to enhance the environment-friendly use of fruit germplasm of the Amazon Basin, while also promoting sustainable family farming systems. The initial work involves drawing up an inventory of fruit species and how they are consumed by local people. The species will then be collected and their morphological and molecular diversity analyzed. They will also be assessed in terms of their agricultural and technical performance, their in-situ preservation and their potential development for local consumption as fresh and processed products.

Citrus canker, caused by *Xanthomonas axonopodis* pv. *citri*, is a bacterial disease that occurs in most citrus-growing regions throughout the world. CIRAD has been investigating this problem in collaboration with FUNDECITRUS, a private Brazilian research centre, since 2000. *Xanthomonas* strains present in São Paulo state have already been characterized. These results will be used to develop tools for early diagnosis of this disease and to adapt control techniques.

Cashew production

Cashew is the top export product of Mozambique. It constituted 22% of export revenues in 1996 and 16% in 1998, and accounts for 4-5% of the gross domestic product. However, national cashew production has dropped from 216 000 t in 1971-1972 to below 50 000 t annually. The stakeholders of this subsector include more than 400 000 growers, 2 000 traders and 8 000 craftspeople.

Mozambican authorities are striving to double cashew export volumes by stimulating production of this crop through a large-scale project set up by INIA, the Mozambican agricultural research institute, and funded by AFD, the French development agency. CIRAD was asked to conduct downstream research over the next 4 years, within the framework of this project, to enhance cashew productivity and quality. Promising results are soon expected in a cashew breeding programme and in a project devoted to developing cashew cropping systems that preserve soil fertility within mixed-crop family farms. Discussions are now focusing on updating the regulatory system that controls the cashew industry in Mozambique.



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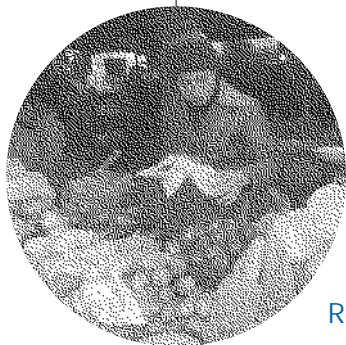
Grafted cashew plants

Flash vacuum-expansion of fruit

As an alternative to traditional blanching-grinding processes, the vacuum *flash-détente*[®] (flash vacuum-expansion) process involves steam-heating the plant material (fruit, vegetables) at 60-90°C, and then rapidly placing it into a vessel under high vacuum (30-50 mb). During vacuum expansion, sudden evaporation of a fraction of the constituent water (about 10%) disintegrates the plant tissues and intercellular microchannels are formed. After a refining step, juices and pastes produced from purple passion fruit, mango and lemon by this novel strategy have unique features as compared to products obtained by traditional processes. They have a much better consistency and viscosity.

The cell wall content of the end products is higher because part of the outer rind of the fruit is included. The products have a paler or more intense colour because whitish tissues (albedo) or colour molecules (anthocyanic pigments) from the fruit rind are preserved. Lemon pastes produced by this technique are more bitter than those obtained by conventional processes.

The *flash-détente*[®] process has also been applied to extract essential oils from citrus peel (lemon, sweet orange, mandarin and grapefruit). Essential oil yields were comparable to those obtained by conventional processes. Oils extracted by the *flash-détente*[®] process were found to be enriched in terpene hydrocarbons and impoverished in oxygenated compounds as compared to cold-pressed oils. This promising novel process is now being tested in partnership with stakeholders in the food processing industry to further assess its potential and improve active molecule extraction. ■



Horticultural crops

The horticultural crops programme conducts research on a broad spectrum of crops, market garden produce, flower and aromatic plants—areas with a considerable economic potential. In developing countries, these products account for a major share of supplies to domestic urban and regional markets. Research currently under way on vegetables is multidisciplinary, which reflects

the complexity of food security and farm sustainability problems that are being addressed. Hence, in humid tropical areas, studies are focused on soil nitrogen and biomass management, and on integrated control of bacterial, fungal and viral pathogens, and on commodity marketing channels and innovation technology transfer. The programme is also involved in research on sustainable diversified cropping systems in the French overseas departments and territories, and on the development of horticultural crop production for export.

Vegetable quality in Asia

Vegetable quality is an increasing concern of urban consumers in Southeast Asia. Leafy vegetables, choysum (*Brassica rapa* cv. *Choysum*) and Indian mustard (*Brassica juncea*), for example, are very popular among consumers in Vietnam. This produce has a short shelf life, so they are grown throughout the year close to urban areas. Fertilizers and pesticides are required to reduce the length of the cropping cycles. Consumers, on the other hand, want to be guaranteed that the products are fresh and safe. How can pollution risks be reduced? Agronomists from the Vietnamese Research Institute on Fruits and Vegetables (RIFAV), in collaboration with scientists from CIRAD and the Asian Vegetable Research and Development Center (AVRDC), were delegated to address this complex question. The analyses of cropping practices are focused on nitrogen fertilizer application and pesticide treatments. Experiments will be conducted at the research station and in farmers' fields with the aim of drawing up technical guidelines that account for seasonal variations in pest populations and former cropping conditions (traditional techniques, soil status, etc.). To study nitrogen fertilizer management in tropical vegetable cropping systems, CIRAD has developed a partnership with INRA, the French agricultural research institute, and with the Strategic Initiative on Urban and Peri-urban Agriculture (SIUPA). The latter, a group of several institutions under the umbrella of the International Potato Center (CIP), is involved in all of the research under way in this field.

Somatic embryogenesis in garlic

As part of an EU project entitled Garlic and Health, CIRAD is focusing on developing new techniques for rapid large-scale propagation of healthy garlic plants. A procedure involving somatic embryogenesis, germination of mature embryos, and conversion into plantlets has been developed.



Thong Khan
market
in Vientiane

© H. de Bon

Four garlic cultivars that are representative of the diverse physiological groups of garlic grown in Europe and the tropics have been tested. Somatic embryos of each of these cultivars were regenerated from embryogenic calli on agar medium, with a rate of conversion into plantlets of 40%.

Improvements have been made for each phase of the procedure. The improved method involves establishing suspended cell cultures for each cultivar using embryogenic nodular calli or friable calli. The behaviour of the resulting embryos, when observed on an agar embryo regeneration medium, resembles that of embryos derived from calli. Moreover, the plantlet conversion rate from nodular or friable calli was found to be higher than that obtained with embryogenic calli.

Histological studies also highlighted the unicellular origin of somatic embryos. The true-to-typeness of regenerated plants was assessed in comparison with plants propagated conventionally from garlic cloves. Flow cytometry analyses demonstrated that 265 plantlets derived from embryos propagated by this new procedure were diploid, like the four in-situ propagated controls.

This method is highly reliable in terms of generating true-to-type plants. INRA is also conducting field tests to assess this new material.

aimed at improving preventive control and breeding resistant varieties.

Bacterial populations were monitored two at a time to assess their interactions. At incubation temperatures above 25°C, biovars 1 and 2 did not compete with biovar 3, whereas at cooler temperatures biovar 2 seemed more efficient. Behaviour tests carried out with *Solanum tuberosum* hybrids and the wild-type *S. stenotomum*, obtained by protoplast electrofusion, acclimatized and installed under a shelter, confirmed the resistance of hybrids to the race 1 strain. They were, however, found to be relatively susceptible to the race 3 strain, like the wild parent.

Processing vanilla

Vanillin is quantitatively and qualitatively the main component of vanilla flavouring. When vanilla pods are harvested, vanillin generally occurs as glucovanillin, its glycosylated precursor. Glucovanillin has no olfactory features and must be enzymatically hydrolyzed by an endogenic β -glucosidase to give rise to vanillin. Vanillin yields obtained via conventional glucovanillin hydrolysis processes are relatively low, ie around 40% of the green pod potential.

CIRAD, in partnership with a French private vanilla flavouring manufacturer, initiated studies on vanillin biosynthesis with the aim of increasing the yield of this process. A two-year laboratory study on the vanillin precursor and on the associated enzymatic system highlighted a substantial potential for increasing vanillin yields from pods during hydrolysis. In 2001, several vanilla processing techniques were tested at a pilot site in Madagascar. ■



Bacterial wilt caused by *Rastolnia solanacearum* on melon

© P. Pflor

Bacterial wilt

Bacterial wilt, caused by *Rastolnia solanacearum*, is detrimental to many different crops, especially vegetables (Solanaceae), in the tropics and subtropics. A thorough understanding of the host plant-bacteria complex is necessary to be able to develop efficient integrated control methods. The department used molecular tools to assess the genetic diversity of

R. solanacearum by probing different regions of the genome. The species was divided into two subspecies, ie *R. s. asiaticum* and *R. s. americanum*, on the basis of the geographical origin of the strains, and this new classification was confirmed. However, recent studies carried out in Réunion, and in collaboration with Australian specialists, revealed that African and Indonesian strains differ from the subspecies noted above. Classifications into five races and six biovars remain in force, but only partially match the classification into large groups. The situation is unique in Réunion since three populations are present that belong to two major races and to three major biovars.

An efficient tool was developed to detect the bacteria in different media (water, soil, plants) and identify genetic variants (biovars 1, 2, 3 from Réunion). This tool should facilitate studies



Freshly harvested vanilla pods

© E. Odoux

Animal production and veterinary medecine

Animal production must be increased in response to growing consumer needs. This generally involves the intensification of livestock production while dovetailing these objectives with other farming concerns.

Potential detrimental impacts on the environment and marginalization of small livestock farmers are serious risks that have to be considered in any intensification initiative, within the context of increasing consumer demand for top quality safe food products.

In 2001, a livestock production intensification project was initiated in Vietnam, as part of a new research thrust, and CIRAD's dairy production research group boosted its field interventions.

The animal health programme continued to focus on priority research themes in collaboration with the Food and Agriculture Organization of the United Nations, l'Office International des Epizooties (the world organization for animal health), and on others for which CIRAD is an internationally recognized reference centre. These include: trypanosomiasis, tick-borne diseases, transboundary epizootic diseases, and epidemiology.

The department invested considerably in a study on health-environment interactions, especially with respect to emerging vector-borne diseases, with joint involvement of the programmes of rangeland and wildlife management and animal health. This included investigations on epidemiological cycles of these diseases and risks of their expansion in both developing and developed countries worldwide.

Research on the management of pastoral natural resources and animal biodiversity has progressed substantially. Wildlife conservation, management and productive use are the focal points of different regional programmes, and have led to the formation of several hubs of research and expertise in Senegal and Burkina Faso, while others are in the budding stage in Southeast Asia.

The department's ongoing training initiatives included setting up new modules, within the framework of many different partnerships with, for instance, the University of Montpellier and French national veterinary schools.



Rangeland and wildlife management

Complex long-term interventions involving many stakeholders are essential for sustainable environmental conservation, land management and resource use. Similarly, research strategies that mesh observations, measurements and continuous multidisciplinary monitoring over long periods are required to understand interactions involving wild and domesticated animal populations.

Interventions of the rangeland and wildlife management programme in 2001 were thus concentrated on multi-year international projects undertaken jointly with other scientific partners.

Ecosystem protection and enhancement

The Long Term Ecological Monitoring Observatories Network (ROSELT), which aims to contribute to the implementation of the Convention to Combat Desertification (1995), has been fully operational for two years. It is run by a consortium involving CIRAD, IRD, the French institute of development-oriented research, and the Sahel Institute (INSAH).

North, West and East African countries have set up observatories for scientific monitoring of the environment and analysis of desertification mechanisms, with the ultimate aim of developing specific biophysical and socioeconomic indicators. CIRAD's involvement chiefly encompasses the fields of pastoralism, wildlife monitoring, and correlations between ecosystem changes and social dynamics, while actively participating in rejuvenating some observatories in the East Africa countries of Kenya, Ethiopia and Djibouti so as to strengthen the African network.

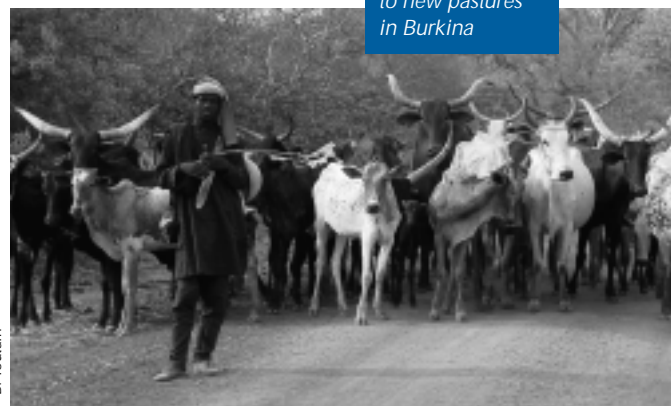
In fragile ecosystems, livestock production is often hastily blamed for being a major cause of natural resource degradation. The Livestock, Environment and Development Initiative (LEAD) is striving to protect and enhance natural resources affected by livestock production while alleviating poverty. In 2001, LEAD created a virtual research and development centre (<http://www.virtualcentre.org>). Its mandate is to promote multidisciplinary research activities and increase awareness among key stakeholders of the complex interactions between human needs, animal production and global natural resource sustainability objectives. The website is managed by FAO for the English version, CIRAD for the French, and CATIE, the Costa Rican agricultural research centre, for the Spanish.

PPZS, a regional research pole on pastoralism in arid zones, was founded in Senegal with ISRA, Senegal's national agricultural research institute, the Ecology Monitoring Centre, Cheikh Anta Diop University in Dakar, and CIRAD. It is analysing the function of ecosystems and their use by pastoral

societies in arid and semiarid regions with the aim of developing tailored interventions that could enhance these systems. The natural and pastoral ecosystems programme is coordinating this initiative. Intervention strategies have already been developed, information systems proposed and decision-support methods tested.

The ECOPAS programme was created for the conservation and development of the W regional park and neighbouring areas of Niger, Benin and Burkina Faso. It was funded by the European Union (EU) in 2001. CIRAD was asked to coordinate the research. It will focus on: management of pastoral activities; biodiversity resource inventory and mapping; assessing ecological dynamics in protected areas, especially wildlife; natural resource use; and impact of communities inhabiting areas within the immediate vicinity of the park. The project will host students from both developing and developed countries.

Nigerian herd on seasonal move to new pastures in Burkina





The
Annamitic
cordillera

© F. Monicat

Safeguarding biodiversity

An exceptionally diverse range of wild and domesticated animals occur in mountainous regions of Vietnam. Two projects, funded by the French Ministry of Foreign Affairs and FFEM, the French fund for the world environment, and jointly coordinated by CIRAD and Vietnamese and French partners, were launched to preserve and make efficient use of these genetic resources. Pilot initiatives are under way in the poverty-stricken high plateau and Annamitic cordillera regions, in conjunction with authorities of four provinces, to synchronize zoogenetic resource management with sustainable use of these resources. CIRAD's role is to supply scientific expertise. The Ea So reserve, on the high plateaus in Dak Lak province, has one of the last patches of open woodland forest harbouring relic populations of wild large Bovidae species, including the gaur, *Bos gaurus*, and the banteng, *Bos javanicus*. Their genetic features and variability will be analysed with the aim of developing conservation policies for these species that could be applied throughout Vietnam, thus stalling further dwindling of their populations, fragmentation of their habitats, isolation and genetic drift.

In New Caledonia, rusa deer, an introduced herbivore, can in some situations prevent forest regeneration. Since 2000, CIRAD has been coordinating a project, funded by the French Ministry of Land and Environment Management, to assess the impact of these feral deer populations on flora biodiversity. Experiments were conducted at two sites that are distinguished by the presence of a broad range of different indigenous forest species. Mixed results were obtained in the forest dominated by sclerophyllous species, ie there was very little or no regeneration of most woody species, while some endemic species showed remarkably high resistance to deer browsing. On the other site, consisting of patches of rain forest and savanna, the deer had a greater impact on the savanna patches than on the



Gaur or
Bos gaurus

forest. In the rain forest stands, only a few endemic plants seemed to be eaten, mainly vines and ferns. Further analyses are under way on rumen contents and faeces, and new sites are being surveyed to validate bioindicators that are being developed.

In Latin America, often uncontrolled hunting is endangering populations of peccary, a pig-like animal of the Americas that is cherished for its meat and leather. Very little is known about how this animal would perform in a production setting—in the natural environment, or under extensive or intensive rearing conditions. An EU-funded project on peccaries, coordinated by CIRAD, was launched in 2001. Testing is under way on novel peccary rearing systems that were developed by drawing on the experience and skills of different Brazilian, English, French, Peruvian and Spanish partners. The aim is to come up with more productive sustainable systems that will not be damaging to the natural environment and biodiversity.

Managing disease outbreaks

In 2000, CIRAD was asked to participate in a working group formed to control an outbreak of West Nile fever in the Camargue (France) and bluetongue disease in sheep in Corsica. On the basis of this experience, the department decided to form a multi-disciplinary, multi-institutional research team, involving IRD, the Pasteur Institute and AFSSA, the French agency for food security, with the aim of developing reliable and efficient tools for monitoring disease outbreaks in both developing and developed countries.

Accurate information on the epidemiology of the infectious agent and its natural reservoirs in the monitored area is essential for assessing outbreak risk. Data from a range of fields and sources—molecular genetics, population dynamics, remote sensing, geographical information systems (GIS)—are required to determine which specific environmental factors could trigger or boost the pathogenic process. Data conceptual models, along with statistical, spatial and temporal data analyses, will be applied to pinpoint outbreak risk indicators. An efficient monitoring network is necessary for effective field management of disease outbreaks—warning, follow-up, control interventions and monitoring. All governmental and private stakeholders should have access to the specially adapted tools developed by the team. ■



© G. Balança

Ringed
bluethroat,
a potential
West Nile
virus reservoir



Animal production

A food revolution is currently under way in developing countries, prompted by higher consumption of meat and dairy products by an increasingly urbanized population. Animal production has an important role to play in addressing this development challenge over the next 20 years. Key areas being examined include how animal production can be combined with crop farming, and how animal production can be intensified without degrading the environment and food product quality.

Environment-friendly local pork production

Since 1999, CIRAD has been supporting development of the pork production subsector in Martinique. One of the main goals is to promote efficient production of creole pigs, which are very hardy and thrive under local climatic conditions. In initial trials, pigs were fed banana cullage, which resulted in the production of very high quality pork that is produced more cost-effectively than that obtained by conventional feeding techniques. A new pork product labelled "cochon banane" ("banana pork") will soon be marketed.

Sludge effluents generated by pig production units were studied to find ways of controlling this pollution. An anaerobic sludge decontamination process using a biodigester was thus tested. However, many constraints hamper blanket adoption of this technique: moderate quantities of water for hog-house cleanup, the slatted floors necessary in hog houses, a limited number of animals can be reared in this manner, and sufficient land must be available to construct the biodigester.

In Vietnam, a CIRAD scientist has been collaborating with the Vietnamese National Institute for Animal Husbandry (NIAH) since 2001. Three research themes were selected on the basis of an initial assessment of the pig production subsector: weanling quantity and quality, quality of raw materials and by-products used in pig feed, and intensification of peri-urban pig production.

Aquaculture in Asia

The successful artificial propagation of the two main catfish species has revolutionized Vietnam's Mekong aquaculture: fry rearing is efficient, fish rearing cages are proliferating and fresh-fish processing units are on the increase. Producers are now seeking to capture new external markets, especially in the United States, but this means meeting restrictive quality and traceability standards. CIRAD's team is collaborating closely with Vietnamese aquaculturists to help them address



A biodigester under construction in Martinique

this challenge. A sanitary assessment was undertaken in 2001. The analyses focused on causes of mortality in fish-rearing cages, risk factors, and losses due to flesh deterioration during processing. The efficiency of pharmaceutical treatments carried out in the cages was also evaluated. A collaborative project with Agifish, a provincial fisheries company, is under way to enhance propagation performance and larval rearing.

In the Philippines, a tilapia-breeding project is being carried out in collaboration with the Philippine Bureau of Fisheries and Aquatic Resources with the aim of obtaining a hybrid that could be bred in salt water. Initial tests revealed that one tilapia hybrid had higher tolerance of salinity than the freshwater parent species. CIRAD is conducting research in the Pampanga region, where freshwater and brackish water fish farms are both present, to determine key factors that need to be focused on in order to succeed with this innovation.

Laitrop

CIRAD scientists from various fields and programmes formed the Laitrop working group to address the booming demand for dairy products in developing countries. The group intends to assess current subsectors, boost production, improve product quality, tailor technologies to local conditions, and model the economic performances of farms and the entire subsector.



Traditional dairy product sales in Kazakhstan

© B. Faye

In Réunion, CIRAD has developed a modelling tool with the following input variables: herd dynamics, pastures, and correlations between different farm elements and the many components that dairy farmers take into consideration in their decision-making processes. This model can be used in aid-granting processes to evaluate the effects of technical innovations and changes on the sustainability of farming systems. It forecasts possible scenarios in terms of employment, dairy-farming self-sufficiency, resource preservation, and income on a regional basis.

In addition, CIRAD has been involved in the development of dairy production in the Mbarara basin of Uganda, in collaboration with local veterinary services. Livestock rearing and dairy production management were modelled on the basis of the results of an analysis of farming systems and zootechnical, sanitary, dietary and socioeconomic monitoring. Decision-support tools have been developed for the entire subsector.

Since 1997, CIRAD has been looking for ways to improve the quality of traditional dairy products in Kazakhstan, eg fermented milk from mares and

camels. The main enzymes involved in the fermentation process were identified in collaboration with researchers from the University of Almaty, and a new lactic acid bacteria strain was also recently isolated.

Food product quality

In Senegal, the local veterinary services, ISRA and CIRAD are collaborating with the poultry industry to improve the sanitary quality of broiler chickens. The aim is to identify and classify low sanitary quality factors. The initial results highlighted a correlation between chicken rearing and slaughtering techniques and chicken meat contamination by *Salmonella* and *Campylobacter*—pathogens that are killed if the meat is cooked at high heat. Stakeholders at all levels of this subsector (hatchers, poultry producers, slaughterers) responded effectively to this situation, as shown by the improvement in microbiological and antibiotic residue analysis results. This is also evidence that their training experience is paying off.

Short-term application of EU sanitary standards in Réunion induced milk producers to monitor the quality of the milk they produce. CIRAD measured butterfat content and somatic cell concentrations in milk in 14 dairy cattle production farms. Poor milking hygiene was found to be responsible for high somatic cell concentrations in tank milk. These concentrations increased during the rainy season because cows' teats were often soiled. Also, at the onset of the lactation phase, butterfat contents were higher after cattle had grazed in kikuyu grass pastures or sugarcane fields as compared to temperate grass pastures. However, butterfat content could be reduced in the milk from cows that graze on kikuyu grass if they have not received a sufficient nutrient supplement.

In September 2001, scientists from CIRAD, ENSAR, the French national college of agricultural engineering, and from various developing countries attended a workshop in Rennes (France) to discuss the quality of animal production subsectors in the tropics. Quality assurance methods were developed on the basis of French examples. A subsequent workshop was held in Thailand, along with assessment missions and the co-supervision of a doctoral thesis in Brazil.

Body reserves of dromedaries

Marked variations were noted in the volume and weight of the hump of the dromedary, which is a visible and measurable appendage that contains most of this animal's essential adipose reserves. Cellular and tape: weight measurements of the hump—average size and adipocyte size profile—

were matched against total adipose reserves of the animal. The results of the analysis revealed that the hump is not a reliable indicator for assessing the fleshing status of the herd due to high genetic variability between individual animals. Stock farmers are now given a checklist that includes other anatomical criteria. This management support tool enables them to evaluate the body reserve status of their dromedary herds. ■



© B. Faye

Breeding
dromedary in
the United Arab
Emirates



Animal health

The animal health programme initiated five European Union projects in 2001. Four development projects began on heartwater, contagious bovine pleuropneumonia, trypanosomiasis and peste des petits ruminants. A containment laboratory (P3) was set up in preparation for the fifth project, on African swine fever, which was launched within the framework of the EU "Quality of Life"

programme. CIRAD also strengthened its support for epidemiological survey networks.

Sequencing the *Cowdria ruminantium* genome

The successful sequencing of the genome of *Cowdria ruminantium* (Gardel strain), the causal agent of heartwater, a fatal disease of ruminants, is an outstanding animal health achievement. It is the upshot of a fruitful collaboration between CIRAD's teams in Guadeloupe and Montpellier, and the Human Genome Institute in Montpellier. With access to this sequence, scientists should now be able to identify genes of interest for developing a vaccine against this disease, along with an efficient diagnostic procedure. This is the first pathogen genome that has been fully sequenced so far, out of some ten causal agents currently studied by the department. Other *Cowdria* strains and pathogens will also soon be sequenced.

A recombinant capripox vaccine

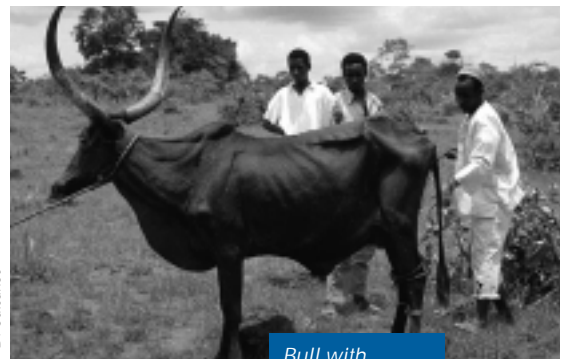
The capripox virus vaccine strain was used in the department's laboratories to develop a recombinant vaccine that could provide immunity to capripox and peste des petits ruminants (PPR). Animals test-vaccinated with the first recombinant vaccine strain showed high immunity to these two diseases.

Another gene that is dependent on different promoters was inserted into the capripox genome. The effects of these promoters on the in-vitro expression of this gene and on immunity levels in vaccinated goats will now be assessed. A recombinant vaccine against heartwater and capripox was also devel-

oped using the capripox vector. This recombinant vaccine, which contains a gene encoding the *Cowdria* MAP-1 antigen, will soon be evaluated in immunization trials.

Congopain expression

Congopain, a cysteine protease of *Trypanosoma congolense*, is the main target of research to develop a vaccine against trypanosomiasis. The difficulty of inducing cysteine protease expression was a major hurdle to overcome, and it took several years of experiments to obtain a suitable recombinant antigen. A high congopain expression was finally obtained in the yeast *Pichia pastoris*, a recently discovered eucaryotic expression system, and subsequently a recombinant antigen



© D. Cuisance

Bull with
trypanosomiasis

was developed that possessed all the required traits. It is inexpensive to produce and the production rate is at least ten times higher than that of cysteine proteases in a eucaryotic system. Immunization experiments could therefore be relaunched under much better conditions.

Contagious bovine pleuropneumonia

Three projects are focused on developing vaccines against contagious bovine pleuropneumonia (CBPP). The thrust of the first EU project is to further analyse the immune response of CBPP-resistant cattle and identify antigens of this mycoplasma that could induce an immune response in the host. The second project, which is coordinated by the Organization of African Unity (OAU) with EU funding, is geared towards validating existing attenuated vaccines, developing new vaccines and especially new CBPP diagnosis tools. In this latter project, CIRAD is developing tools for genetic transformation of the causal agent, with the aim of gaining insight into the function of specific genes, especially those responsible for the virulence of these pathogens. All of these projects are managed by the department, thus confirming its world reputation as an FAO reference centre for this disease, and fostering collaboration with stakeholders in many countries (Cameroon, France, Kenya, Mali, Portugal, South Africa, Switzerland and United Kingdom) and with the International Livestock Research Institute (ILRI).

African swine fever



P3 containment laboratory in Montpellier

© O. Kwiatek

This EU project was initiated to improve epidemiological tools and methods concerning African swine fever. The results of studies under way on virus-host interactions could give rise to the development of a vaccine against this disease. The research was launched after agreement was reached on containment laboratory 3 (P3). Work to set up the laboratory began in 2001 and was completed in early January

2002. CIRAD scientists taking the necessary containment precautions will now be able to safely conduct research on the African swine fever virus in this new 180 m² facility. The laboratory is also in compliance with EU regulations on handling of the foot-and-mouth disease virus.



Buffalo in the Zakouma National Park, Chad

© P. Chardonnet

Regional epidemiological survey networks

CIRAD is providing strengthened epidemiological survey support in five priority intervention areas. This support is methodological—organizing veterinary services and providing performance indicators—and also practical—developing or adapting diagnostic tools, databases, and new information technologies.

Four CIRAD epidemiologists are involved in the Pan-African Programme for the Control of Epizootics (PACE) in Africa. West and Central African countries are seeking recognition as rinderpest-free zones, whereas rinderpest outbreak areas in Sudan and Somalia still represent a threat for East African countries. A workshop was held in Montpellier, with participants from Algeria, France, Morocco and Tunisia, with the aim of regionalizing surveys of serious diseases such as foot-and-mouth disease, sheep pox and bluetongue disease that could endanger the Mediterranean region. Elsewhere, in the Indian Ocean region a regional epidemiological survey support system is planned. In the West Indies, a regional network of laboratories was formed, with the accompanying creation of an information exchange platform and a website that CIRAD designed and is managing. Disease upsurges occur regularly throughout the world. It is thus essential to remain mobilized by conducting tropical animal disease surveys where there is a genuine risk of outbreaks, not just within the borders of Europe.

Bovine dermatophilosis

Bovine dermatophilosis is a severe skin disease that affects ruminants in the tropics. No efficient vaccine is currently available. In cattle, however, there is clear evidence that it is a genetically deter-

mined disorder. Genetic marker-assisted selection for resistance to bovine dermatophilosis shows promise as an integrated control strategy. A set of alleles of a major histocompatibility complex gene, ie *BoLA-DRB3* class II, was found to be a good marker of disease susceptibility. Very convincing results were obtained that confirmed the validity of this marker in several completely separate cattle populations.

In Martinique, a breeding strategy, involving early elimination of animals bearing the susceptibility marker, reduced disease prevalence from 75% to zero within five years. A crossing programme was

set up to compare phenotypic and genotypic transmission of the markers. Based on the results of a biology study, a 3-D model of the *BoLA-DRB3* molecule was developed and several biological hypotheses were put forward re the molecular mechanisms of bovine dermatophilosis susceptibility. ■



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Brahman zebu
in Martinique

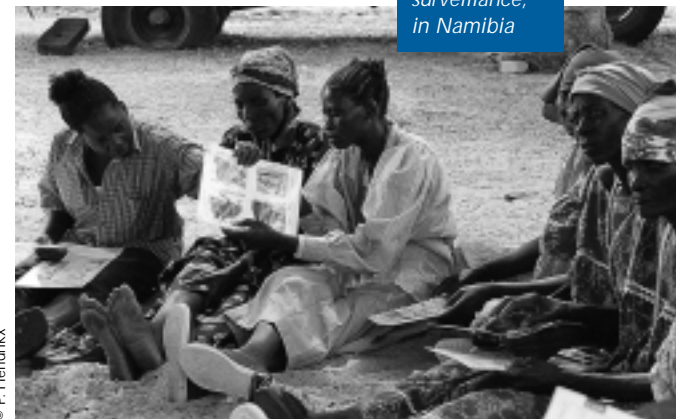


Training

In 2001, CIRAD-EMVT consolidated its activities and skills in the fields of higher education, professional training and educational engineering.

The department organized 900 h of diploma training and hosted more than 150 trainees. The first graduates of a DESS (1-year postgraduate diploma course in an applied subject) on animal production in hot regions, offered in partnership with the University of Montpellier II, obtained their degrees. Twenty-one students were recruited for the 2001-2002 session on the basis of their personal qualification records. ISTOM, the French professional institute of international agro-economics, and the Nantes Veterinary School included some training modules of this DESS in their curriculum, so some 30 students from these establishments also received training at CIRAD. The first session of a postgraduate diploma course in animal epidemiology, jointly organized by the Maisons-Alfort Veterinary School and CIRAD, was offered this year and 11 students participated. A postgraduate veterinary science diploma course on animal pathologies in hot regions and epidemiological surveys was organized in collaboration with the Toulouse Veterinary School. Fourteen students attended nine weeks of courses given by CIRAD, which also hosted 74 students for applied training.

Qualification training was also offered, through individual training tailored to specific professional needs, or through collective training modules organized by the department. These activities benefited 88 trainees, mostly from developing coun-



© P. Hendrikx

Training
in priority
diseases under
surveillance,
in Namibia

tries. An educational CD-ROM entitled "An introduction to GIS and epidemiological applications" was published in partnership with CIRDES, the international livestock production research and development centre (Burkina Faso), to supplement the epidemiological survey data processing and management module.

Educational engineering training was proposed to meet partner institutions' demand for different training plans and programmes. In September 2000, CIRAD signed an agreement with the Livestock Production Directorate of Senegal, as part of PSAOP, the Senegalese agricultural services and farmers' organizations programme, funded by the World Bank. Thirteen participants were trained in 2001. PACE also asked CIRAD to train its senior staff. Six training modules were developed, four were assigned to CIRAD, one to EISMV, an inter-state science and veterinary medicine school in Dakar, and the last one to the International Trypanotolerance Center (ITC) in Banjul (Gambia). ■

Forestry

Forests have at last been fully recognized in the fight against the greenhouse effect. The sixth conference on climate change, held in Bonn in July 2001, revived the Kyoto protocol, and the 180 countries that signed the United Nations treaty managed to reach agreement, despite opposition from the United States.

The protocol reflects a marked shift in the nature of North-South relations, revealing a new interdependence between industrialized and developing countries: both groups will now have to share responsibility for managing their common global heritage. Moreover, the topic chosen for the CIRAD stand at the 2001 Paris International Agricultural Fair (SIA) – tropical forests and mankind – resulted in the organization of a debate at the fair on “tropical forests, areas to be shared, issues to be negotiated”. An integral part of CIRAD’s research operations is the implementation of international agreements on managing biodiversity and controlling desertification and climate change to benefit developing countries.

The department’s policy on partnerships aims to link different scientific communities by collaborating with French universities, participating in joint research units such as the forest ecology unit in French Guiana, and encouraging the establishment of poles of excellence (clusters of institutions) in conjunction with research organizations in developing countries, particularly Madagascar and Mali.



Natural forests

To understand how one of the most complex ecosystems on the planet functions, particularly as a result of human intervention, is a double challenge. It is crucial to preserve biodiversity in forest areas, but also to guarantee the long-term future of the products and services such areas provide to local communities. The Natural Forests Programme favours an integrated approach aimed at finding a compromise between rational logging practices and biodiversity conservation, and thus ensuring sustainable tropical forest management.

Forest taxation

A training course in forest taxation and economic instruments was organized in 2001 in Madagascar, in conjunction with the CIRAD-TERA Land and Resources Programme. The main aim of the ten-day course was to support implementation of the new Madagascar forestry policy. It was attended by national and regional representatives of the Forestry Ministry, heads of local authorities in the region, and researchers from FOFIFA, the development-oriented research centre, and CFSIGE, the national training centre. Among the topics covered were: What are the issues involved in reforming forest taxation and what are the available choices? How can the effects, risks and advantages of the different development options be assessed? How can administrative procedures be implemented successfully?

The approach taken for the training course was tailored to meet needs, and was thus deliberately practical: questions-and-answers, role-playing followed by discussions, field visits, case studies and the lessons to be drawn from them. Two tutors from ESSA, the Agricultural Sciences College of the University of Antananarivo, were also involved in the course, since transferring the initiative for this type of seminar to ESSA was another aim of the course.

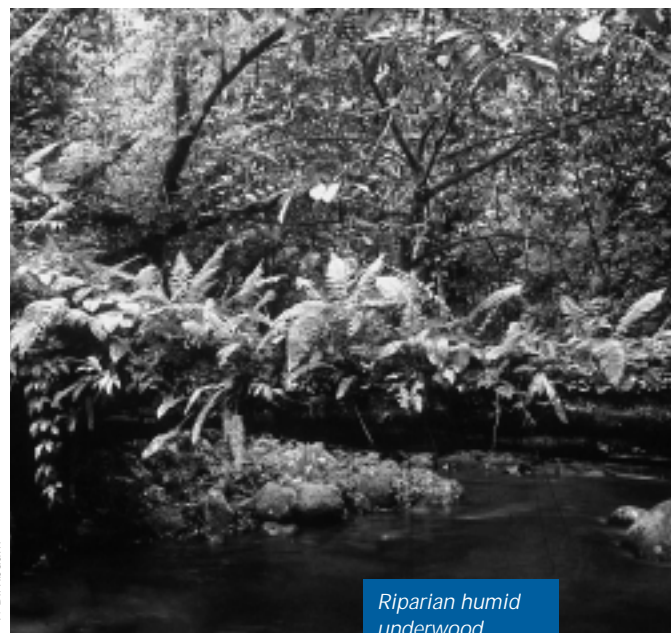


Training in Madagascar

© P. Montagne

Forest inventory in Indonesia

At the request of the Indonesian Forestry Ministry, IFRIS, an information system on forest resources, that is intended to provide support for forestry management operations, has been designed and installed under a project funded by the European Union. The IFRIS system was designed for forestry managers and landscapers. It compiles, classifies



© P. Birnbaum

Riparian humid underwood environment in Sumatra

and manages a set of precise, constantly updated data intended to ensure that the development of forest areas, a major national resource, is based on consistent, reliable criteria. The many modes of accessing information, which are tailored to users' needs, reflect the multiplicity of factors to be taken into account when planning development: satellite data processed and used to generate thematic maps; forest inventories; reports on plant cover, soil and biodiversity status; socio-economic studies; and photographs of the local flora and fauna. The available data currently cover around a dozen districts of eight provinces in Sumatra, Sulawesi and Sumba.

Botanical studies in French Guiana

The botanical trail at the Paracou experimental station in French Guiana offers both scientists and the general public a selection of more than 1 000 recorded trees. IRD and CIRAD, the French development-oriented research organizations, have worked together within the Silvolab group on every aspect of the operation, from collecting samples for a herbarium to identifying them, and management of the station's collections. For each tree recorded there is a precise description of its vegetative characteristics, plus a set of digital photographs illustrating the specific characteristics of the species. This information has been input into the Kimboto database, which is dedicated to the trees at the station, and which contains an illustrated plant guide and a compilation of the available data, including observations per family, or taxonomic group, per group of individuals or per site. This trail, which has about 259 different species, is a showcase for biodiversity in French Guiana.



Miconia sp.
flowers

© P. Pétronelli

Guide to trees in the Sahel

Trees and bushes play many crucial roles in the daily life of the Sahel. The handbook, *Arbres, arbustes et lianes des zones sèches d'Afrique de l'Ouest* (Trees, bushes and creepers in dry areas of West Africa), which is the fruit of 15 years of field work, fills a gap by recording more than 360 species. The individual descriptions include an updated inventory of common uses of different parts of each plant, along with their traditional uses for pharmaceutical and dietary purposes, for both humans and animals. The 1 300 colour photographs and keys to identification, based on the flowers, leaves, fruits and prickles or thorns, make this work a field handbook that combines the accuracy of a plant guide with the simplicity of a catalogue. Forestry, agricultural and animal production specialists, teachers and students, researchers, institutional decision-makers, and interested amateurs now have a valuable reference work on the bushes and forest species of the region.



Underside
of Liconia alba
leaves

© D. Sabatier

Stratagèmes

Many people involved in development—mayors of rural communities, traditional doctors, industrialists, crop exporters, foresters, scientists, or heads of nongovernmental organizations—sometimes have to collaborate on drawing up local plant genetic resource management agreements, taking account of biological, economic and legal aspects. Stratagèmes, a computer-assisted role-playing game, puts players in this situation. Through different scenarios, players find out about legal devices such as patents and certificates of variety protection, and discover and test management and negotiating tools—forest management plans, logging permits, collection systems, etc. They share their knowledge and are made aware of the consequences of the decisions taken.

The simplified, structured image of the real world makes for easy learning and provides a forum for discussion between a range of players with varying skills and interests. There is a Malagasy version for direct use in the field, with local participants, or during training courses for environmental mediators or administrative staff; it teaches how to negotiate local management of genetic resources under agreements that transfer management responsibility to local communities.

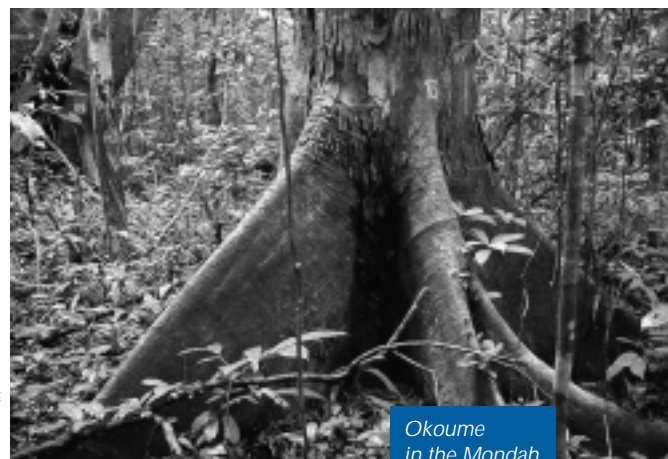
Stratagèmes was developed with the help of a team from CIRAD-TERA and in conjunction with Madagascar partners—FOFIFA, the University of Antananarivo and the Madagascar patents office—and with the support of the French genetic resources bureau, the Ministry of Foreign Affairs and the legal anthropology laboratory in Paris. Stratagèmes is jointly owned by CIRAD and FOFIFA.

Forest management in Gabon

By adopting a new forestry code, Gabon has opted for a logging policy that takes account of every role—social, ecological or economic—played by dense forests. SBL, a logging company in Lastourville, east-central Gabon, has embarked on a forestry management plan, the first step on the road to certification of its timber. The concession in question, which covers 300 000 hectares, is within the zone of influence of the trans-Gabon railway.

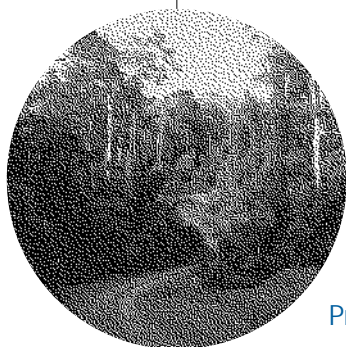
The main product is logs from the okoume tree (Gabonese mahogany), and a primary processing plant capable of handling various types of wood has been built in Lastourville. SBL, a French-backed family-owned company, has linked up with Thébault, the second largest plywood manufacturer in France, to build an okoume veneer factory in the industrial suburbs of Libreville. CIRAD is providing the company's forestry development service with technical backup. With a view to finding a compromise between the different interests at stake, it is also working to develop a wood resource inventory and technical, socio-economic and biological study methods, to support companies up to the final drafting of development plans. To optimize logging techniques and define a suitable industrial tool, a user-friendly software has

been coupled with a geographic information system to facilitate the queries and simulations required to establish medium- and long-term management strategies. Forests can thus be stratified by direct analysis of satellite images and geomorphological landscapes. Precise inventories of logging activities are also useful in helping to introduce low-impact techniques. This partnership, which is due to run until 2003, has enabled the rational consideration of biodiversity in a tropical forest environment. ■



Okoume
in the Mondah
Forest, Gabon

© D. Leuppe



Trees and plantations

Forest plantations, trees integrated into rural landscapes, and agroforestry initiatives can all play various roles and generate a wide range of products, from wood, fodder and gum arabica production to carbon sequestration and soil fertility restoration. One of the main challenges for the Trees and Plantations Programme is to take account of this versatility while reconciling the interests of the players involved, all the way from farmers to paper manufacturers, not forgetting the State and its administrative authorities.

Climate change

An agreement was reached at the climate talks held in Bonn in July 2001, on the means of applying the Kyoto protocol. The agreement, which was subsequently adjusted in Marrakech the following November, sets out the future of the CDM (clean development mechanism). The mechanism, which involves developing countries through industrial, energy or forestry projects, is a potential source of funding. In the forestry sector, it is now widely accepted that only planting or reforestation projects that respect biodiversity and the concept of

sustainable development will be eligible for such funding. Forest conservation or management projects are currently excluded from consideration as elements in the fight against climate change, but fuelwood projects will be considered. However, the only "additional" projects that will be chosen will be those that would not have happened without the CDM.

Several elements of the programme have raised questions linked to the methods of application of the CDM, in order to ensure that it really does contribute to sustainable development in developing countries. These issues are addressed through local studies, such as those on eucalyptus plantations in Congo, forest management in Chile, agroforestry practices in Costa Rica, or regional operations, such as the plan to provide training and institutional support in Central America.

Trees in savannas

The characteristics of the tree resource in the smallholder areas of northern Cameroon are changing, as a result of clearing for agriculture and felling for firewood, sometimes on a regional scale. On the one hand, the few remaining brushwood areas are shrinking, modifying animal production patterns and wood-gathering practices and, on the other, it is taking some time for trees to become a sustainable part of the agrarian landscape. How can rational exploitation of savannas to which access is totally uncontrolled be organized and, in parallel, how can trees be integrated into the agrarian landscape more effectively?

CIRAD has been working with IRAD, the Cameroonian development-oriented agricultural research organization, on adaptive studies and operations in PRASAC, the regional centre for development-oriented research on the savannas of Central Africa. Their diagnoses, which were based on surveys, inventories and maps, identified the main management issues and triggered local discussions on the future of the country's tree resource. The operations decided on during these exchanges were implemented in conjunction with the Cameroonian



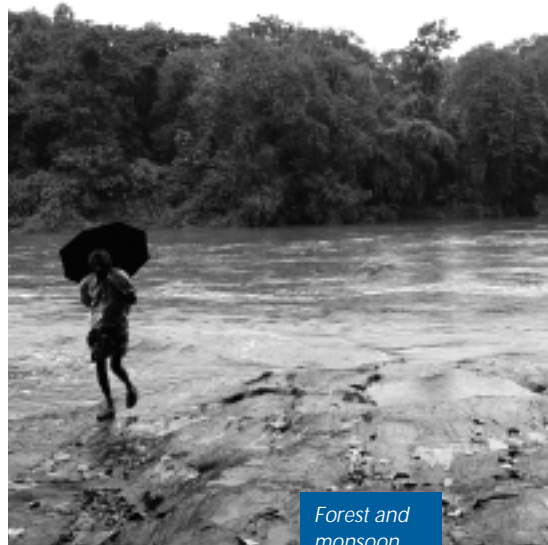
Azadirachta indica in a brick shelter to project against goats

© D. Depommier

Village in northern Cameroon



© J.-Y. Jamin



© E. Löffler

Forest and monsoon in India

Ministry for the Environment and Forestry, as regards community forest aspects, and with the smallholder development and land management project funded by AFD, the French development body. These operations, coupled with joint studies of rural forestry, have led to the definition of new lines of work centring on the issues surrounding usage rights of trees.

Calliandra in the humid tropics

The Mimosaceae *Calliandra calothyrsus* can serve many purposes, from fodder production to firewood, to shading and preventing erosion. A team of scientists from both industrialized and developing countries—Cameroon, Finland, France, Kenya, New Caledonia, and the United Kingdom—funded by the European Union, has studied the productivity of this legume crop, which originated in Central America and Mexico. Through symbiosis with a rhizobium found in the soil, *C. calothyrsus* forms nodules that fix atmospheric nitrogen, and phosphorus nutrition to the legume is improved by a mycorrhizal fungus.

How can fodder production in small farms in the humid tropics be improved? To identify the most effective mixed rhizobium-endomycorrhiza inoculum, a collection of strains was initially built up from nodule and soil samples. Nursery and greenhouse experiments were then conducted in Kenya, New Caledonia and Senegal. Following the project, a small production unit was created in Cameroon and pure cultures were deployed in Cameroon, Costa Rica and Kenya with a view to producing inoculums containing the two symbionts. Under a new project, intercropping trials of woody legumes and food crops are currently being carried out on smallholdings in Kenya and Zimbabwe.

Organic matter and planting

The effects of replanting savanna soil with eucalyptus trees intended for paper pulp production have been studied on the Congolese coast. The aim was to maintain more effectively the supply of minerals and production of trees in these plantings. Despite the impoverished soils, hybrid eucalyptus trees bred in Congo by a genetic improvement programme are producing large quantities of biomass as a result of intense nutrient recycling. However, nutrient biogeochemical cycles within the ecosystem have been significantly modified by reforestation of the savanna. The nitrogen cycle, which has been most severely affected, since burning is no longer practised and there is no longer symbiotic fixation, is the main factor limiting plantation growth.

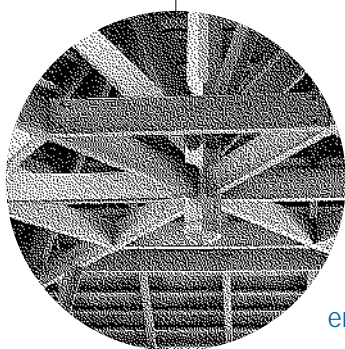
Studies of mineral inputs and outputs have shown that the high biomass production of the eucalyptus trees is achieved at the expense of the savanna's inherited nitrogen resource. The amounts of fertilizer required to maintain production have been determined. The results of this study and others by UR2PI, a research unit working on productivity in commercial plantings, were presented to researchers from nine tropical countries at a work-

shop organized by the Centre for International Forestry Research (CIFOR). They confirmed that it is crucial to conserve organic matter stocks in order to guarantee the organic and mineral status of soils and sustainable production in tropical forest plantings. ■



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Eucalyptus plot in Congo



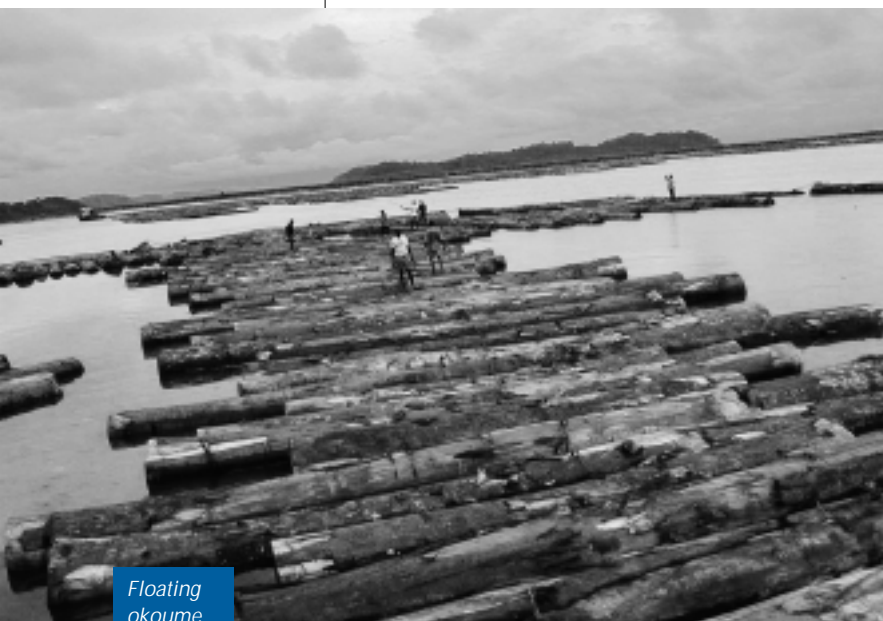
Forest products

In 2001, the Forest Products Programme stepped up its operations aimed at promoting the optimum, biodiversity-friendly use of wood from natural forests and at improving wood production in line with market demand. It also looked in detail at the life span of wood-based products, at more environmentally friendly techniques and procedures, and at possible uses

Sector competitiveness

Three complementary approaches have been proposed to improve the competitiveness of wood-based industries. The first is the development of decision support tools for logging and rational timber processing in managed forests. A thesis centring on a method for adding value to timber in a particular forest has been written. It recommends that the technical, economic and strategic aspects be taken into account for primary wood processing and be incorporated in five retroactive stages,

for the waste and byproducts generated by the sector. The economic aspects of the different production chains, market dynamics and the relative positioning of wood-based products have also been studied. These operations are contributing to the drive to promote effective use of forest and woody resources, under a range of international agreements.



Floating
okoume
logs

© D. Louppe

before identifying the priorities. A case study of a forest in Cameroon is verifying the appropriateness, advantages and disadvantages of this approach.

The second approach is countrywide, consisting in analysing the priorities for different products depending on the world market and checking the technical, economic and social strengths and weaknesses of the national processing and marketing sector. This approach can also be applied to individual forests, provided they are sufficiently large. As an example, the marketing of wood products manufactured in Brazil, in the heart of the Amazonian rainforest, has already been studied through a support mission.

The third approach consists in supplying companies with diagnoses and recommendations. It involves looking at whether the products manufactured satisfy market demand in terms of the type of wood, quality and quantities, or internal organizational aspects, or production factors such as what equipment, skills and training are required, and economic conditions in terms of production capacity, product quality and production costs. Several appraisal and technical training missions have already taken place at a sawmill in Mozambique.

Biofuels

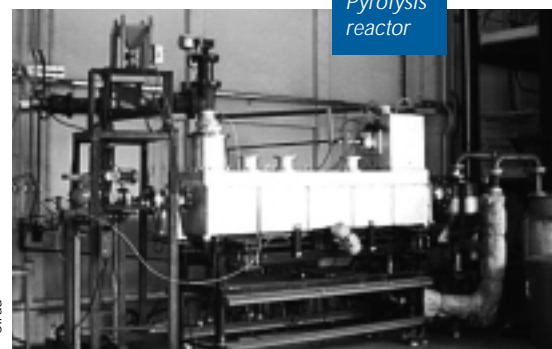
Converting organic waste into energy and producing electricity in small decentralized units is of interest to both developed and developing countries. CIRAD has coordinated the development of a system that produces gas from straw, pine bark

and rice chaff. The pilot-scale laboratory unit, with a biomass capacity of 50 kilos per hour, has been patented.

To ensure good yields, gas production means working at high temperatures (around 1 000 °C). However, during the conversion reaction, the straw produces a large amount of ash, which fuses and clogs the apparatus.

The innovative procedure developed by CIRAD and its partners breaks the operation down into three stages. The biomass is first converted into charcoal in a pyrolyzer, and the charcoal then converted into gas at moderate temperature in a reduction chamber. The residues—charcoal dust, smoke, ash—are recovered and treated in a combustion chamber at a much higher temperature (1 500 °C). This vitrifies the ash, and the gases produced (CO₂, H₂O) provide sufficient energy for the gasification reaction to generate gas (CO and H₂) with a high heating capacity. Once the gases have been washed, they are used in turbines or motors to produce electricity.

The project was conducted jointly with the Technological University of Compiègne, ITC, the French pipe and boiler manufacturer, and several Danish companies. It was funded by the European Union, the Danish Energy Agency, EDF, the French electricity company, and ADEME, the French environment and energy agency. In view of the promising results obtained, work is continuing under another European project.



Pyrolysis
reactor

© Cirad

Natural insecticides for termites

Using insecticides manufactured from wood processing byproducts can avoid the need to apply wood preservation products that are environmentally harmful. The wood preservation laboratory team has been applying its extensive experience of natural wood durability mechanisms to a study of two Lauraceae species from French Guiana that are naturally resistant to termite attacks: rosewood, *Aniba rosaedora*, and determa, *Ocotea rubra*.

Laboratory trials have proved that products extracted from the two species are effective against termites. The potential uses of these two extracts are such that research is continuing to assess their efficacy thresholds. This will eventually result in a wood protection product containing these active ingredients. The studies are being conducted jointly with the neurobiology laboratory of CNRS, the French national scientific research centre, in Tours, and a manufacturer, with funding from the ADEME wood commodity project. A patent has already been taken out on the use of wood waste or wood extracts as insecticides.

Cooperation between France and Australia

A research project on heat treatment of wood, involving the French national forestry college (ENGREF) forest products laboratory and CIRAD, now has Australian partners.

Heat treatment of wood has existed and been studied for some two decades, and ensures better dimensional stability and durability, albeit sometimes at the expense of mechanical properties such as shock resistance. However, the technological gap between optimum operating conditions and the industrial procedure has often not been grasped sufficiently. Fundamental studies are therefore still required to define the appropriate treatments clearly, particularly in terms of temperature and duration. This is the reason why the existing links with Australian research organizations have been strengthened and contact has



Window frame of poplar wood treated at 230°C

© P. Rousset



© D. Fourquet

Soldier termite

been established with specialist laboratories. To benefit from the progress made in digital simulation, a technical partnership has been established with the Queensland University of Technology, which specializes in modelling heat and mass transfers in porous media. The improvements made to the Transpore wood drying simulation software should make it possible to predict wood performance in extreme temperature conditions and overcome the difficulties of ensuring uniform treatment of a whole load of wood.

This cooperation agreement between France and Australia was sealed by the secondment of a French doctoral student to Australia for a year. An initial exchange of researchers between the Queensland Forest Research Institute and CIRAD is scheduled for 2002, with financial support from the French Embassy and the Australian Academy of Science. These exchanges of knowledge will be backed up by a range of new links with Australian industrial partners. ■



Territories, environment and people

Which research questions are relevant in today's context of economic liberalization, decentralization and international conventions? How can research incorporate the debates relating to the recognition of agriculture's multifunctionality and issues of sustainability, the fight against inequality and resource and environmental management?

How can answers be negotiated to address the territorial, economic, social and environmental challenges facing rural societies? What approaches and methods should be implemented to analyse, represent and model the different situations and to build information systems? How can the knowledge obtained improve the capacity of stakeholders to coordinate, negotiate and make decisions? How should this be organized by ourselves so that these questions can be understood, addressed and answered? Which CIRAD programmes and partners should be involved?

Since its creation three years ago, this department has debated these issues in order to come up with a common vision, to decide which field and scientific questions need to be addressed and to develop a strategy for implementing the results. The department's new project will be evaluated in April 2002 by an external commission of scientists and implemented in the second half of that year.



Family agriculture

Family agriculture has to deal with the consequences of economic liberalization and the emergence of new concerns about sustainable resource development and the quality of food products. It has to adapt to this situation despite the frequently inadequate economic and institutional environment, the lack of training available to farmers and the difficulties faced by rural

organizations. Based on the analysis of the diversity of local situations, the family agriculture programme is investing to promote support mechanisms and strengthen the capacities of stakeholders and their organizations.

Family agriculture in Brazil

The seminar "Family agriculture, comparison of the dynamics in Brazil and France" was organized in Recife, Brazil in November. The aim was to compare the agricultural trajectories in the two countries so that lessons could be drawn in order to define public policies. It was organized jointly by the Brazilian Ministry of Agrarian Development, INRA and CIRAD and brought together 60 people from Brazilian and French institutions. Despite the obvious differences in the processes involved in the evolution of family agriculture in the two countries, the participants underlined the similarities, particularly in terms of the problems of development and public action. The research on public intervention methods was confirmed as being legitimate. The value of research into techniques adapted to family agriculture—in order to add value to farm products and improve their quality—was also recognized. Other topics were identified: market organization, the recognition of agriculture's multiple functions, and regional development. Further investment in training human resources was also recommended.

CIRAD has published a book, *Paysans du sertão* that, contrary to widespread belief, shows the great diversity of family agriculture in the Nordeste region of Brazil and the importance of the corresponding technical, economic and social changes.

Appraisal of agriculture in Mayotte

In Mayotte, the research team for livelihood systems, organizations and local development started with an assessment and appraisal of local development in partnership with the Department of Agriculture and Forests and under the supervision of the prefecture. Five hundred farming households and 60 organizations were surveyed, the agricultural produce markets were studied and the agricultural dynamics were zoned.

Mayotte's agriculture is now experiencing tremendous problems and is poorly organized. It is



© J.-C. Legoupil

Small irrigated farm in Brazil

supported by technical services that have difficulty meeting the needs of rural people. Yet, the majority of households on the island are involved in agriculture. They are developing complex systems of activities with multiple objectives: food, income, preservation of a fragile natural environment and maintenance of an interdependent network. There is a very strong collective dynamic organized around neighbourhoods, villages or the region. This contrasts with the dysfunction of the agricultural organizations, which are boosted by the administration but only affect a minority of households.

With this assessment, it is possible to refocus the agricultural debate and propose a shift from a sectorial perspective to one of local development by recognizing that agriculture does have multiple functions.

Farmer and rural organizations

The World Bank—which is reviewing its rural development strategy in order to combat poverty more effectively—commissioned CIRAD and the Overseas Development Institute (ODI) in the United Kingdom to publish a reference text on the role of farmer and rural organizations in the context of globalization. Propositions were presented and discussed in Washington at an annual meeting of teams from the World Bank working in rural development (Rural Week). This report is being published by the World Bank.

The study underlines the central role that farmer organizations have to play in drawing up any rural development strategies, and the importance of discussion and negotiation. CIRAD proposes that these organizations be included in discussions and associated at the different stages of the projects, from identification to evaluation, so that they can be involved in the World Bank's action programmes. This presupposes that farmer organizations have access to new funds for training so that they can improve their skills and better understand the changes affecting family agriculture in order to strengthen their strategic positioning. CIRAD proposes creating a resource centre within the World Bank that would provide support to project supervisors and World Bank representatives in the countries where it operates.



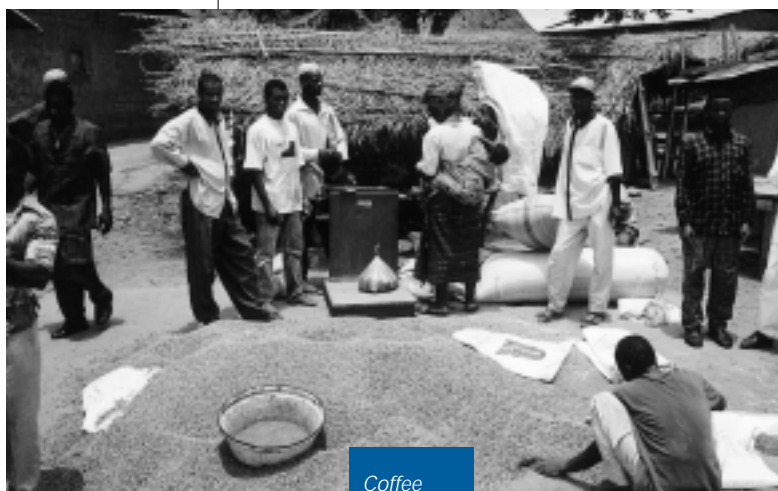
© M. Bina

Farmer
in Mayotte

The African Farmer University

The African Farmer University is an international training course for leaders of farmer and professional organizations. It is partly organized around the participants' professional activities in order to strengthen their skills and their influence when negotiating. It was set up by a small-scale agriculture and modernization network that is based in Cameroon. It is supported by the Charles Léopold Meyer Foundation and receives funding from the French Ministry of Foreign Affairs. CIRAD and the Centre International pour l'Éducation Permanente et l'Aménagement Concerté (CIEPAC) were involved in designing the project and defining the course content.

The training course consists of six modules and runs for two years. Participants are invited to reconstruct their experience and that of their organization in a historical context. The first module was in Senegal, in February, and focused on the evolution of local societies in national and international contexts. Twenty-five leaders of farmer and professional organizations in 12 countries took part. The second module, on the new economic environment of agriculture, took place in Cameroon in May. The third, on institutional reorganization, took place in Benin in September. The last three modules, which will take place in 2002, will look at the role of organizations in a world of change, the objectives of and approaches to strategic planning, programme planning, and negotiation. ■



Coffee
market
in forest
Guinea

© B. Goud



Land and resources

The land and resources programme analyses the management of rural areas and the stakeholder strategies that affect the production, the mobilization of resources and the organization of these areas. It represents and models obtained knowledge and information and develops approaches to support decision-making for rural development managers.

Multi-agent systems

Following courses organized in Thailand (1999 and 2001) and in the Philippines (2000), several Thai universities and CIRAD are jointly organizing a new training course on multi-agent systems for integrated natural resource management and social sciences. The project is funded by the European Union. It started in August and should continue until the end of 2003.

Researchers and teachers from CIRAD, CEMAGREF, IRRI, French and European universities (Paris VI and Aix-Marseille in France, Manchester and Surrey in the UK, Amsterdam and Wageningen in the Netherlands, and Neuchâtel in Switzerland), provide courses in computing, social sciences and natural resource management. These courses alternate between three Thai universities: Chulalongkorn (Bangkok), Chiang Mai and Khon Kaen. The objective is to create a core of researchers and post-graduate students who attend the entire course and who make up a network that will develop different applications for natural and renewable resource management.

Irrigation schemes in South Africa

The irrigation schemes in the former Bantustan homelands of South Africa are now experiencing serious problems: deteriorating infrastructure; low yields; poor institutional framework; lack of support and access to services. The government would like to rehabilitate these areas and transfer their management to their users.

In order to help the decision-makers organize these operations, a team from CIRAD and Pretoria University are proposing an action-research approach that aims to model the different elements that affect the economic viability of the transferred areas. Scenarios are then evaluated with technical stakeholders and local politicians.

The approach was first tested in two irrigation schemes in the northern province. A model called "Smile" was developed which takes into account the costs, land distribution, cropping systems,

farmer strategies and possible options for fixing a scale of water rates.

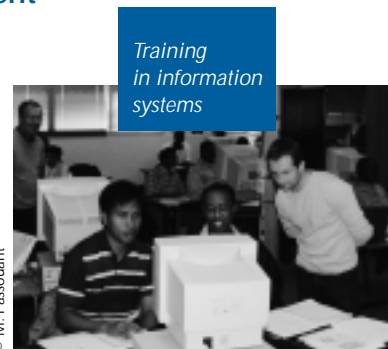
Scenarios were tested and they show that: the current situation is unviable; costs are difficult to reduce; the main problem is the large number of inactive occupants who are reluctant to pay water rates; and low productivity limits the farmers' capacity to pay. The scenarios demonstrate that it is possible to improve the situation by clarifying the issue of land rights in order to reduce the number of inactive occupants or by training farmers to develop their cropping systems. The approach will be included in the national Department of Agriculture's recommendations to the provincial departments. A software package is now being developed.

Training for rural development

Nineteen researchers and engineers from Mali, Madagascar, Senegal, Cameroon, Benin and Vietnam took part in a training course on information systems, particularly geographic information systems, for rural development. The course was organized

with the forestry department and took place in November in Montpellier. The trainees learned the methodological and operational basics required for building and implementing an information system linked to existing databases.

The objective of the course is to provide the knowledge and practices to describe, represent and analyse the thematic and geographic dimensions of development processes. The course falls within the scope of the department's cooperation projects: sorghum biodiversity, improving cultivation systems in cotton-growing areas, and information systems at the Office du Niger in Mali. As



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a result, the links between CIRAD and the institutions that participated have been strengthened. Eighteen trainees from Brazil, France, Madagascar, Portugal and Vietnam participated in a workshop on natural resource and environmental economics that was held in Montpellier in December. The participants learned about the concepts and theoretical foundations of environmental economics and were shown negotiation and decision-making support tools—modelling and evaluation methods—for environmental and resource management policies. A role-playing exercise, case studies and practical work were used to demonstrate to the participants how to apply the theories and methods to real situations.

Information systems

Information management is essential for the administration of irrigation schemes and for helping managers consider the strategic implications and define new methods of organization as well as new relationships with the users.

Since 1998, CIRAD has been working with the Office du Niger in Mali to set up an information system for monitoring the maintenance of hydraulic networks. A software package named “Simon”, for computerized programme planning and monitoring, was developed with the users’ participation. After a development and testing

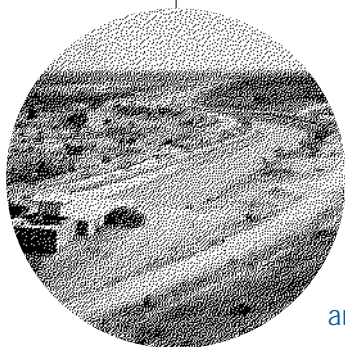


© E. Daou

Rice planting
in the Office
du Niger zone,
Mali

phase, the software application was set up. A considerable amount of effort went into training software managers and users.

The Office du Niger’s decentralized services have been using the software since October 2000. The Office now has computerized data for almost its entire network of primary and secondary channels. In Mali’s N’Débougou zone, all the software’s functions have been used, and a provisional maintenance programme set up and reconciled with the work actually achieved. After a cartographic reference collection was compiled, a geographic information system was combined with the data base to represent not only the irrigation network but also the maintenance that was planned and actually carried out. ■



Savannas and irrigated systems

The savannas and irrigated systems programme implements multi-disciplinary approaches at different levels—regions, villages, irrigated areas and farms—to further understanding of how these complex areas function. It develops decision and negotiation support tools for management and decision-making bodies, encourages stakeholder discussion forums and the drafting of development plans on different scales.

Collective irrigation schemes

Since 1999, the joint programme for irrigated systems has been conducting research into agricultural water with CEMAGREF, CIRAD and IRD. In January, it organized a seminar in Montpellier on “The management of irrigation schemes at the dawn of the 21st century: issues, problems, approaches”, which was attended by 130 participants. Research conducted in Brazil, Ecuador,

France, Mali, Morocco, Senegal, Sri Lanka and Tunisia was presented. The debates underlined the complexity and diversity of irrigated systems and the value of using approaches that encourage farmer participation and process modelling.

The results of research conducted in the framework of this programme were presented in December at a seminar in Brazil organized by the

São Francisco valley development company, CODEVASF, EMBRAPA and CIRAD, and 150 people attended.

Although the management of irrigation schemes was transferred to farmer organizations more than 10 years ago, questions about the real participation of these organizations and the State's role, in terms of infrastructure and agricultural policy, remain unanswered. The importance of producing and sharing information was underlined: at the farm level to improve results; at district level to manage water distribution, maintenance, the water rates policy and to support technical assistance; at the level of CODEVASF's administrative units in order to monitor and evaluate the performance of publicly owned irrigation schemes.

Monitoring cotton sectors

A network for monitoring the cotton sectors in Africa, RESOCOT, was set up in order to determine the performance of the different methods of organization, to help operators redefine their role in the sector and to help decision-makers find a balance between competition and regulation. The network covers six countries: Benin, Burkina, Cameroon, Côte d'Ivoire, Ghana and Mali. It involves researchers in these countries, the Imperial College of Wye in the United Kingdom and the Centre for Development Research in Denmark. It is funded by the French and Dutch Ministries of Cooperation and is coordinated by CIRAD's programmes on savannas and irrigated systems, and on cotton.

The 18-month pilot phase began in February. A common methodological framework was adopted to describe the organization of the cotton sector and to determine performance, in terms of poverty reduction, environmental sustainability and international competitiveness. This was

Cotton market
in Cameroon



© M. Braud



© J.-C. Legoupil

Irrigation
scheme
in Nigeria

helped by indicators taken from the neo-institutional economic theory. Launching workshops were organized in all six countries to inform sector stakeholders of the approach and the need for their participation.

Information obtained was organized into a data base designed to facilitate the use of information and the drafting of reports. Workshops will take place in each country to release results locally. A similar mechanism links four English-speaking countries thanks to funding from British donors.

Management advice for farmers

In Benin, in November, 45 practitioners attended a workshop on management advice for family farmers. They included leaders from farmer organizations, development workers, management advisors, researchers, and experts. The workshop was jointly organized by CIRAD, IRAM, Inter-Réseaux, a forum for discussion that stems from the merging of several thematic rural development networks, and the Ambra consulting firm. Twelve teams from the field presented their experiences in Benin, Burkina, Cameroon, Côte d'Ivoire, Chad and Mali.

The conclusions reached included options for improving the current mechanisms and for launching innovative methods. Primarily, it was recommended that counselling tools and methods should be adapted to socio-economic conditions and should meet farmers' expectations, particularly those who are illiterate and who manage small farms. It was suggested that these

mechanisms will only continue if farmers' organizations and inter-professional structures are involved in managing them, and that there should be more collaboration with other agricultural support services. A final recommendation was that if support services, particularly farmer counselling, are to develop, then certain issues need to be addressed, eg agricultural policies, the State's role in training farmers and financing support mechanisms, as well as the impact that these mechanisms have on social disparity.

Savannas of Central Africa

PRASAC, the regional centre for applied research for the development of savannas in Central Africa, brings together agronomic research organizations from Cameroon, the Central African Republic and Chad (IRAD, ICRA, ITRAD and LRVZ), which are allied with scientific partners from the North (CIRAD, IRD and Leyde University). In 2001, the centre concentrated on making the most of its knowledge and experience, publishing a book, "Changes in southern Chad: from cotton fields to the sirens of black gold" (Le sud du Tchad en mutation : Des champs de coton aux sirènes de l'or noir). The publication presents a dynamic picture of Chad's Sudanian zone and examines the factors of change in this region including the outlook for the privatization of the cotton sector, new road constructions and the promise of petroleum.

The book won the Albert Bernard prize from the French Overseas Academy of Science.

In addition, an agricultural atlas of the savannas of Central Africa was published and an interactive electronic version is being produced in collaboration with CIRAD's agronomy programme. Fact sheets were compiled to distribute widely research results that relate to food technology. They cover three main areas: marketing methods—knowing your market, conducting a marketing test, organizing farmers, exchanging know-how; product processing—fruit juice, powdered onions, cassava starch, yam fritters; sectors—dairy production and dried tomatoes. Also, the cotton programme is working on the completion of "Simbad", a model that simulates insect damage to cotton. ■



© G. Faure

Management
support debriefing



Humid and insular tropics

The humid and insular tropics programme is involved in the design and promotion of inter- and multi-disciplinary research projects for regional development. It encourages CIRAD and its partners to combine and apply their scientific expertise to the use of ecosystems where perennial crops are predominant and those, such as in the Amazon, where livestock production has a privileged position. Its research is also used by those responsible for regional planning.

The Amazon

Current land use in the Amazon region is the outcome of a complex historical background, heterogeneous government strategies, and erratic economic cycles linked successively to rubber, ore, large development projects designed to attract private investors, and recent strategies that aim to integrate the region into the world economy.

A team of researchers from CIRAD and the Brazilian Ministry of the Environment analysed the diverse factors and social stakeholders linked to each form of land use in the Amazon. The analysis was published in a book, *Diagnóstico dos formatos de ocupação do espaço amazônico* ("A diagnosis of forms of land use in the Amazon

region"). Four chapters discuss in detail: regional dynamics and methods of land use; the socio-economic and environmental problems; the impact of State action; and conflicts provoked by land appropriation and natural resource use.

The analysis shows that most of the problems in the region stem from the implementation of disparate sectorial policies which do not take account of how the Amazonian environment functions or of the region's complexity. The organization of production is gradually improving but it is still poorly structured and inadequate. It has difficulty promoting sustainable regional development, providing an adequate standard of living for local populations, and is harmful to the preservation of natural resources.

Agricultural zoning in Guinea

With scientific support from CIRAD and funding from the French Ministry of Foreign Affairs, the Agronomic Research Institute in Guinea has zoned the four main natural regions in the country: maritime Guinea, central Guinea, upper Guinea and forest Guinea. The results have been distributed in a series of technical fact sheets. A fact sheet on each natural region includes a map of the homogenous agro-ecological zones, their physical environment, production systems and agropastoral problems. It is accompanied by thematic cards and an explanation of the method used and the results obtained.

"Study villages" were set up in each region based on this zoning. They form the basis of a network of experimental farmers on whose farms researchers set up a participative approach to identify needs, test innovations, evaluate the adoption of techniques, and measure their impact on farms. Farmers and the development organizations

involved in the village are working together to plan the programme of activities and release results. The results of this research will be used to organize sessions with new regional research-development committees and to improve the programming of thematic research.



Lentil fields
in Cilaos

© S. Aubert

Land use contracts

In Réunion, the Cilaos wine growers' cooperative and an association for the promotion of rural areas have set up a project, under the auspices of the Commission for Highland Development, that involves the design of land use contracts in the Cirque de Cilaos zone. CIRAD was asked to provide support in the form of methods and tools for compiling a regional appraisal that brings together all the stakeholders involved. The appraisal focuses on the conditions necessary for maintaining good quality agriculture, its impact on tourism and its environmental dimension. Forecasting scenarios to show the evolution of communal land, particularly as a result of urban development, were simulated on the basis of an analysis of farmer strategies, zoning according to stakeholders and a land study.

The project coordinators and CIRAD drew up the action plan for the land use contract and coordinated the two seminars which involved 40 partners, local stakeholders, technical organizations and associations, institutional stakeholders and elected representatives. This work made it possible to test an innovative method of organization and appraisal prior to the establishment of a land use contract. The approach will soon be monitored and evaluated so that useful information can be extracted for the benefit of other projects in Réunion. ■



Farmers
involved in trials
in N'Zérékoré,
Guinea

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Advanced methods for innovation in science

In 2001, CIRAD's Department of Advanced Methods for Innovation in Science (AMIS) not only continued its scientific pursuits, but also developed and disseminated the tools, software, models and methods that are the leading elements of its mandate.

Important research themes were developed in collaboration with stakeholders in developing countries, nurtured by ambitious scientific programming, tapping results obtained with partners from these countries, and through training initiatives. Renewed alliances came about as a result of fostering the development of collaborative research poles (clusters of institutions) in Senegal, Brazil and Vietnam. Excellent results were obtained in the fifth European Union Framework for Programme of Research and Technological Development.

The department is also forming joint research units to offer courses in several graduate schools, especially in Montpellier (France), Réunion and Nogent-sur-Marne (France), and distance training sessions through the e-campus of the Jardin tropical de Paris.

CIRAD scientists have been posted at INRIA, the French informatics and automation research institute, to collaborate closely on specific projects. It is involved in the Baillarguet crop protection initiative, with its entomology research team working hand-in-hand with several partners in France—including INRA, the national agricultural research institute, IRD, the development research institute, ENSAM, the Montpellier-based school of higher education in agriculture—and abroad, especially the Commonwealth Scientific Industrial Research Organization (CSIRO). In Réunion, the year was highlighted by the creation of a crop protection pole and an agrifood pole. In New Caledonia, there are prospects for collaboration to create a pilot agrifood pole to be launched by local authorities.

All job positions that had been opened in the wake of CIRAD's new strategic plan were filled. The new members of staff have enabled the department to expand its field activities in developing countries, while underpinning new dynamic research initiatives.

The department also continued its work to promote quality, especially concerning project development and management, from scheduling research initiatives to processing the resulting data, while hosting and training scientists from other partner institutions, and enhancing research data reliability and follow-up.



Agrifood systems

Global food demand is rising and consumers are increasingly concerned about food quality. Tropical produce has to be less expensive, safer and of better quality, with efficient rural and urban market distribution systems, in order to enable producers to gain a competitive edge on domestic and world markets. The agrifood systems programme is developing tools and methods

to enhance the value of agricultural produce, perfecting processing techniques and equipment, and improving product quality. It grants commercial enterprises access to its technological innovations, while collaborating with them to develop systems that assure quality. In addition, the programme is focusing on food-related socioeconomics, especially the analysis of food consumption patterns.

Food security management

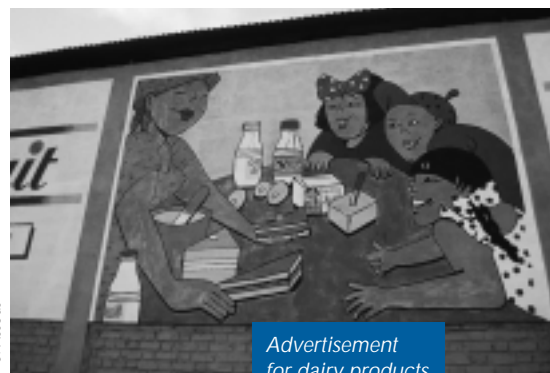
Meeting consumer requirements is a new challenge for the agrifood sector in developing countries. First, European Union regulations are becoming stricter with respect to the sanitary status and origin of food products, thus seriously restricting developing countries' access to markets in developed countries, further marginalizing developing-country producers and aggravating the socioeconomic impact in their countries. Second, urban and rural consumers in developing countries are now more concerned about food product quality and safety.

Studies on different topics—poultry, traditional cheese, camel milk, cereal and yam production—conducted by researchers in various disciplines, highlighted that the agrifood sector has a key role to play in controlling food quality. It was also found that social awareness of the importance of food quality should be boosted with the support of various stakeholders. CIRAD has been gradually developing new food quality and security management strategies on the basis of this multidisciplinary approach that combines socio-economic planning, risk awareness, consumer risk management, and quality assurance tools tailored to local conditions.

Plant enzymes

Trials were carried out in collaboration with CIRAD-FIhor technological specialists on the biocatalytic activity of some agricultural by-products, with the aim of making more effective use of agricultural raw materials. These studies focused specifically on papain, a lipase constituent of papaya latex, and bromelain, an enzyme from pineapple rachis endowed with lipase and acyl-transferase qualities.

The papain investigations clearly revealed that dried and ground papaya latex has high acyl-transferase activity, in addition to its well-known proteolytic activity. This hardy catalyzer, which is stable and inexpensive compared to commer-



Advertisement
for dairy products
in Madagascar

cial microbial enzymes, is an invaluable agent. It also has a substantial industrial potential, as demonstrated in studies on medium-chain triacylglycerols to be used in formulating baby food. Latex is an enzyme cocktail, so the activities of other interesting constituent enzymes, eg beta-glucosidases, polyphenol oxydases, etc., could ultimately be detected.

In contrast, the bromelain preparations analysed showed very low lipolytic activity and no synthesis activity. Thus not all plant biomass with protease activity can be expected to have lipase activity. The enzymes whose activities were analysed could now be implemented for food processing applications. ■



Agronomy

Agronomists working on sustainable, environment-friendly farming production systems and management of their natural resource base require an advanced scientific support structure. The agronomy programme's task is to provide CIRAD teams and their R&D partners with this scientific support, along with complementary expertise and adapted research tools. The programme objectives

are: to conduct baseline research in tropical agriculture fields requiring specially designed or adjusted methods and tools; to develop diagnostic tools and decision-making aids; to provide support for partner organizations using these tools and aids; and to train research scientists.

Interactive numerical atlas

High software and equipment costs, and long training times, can hamper the adoption of geographical information systems (GIS). The programme has attempted to meet its partners' needs by developing an inexpensive user-friendly software package. It is designed to pool data from different projects, including text, images, maps, data tables, remote-sensing data, etc. It can also perform spatial analyses through GIS functions integrated in the software.

This software package can be readily used by non-experts to present project results in a much clearer way than is possible in a conventional hardcopy report or atlas. Its runtime component, or "engine", is designed to host various databases with minimal modification. Its toolbox-type interface can be reused for different project applications, and certain functions can also be added or modified.

Water stress determination

Plant covers require adequate water supply to function properly. For more than 20 years, ground temperature, measured at the soil surface or via remote sensing, has been the main parameter used to determine soil-moisture status. However, water stress indicators calculated on the basis of these measurements are not very reliable

when patches of bare ground are within the range of the sensor.

CIRAD-Amis scientists overcame this constraint by measuring directional ground temperature in a row cropped cotton field by two methods: in-situ experiments conducted in Montpellier, and using the Thermo (AMAP) 3-D energy balance model, which takes into account cotton plant architecture, soil cover and

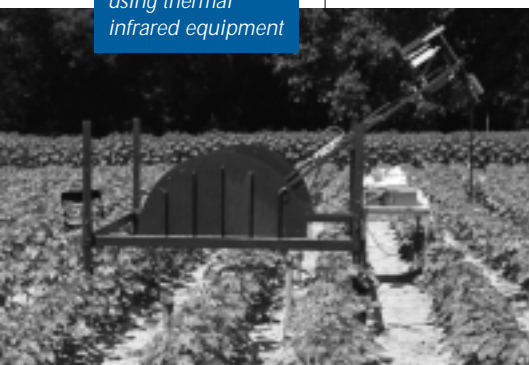
physical phenomena. The model's simulations could help to design more reliable blanket methods for determining water stress indices. Thermo can also perform detailed analyses on a broad range of problems concerning plant water use, and could also be useful for irrigation management.

Sorghum photoperiodism

Until recently, breeders have sought to improve sorghum by overcoming its photoperiod limitations. The aim is now to develop highly photoperiodic varieties with a plant architecture that will guarantee a high harvest index and yield, thus enabling farmers to adjust their sowing dates according to climatic conditions. What would the structural features of such a plant be?

CIRAD, in collaboration with the International Crops Research Institute for the Semi-Arid Tropics (ICRISAT) and IER, the Malian rural economics institute, carried out a comparative phenological study on sorghum in the field, in Mali, and in a phototron in Montpellier. The combined experimental and simulation results highlighted that, in addition to reacting to absolute daylength, sorghum plants are also very sensitive to relative between-day variations in daylength—even when these variations are as small as a minute. The study of this unexpected phenological characteristic, which clarifies some previously unexplained field phenomena, has just begun. The initial observations have already raised the question as to whether this phenomenon is only specific to sorghum or latent in all crop species.

Monitoring cotton plant water status using thermal infrared equipment

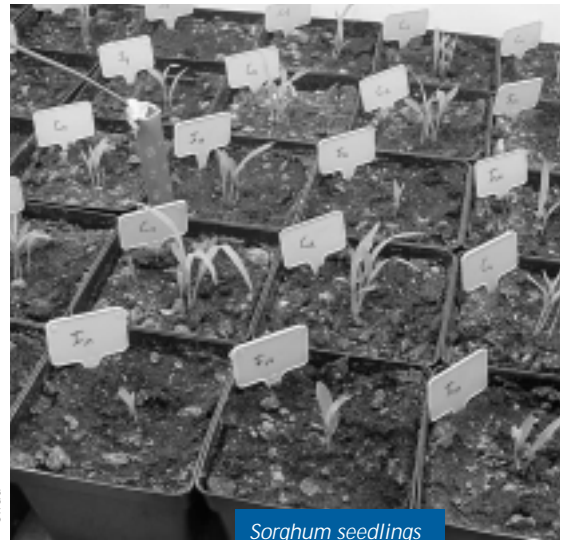


Fertilization management

A clear overall understanding of soil functioning and crop traits is needed to ensure efficient fertilization management, which often involves striking a balance between sometimes contradictory production, economic and environmental objectives.

In southern Mali, a toposequence study on an annual crop system (millet, sorghum and maize) in a stand of shea-nut trees revealed that the characteristics of the stand (eg density) and trees (eg trunk diameter and canopy size) differed according to their position in the toposequence. Soil fertility was found to be higher midway up slopes than at the bottom, where the quantity of soil-borne nitrogen was 60 kg/ha under tree cover and 30 kg/ha beyond the canopy.

In Cameroon and Colombia, as part of an EU-funded project, maize varieties tolerant of or susceptible to soil acidity were tested with different blends of fertilizing elements, including chemical phosphate, organic phosphate (dung), lime, and crop residue. Susceptible varieties only responded to a blend of lime crop residue and phosphates, while tolerant varieties flourished



Sorghum seedlings
in a phototron unit

© Cirad

after treatments with any of the blends. The data gathered in these fertilization tests will help to develop efficient fertilization management strategies. ■



Plant biotechnologies and genetic resources

CIRAD's plant biotechnologies and genetic resources programme supports plant breeding by developing new techniques to improve genetic resource management, to facilitate the development and identification of improved genotypes with high quality and tolerance to biotic and abiotic stresses, and to accelerate the dissemination of improved varieties. The team conducts specific projects to develop new biological resources, and is increasingly involved in offering biotechnology training courses.

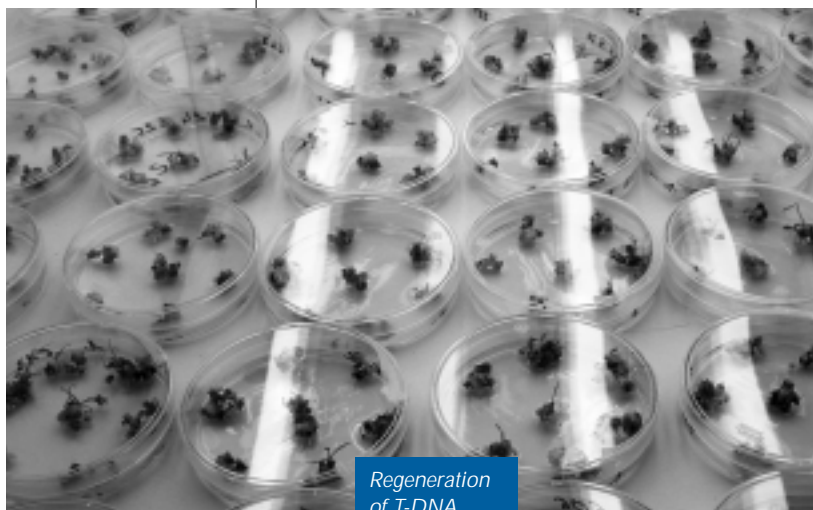
Large-scale genomics research

CIRAD hosts two platforms of the Montpellier Génopole. The automated systems platform was founded in 2000 to fulfil the needs of genomics projects. It involves five robotic systems that are used to develop genomic libraries (clone picking, clone rearraying, library duplication), make high-density filters, extract genomic and plasmid DNA, and perform polymerase chain reaction (PCR) analyses. The gene-typing platform was launched in 2001 and is equipped with a robotic PCR analysis system (384 wells), thermocyclers

(96 and 384 wells) and two automatic DNA sequencers that are used solely for gene typing (with microsatellites, amplified fragment length polymorphism [AFLP], etc.).

All Génopole laboratory researchers have access to these platforms, and the equipment was funded by Génopole and through other regional, institutional and contractual sources. Operational

aspects are managed by CIRAD and financed by the different laboratory users. These advanced technological tools should promote large-scale biological studies by state-run and private research institutes and establish Génopole's reputation as a forerunner in different industrial and biotechnology fields.



Regeneration
of T-DNA
insertion lines

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Functional genomics

Functional genomics research is aimed at unravelling the function of genes, how they are regulated, and their interactions within the genome and within biological systems. This research involves rapid analysis of transcription products and translation of millions of genes. These analyses are performed stepwise—building libraries of expressed sequences, comparative analysis of the expression profiles of these sequences under contrasting conditions (in terms of the variety, organ, stress, growth stage, etc.). This helps to detect differentially regulated candidate genes and interactions between genes, and then to confirm their function by locating their position on the genome (colocalisation with quantitative trait loci [QTL]), by their inactivation (insert mutant lines), or by their over-expression in plants.

In addition to these stepwise analyses, systematic studies are undertaken on interactions between proteins or protein regulation sequences using simple and double yeast hybrid systems to detect gene regulation factors and map their relational networks.

CIRAD is building libraries of insertion sequences and developing recombinant rice lines which—with tools derived from the Génopole initiative—will be used to pinpoint genes involved in complex traits of interest, eg plant architecture and tolerance of abiotic constraints.

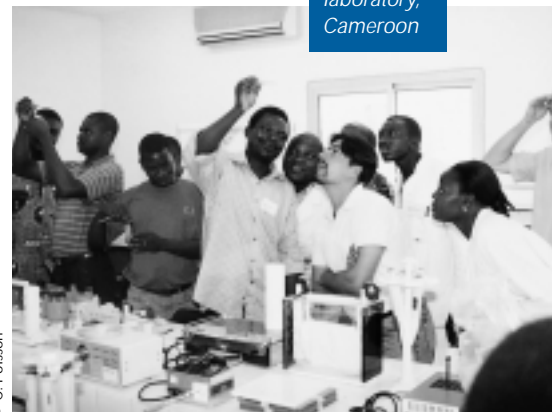
Training

CIRAD has coordinated training seminars in Abidjan (Côte d'Ivoire) and Njombé (Cameroon) within the framework of a biotechnological training initiative to benefit its developing-country partners. These sessions focused on the use of molecular markers in plant breeding programmes, especially for rice improvement in Côte d'Ivoire and banana and plantain improvement in Cameroon. Some 20 African scientists and academic researchers—breeders and phytopathologists—participated in each seminar, which was coordinated by a team of CIRAD scientists and academic researchers from the host countries.

The success of these training courses could be explained by the fact that they addressed actual concerns of breeders in the field and that there was close collaboration between the teachers and trainees. Trainees collaborated in planning the courses in order to tailor them to their specific needs.

Practical laboratory training in partner agricultural research centres was a keystone of these sessions. Trainees were supervised in hands-on techniques to extract DNA from plant material collected locally, and were thus able to assess the genetic diversity detected. This experience also demonstrated that these local laboratories, most of which had just been built and equipped, were fully operational for the application of these new advanced tools. ■

Trainees at
the Njombé
laboratory,
Cameroon



© C. Poisson



Economics, politics and markets

There is a widening gap between countries with respect to their market competitiveness and natural resource assets. Market liberalization is creating a range of socioeconomic problems associated with economic adjustment and policy making. In some cases, adjustment requires intervention by government or local bodies to improve production and trade efficiency

and equity. The economics, politics and markets programme aims to identify these situations as a basis for developing an economic scenario that reflects stakeholders' needs and aspirations. It also aims to outline policy instruments or market interventions adapted to the economic needs of developing countries, while striving to detect areas of market dysfunction. Tools and methods have been designed to probe and clarify specific situations, to represent them objectively and to assess potential impacts.

European Union and ACP states

The relationship between farmers of the European Union (EU) and of African, Caribbean, and Pacific states (ACP) is both competitive and complementary. A study was conducted to determine areas in which these farmers have a shared interest and others in which they are competing. The aim was to highlight the challenges to cooperation between these two entities and to convince policy makers of the potential benefits of establishing partnerships within the framework of world trade negotiations.

The results of this study were published in a document that consists of discussion notes on the Lomé Convention, the World Trade Organization (WTO) and the Common Agricultural Policy (CAP), macroeconomic context analysis concerning trade between EU and ACP countries, and 15 product fact sheets with corresponding maps. It concludes with an overview of sub-regional problems, highlighting the extent of competition between EU and ACP farmers, and suggests potential alliance strategies within international bodies.

This document was presented to the French Ministry of Agriculture and Fisheries and the European Commission (EC), and should become a useful negotiation support tool. It could also be useful for formulating "likely scenarios" for subsequent assessment by model simulations.

Greenhouse gas

The programme participated, along with some ten other EU research centres, in a project on strategies to control greenhouse gas emission. The specific objective was to draw up climate policy analysis scenarios. In association with RIVM, the Dutch institute for public health and the environment, CIRAD focused on agricultural techniques that could reduce agricultural gas emissions and on quantifying marginal deduction costs. A database was built to host data compiled in previously published studies and collected by



Sorghum fields
in Africa

© J. Chantreau

experts on a systematic basis. A simple economic model was developed to perform climate policy simulations on a per-country or regional scale. This model can be used to analyse the potential impact of carbon emission taxing on emission levels and on technical choices in the agricultural sector.

Training

In view of current international trade liberalization and state divestiture trends, government intervention priorities in the agricultural sector need to be based on solid concepts, focused on

market and government failure hypotheses—ie government intervention is collectively beneficial in areas where the government and market do not ensure sufficient stakeholder coordination.

A discussion group was formed with 19 specialists from 11 western and central African countries to find effective ways of drawing up agricultural policies. The chief goal was to encourage members of this African trainers' group to strengthen their skills in this field and to provide training

for those involved in agricultural policy making: senior administrative staff, NGO coordinators, and heads of local governments and farmers' associations.

The discussion focused on steps required to formulate a well-founded agricultural policy. It involved three one-week workshops held at two-month intervals. Participants returned to their separate countries

between each workshop to directly apply their newly acquired skills in grassroots situations. A training handbook was compiled after the workshops and given to each group member to keep as a methodological guide. Some of these trained people have already been asked to apply the method in a consultative or training context.

The African training team



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Multifunctional agriculture

Agriculture can be defined as multifunctional when non-marketed goods or services are produced in addition to its primary role of producing food and fibre, eg environmental goods, unsalaried family jobs, landscape maintenance, etc. By this definition, government intervention in some circumstances would be warranted to shoulder the cost of production of these goods or services.

There is currently heated WTO debate on whether or not government intervention should be sanctioned in a multifunctionality setting, and if so on what terms. Can one country safeguard its jobs and environment without disadvantaging its trading partners? Can a country fully tap the multifunctionality of its agriculture under current WTO cooperation regulations? If not, what trade cooperation criteria modifications could be made?

The programme addressed these questions as part of a study conducted by the French Ministry of Agriculture. Surprisingly, it was found that when multifunctionality is effective, protectionism, which is generally destructive of welfare in a standard economic setting, can boost welfare to a higher level than is possible under free trade conditions. It is thus essential to recompense those who lose out under a protectionist umbrella by granting them "international compensation", paid out of tariff revenues and out of subsidies designated for the protectionist country. ■



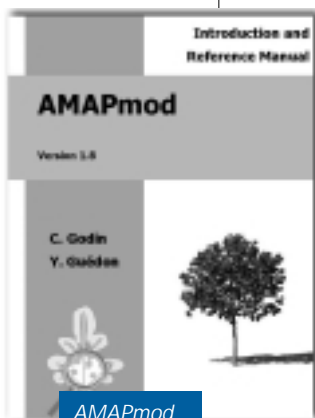
Plant modelling

The plant modelling programme is a joint research unit that pools researchers from the French scientific research centres (CIRAD, CNRS, EPHE, INRA, IRD), the French schools of higher education, and the University of Sciences (Montpellier II). The unit merges different disciplines—botany, ecology, applied mathematics and computer science—to develop generic methods for measuring,

analysing and modelling architecture, growth, physiology and productivity of plants and stands. The methods and tools designed by the unit are made available to scientists it hosts and trains, and to students participating in its training courses. Commercial software is sometimes a profitable spinoff from this research.

Bioinformatics

Since the early 1990s, the plant modelling programme has been developing a sequence analysis method hinged on two themes: analysis of series of homogeneous areas in sequences, chiefly involving hidden Markov models and especially Markov half-chains; and analysis of repeat



AMAPmod
software
handbook

motifs in stationary sequences, based on seeking local regularities rather than on overall sequence structure. The main statistical models used are variable Markov chains and state clustering models, which are also applied in DNA sequence analysis. Sequence analysis is currently used mainly for cognitive and applied analysis of branching structures.

By a similar strategy, CIRAD decided to develop a consistent hierarchically based analysis procedure, including exploratory analysis, statistical modelling and comparison methods. Hierarchical comparison methods

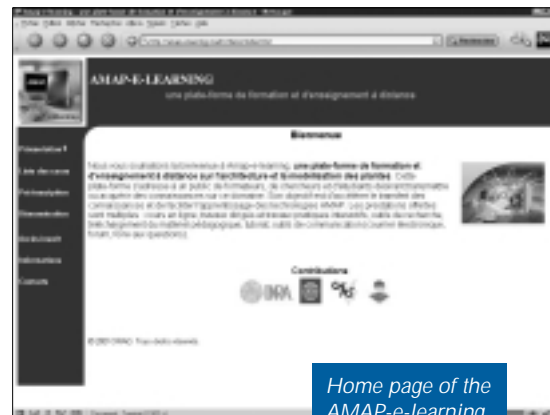
were developed in the first phase. Statistical models will now be designed to extend hidden Markov chains to hierarchical data in order to locate homogeneous sequence zones. This second phase is being conducted in collaboration with INRIA.

Greenlab project in China

The Greenlab project was launched in 1998 by the Sino-French Joint Laboratory in Computer Science, Control and Applied Mathematics (LIAMA), which itself was established by INRIA and the Institute of Automation of the Chinese Academy of Science in Beijing. The objective is to promote Chinese-French cooperation for the development of mathematical models for plants and agricultural and forestry applications. It brings together mathematicians and computer scientists from the Chinese Academy of Science, agronomists from the Chinese University of Agriculture, where the experiments are conducted, and scientists from CIRAD, INRA and INRIA. This project has now reached a decisive phase subsequent to three years of operations and renewal of the CIRAD team.

The developed model was tested on Chinese crops such as wheat, maize, soybean, sunflower and cotton, leading to the development of the first software prototype. This structure-function type of model simulates plant growth by combining an automaton, which accounts for plant morphogenic patterns, and feedbacks, which link organogenesis, photosynthesis and environmental parameters on the basis of a plant architecture concept. The scientific prospects have

been considerably enhanced through this partnership due to the substantial research potential of LIAMA, and to the broad range of applications of the model for simulation of crop plants and crop management sequences. The project also has a substantial reputation based on the fact that it showcases a successful international collaboration.



Home page of the
AMAP-e-learning
website

Training

Training activities of the programme were escalated in 2001. Three modules were created in university graduate schools in Montpellier: integrated modelling of plant and plant cover architecture and physiology, in collaboration with LEPSE, the French laboratory on the ecophysiology of plants under environmental stress; multiple-scale structures, formal aspects and algorithms, in collaboration with LIRMM, the French laboratory of computer science, robotics and micro-electronics; and stochastic modelling of biological phenomena.

Workshops and training sessions for researchers were held, with more than 80 scientists and engineers from CIRAD, INRA and other institutions attending. Workshop components were: introduction to plant digitalization and to AMAPmod software; simulation of plant development and use of AMAPsim software; 3-D imaging; use of the CAPSIS software platform for modelling forest stand dynamics; and the use of different CEPHA software packages.

In parallel, weekly seminars on plant modelling were held in China, and graduate courses on remote sensing, image processing and landscape simulation were offered in Ait, Thailand. An e-learning platform on plant architecture and modelling, ie AMAP-e-learning, was also set up. In 2001, it was successfully tested within the framework of a training session given on plant architecture measurement and analysis.

Chinese
and French
researchers
from the
Greenlab
project

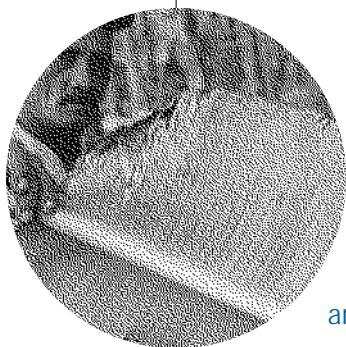


© Amapi/Cirad

Commercial development of software packages

In 1991, CIRAD began developing AMAP software for landscape design and synthetic imaging on the basis of original plant architecture modelling concepts. There was a promising response to the market introduction of these products, with

more than 1 000 professional licences granted worldwide. CIRAD handed over the industrial and commercial development of AMAP software to Bionatics, a specialized software publishing company. An agreement was signed with Bionatics, which stipulates that CIRAD will receive royalties and a share of the software sales profits. ■



Crop protection

The crop protection programme conducts research on integrated control strategies against pests and diseases of tropical and subtropical crops. The strategies developed are based on environment-friendly and rational use of genetically resistant plants, adapted cropping systems, pesticides and biological antagonists. This research is currently focused on the analysis of pathogen and pest populations, plant-parasite interactions, and epidemiological components.

Locust control

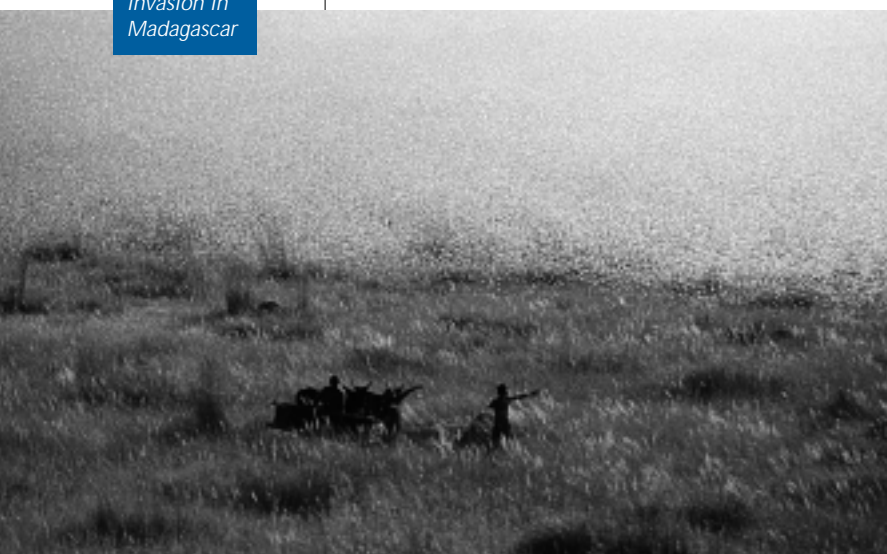
Madagascar was recently hard hit by a plague of migratory locusts (*Locusta migratoria capito*) along with outbreaks of red locusts (*Nomadacris septemfasciata*). It took four years of costly control operations involving chemical pesticide treatments over an area of more than 4 million ha to stall this plague. As early as the 1970s, locust upsurge forecasts were made on the basis of scientific data that CIRAD scientists helped to collect. The south-western part of the island, where the core outbreak area is located, is the only

region that has to be closely surveyed during recession periods. Regions risking outbreaks, and where early control treatments should be conducted, can be determined simply by monitoring rainfall patterns and locust population densities in this source area.

The French Embassy asked CIRAD to backstop the newly founded locust warning section of CNA, the Malagasy locust control centre, to help restore this plague prevention system. One of the aims was to develop a decision support tool to monitor the locust situation. This will involve logging meteorological and locust data on a 10-day time scale into a GIS to locate outbreak-risk areas and guide preventive treatment operations.

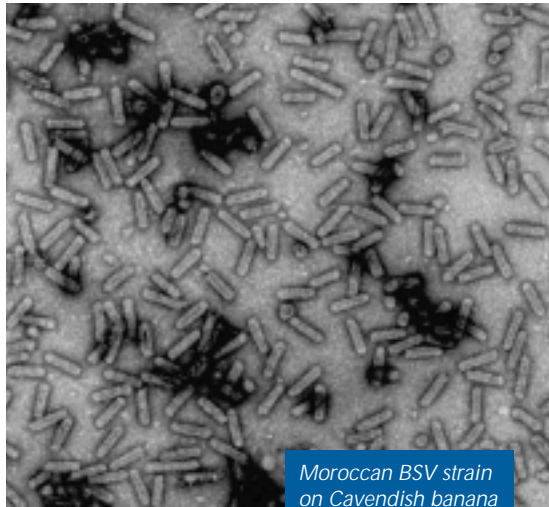
The first phase of the project is finished. Work has begun on the GIS and on updating maps of migratory locust outbreak biotopes. The red locust research programme has been organized and set up in the field, and the Malagasy technical staff is now trained on survey procedures. CNA will have a new early locust warning system designed to detect budding plagues by the end of this three-year project.

Migratory locust invasion in Madagascar



Virology

Plant viruses are often spread from host to host by vectors. The banana streak virus, a badnavirus that causes banana streak disease, is generally



Moroccan BSV strain
on Cavendish banana
from New Caledonia

© B. E. Lockhart

transmitted via this route. However, a recent study conducted by CIRAD's virology laboratory revealed that this pathogen can also be genetically propagated, the first time that such a phenomenon has been documented in the plant kingdom. It was found that a dormant virus motif integrated in banana (*Musa balbisiana*) chromosomes is able to overcome the complex genetic arrangement to reconstitute a pathogenic virus particle when triggered by a biotic or abiotic stress induced by cross hybridization, mass micropropagation or a temperature shift, etc. This phenomenon was observed in interspecific hybrid plant populations derived from healthy parents, where half of them developed the disease even though there was no possible external source of contamination.

The results of a detailed genomic AFLP analysis proved the genetic origin of the disease, which was linked with the presence of viral sequences within the genome of the *M. balbisiana* parent. Studies are under way to determine the mechanisms responsible for banana streak virus expression during cross hybridization.

It was also found that the proliferation phase prompts this expression during in-vitro culture of "silent" bananas that contain dormant viral sequences. This contamination pattern could also occur in other badnavirus host plants that, like bananas, are vegetatively propagated, eg sugarcane, yam and pineapple. The features of these interactions, which could have arisen as a result of coevolution of the host and virus genomes, represent a new challenge for agricultural research.

Systematics

Changes in farming practices and accidental introduction of pests constantly modify phytosanitary conditions of agrobiological communities in tropical regions. It is essential to accurately identify all organisms present to be able to determine the impact of these changes and imbalances that can lead to pest outbreaks, and also to detect beneficial organisms that could potentially check these outbreaks. This is the goal of the fauna systematics research unit.

New tools have been developed as a supplement to conventional analyses of morphological traits that help systematians in their species identification research. These include: biochemical and especially molecular markers which enable more accurate organism identifications, ie to the subspecies level—with the possibility of identifying the population from which the organism derives. These tools can even be implemented for analyses at early development stages. They also include computer tools, such as software for phylogenetic classification, identification aid systems and, very recently, automatic shape and species recognition systems.

The potential of these new techniques will be tapped to the fullest by a new systematics group that is being set up at Baillarguet, near Montpellier. In addition to the CIRAD fauna unit, it will host INRA and IRD teams and collaborate with CBGP, the biology and population management centre, which is already located there. The plans include compiling a molecular database for routine determinations, which will substantially lighten systematians' workload, thus enabling them to concentrate more fully on their research. ■



The cotton pest
Dysdercus sp.

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CIRAD at a glance

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Organizational chart

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Scientific Advisory Committee

Ethics Committee

Research coordination

Regional representatives

CIRAD worldwide

Budget and staff

Training

Addresses

List of acronyms

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(see page 87)

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Yves Nouvellet, Deputy

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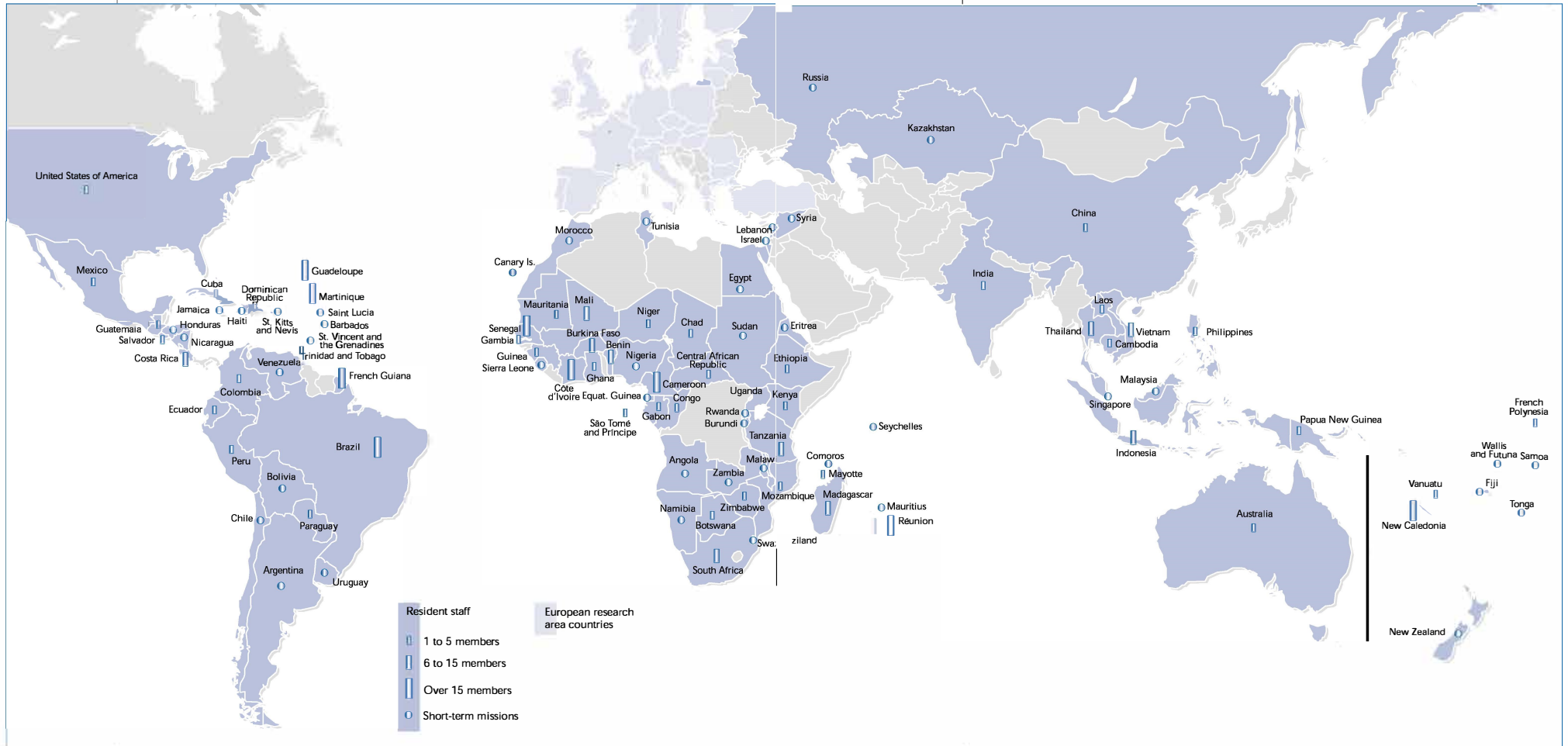
Thailand, **Eric Gohet**

United States of America, **Jill Barr**

Vanuatu, **Jean-Pierre Labouisse**

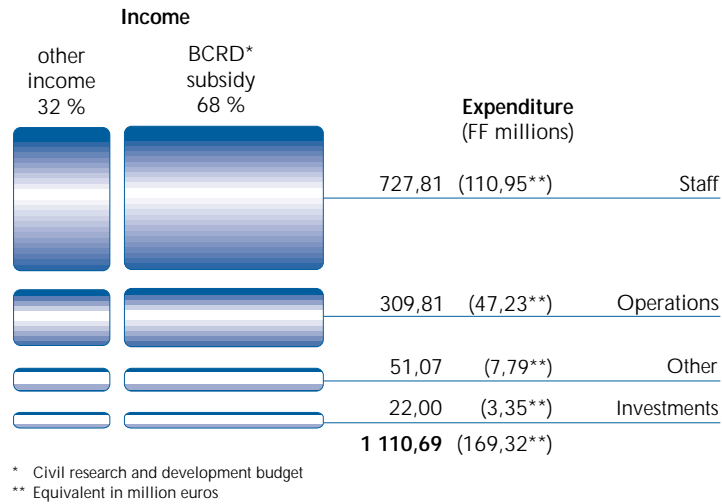
Vietnam, **Gilles Mandret**

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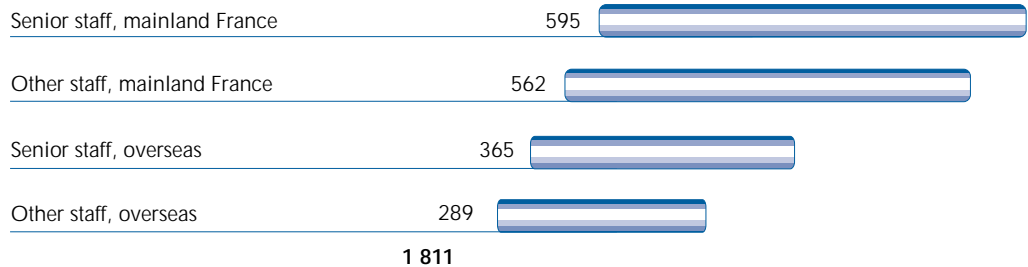


Budget and staff in 2001

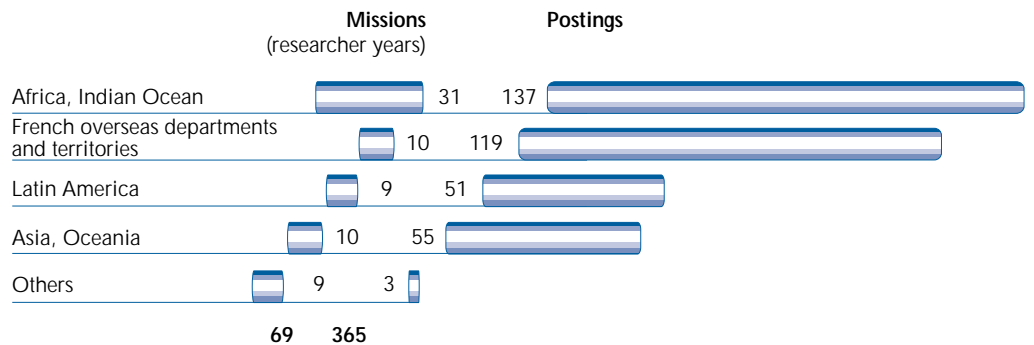
Income and expenditure



Distribution of staff by category and location

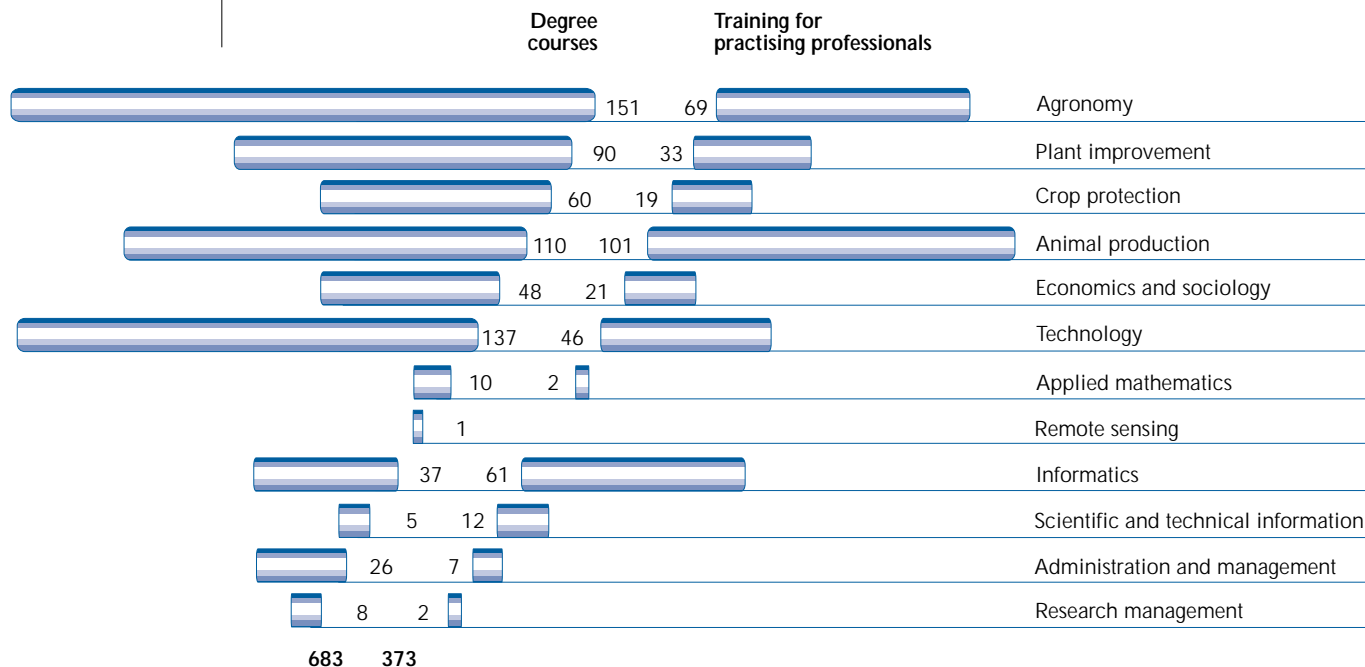


Geographical distribution of senior staff overseas

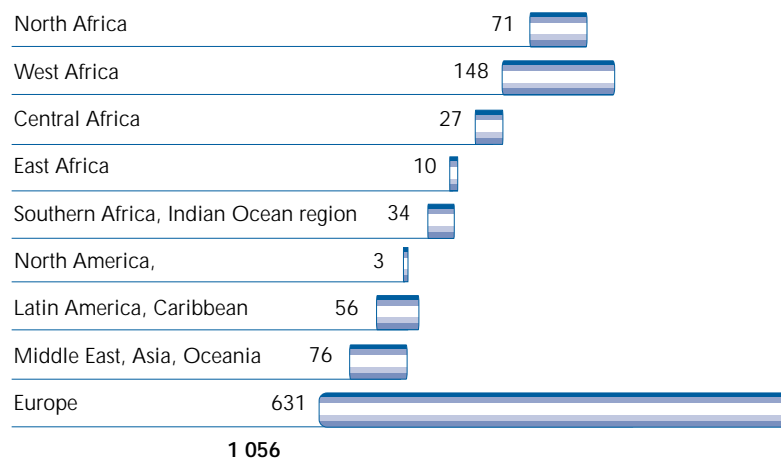


Training in 2001

Distribution by discipline and type of training



Distribution of trainees by geographical origin



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List of acronyms

- AAC, Australian Academy of Science, Australia
- ACIAR, Australian Centre for International Agricultural Research, Australia
- ACP, Africa, Caribbean and Pacific
- ADEME, Agence de l'environnement et de la maîtrise de l'énergie, France
- AFD, Agence française de développement, France
- AFLP, Amplified Fragment Length Polymorphism
- AFSSA, Agence française de sécurité sanitaire des aliments, France
- Agro Montpellier, Ecole nationale supérieure agronomique de Montpellier, France
- AIT, Asian Institute of Technology, Thailand
- ANACAFE, Asociación Nacional del Café, Guatemala
- AVRDC, Asian Vegetable Research and Development Center, Taiwan
- BNETD, Bureau national d'études techniques et de développement, Côte d'Ivoire
- BRG, Bureau des ressources génétiques, France
- CAOBISCO, Association des industries de la chocolaterie, de la biscuiterie et de la confiserie, Belgium
- CAP, Common Agricultural Policy
- CARBAP, Centre africain de recherches sur bananiers et plantains, Cameroon
- CATIE, Centro Agronómico Tropical de Investigación y Enseñanza, Costa Rica
- CBGP, Centre de biologie et de gestion des populations, France
- CEDIMES, Centre du développement international et des mouvements économiques et sociaux, France
- CEMAGREF, Centre national du machinisme agricole, du génie rural, des eaux et des forêts, France
- CENARGEN, Centro Nacional de Pesquisa de Recursos genéticos y biotecnologia, Brazil
- CERAAS, Centre d'étude régional pour l'amélioration de l'adaptation à la sécheresse, Senegal
- CERNA, Centre régional de nutrition et d'alimentation appliquées, Benin
- CES, Centre de suivi écologique, Senegal
- CFC, Common Fund for Commodities
- CFSIGE, Centre de formation aux sciences de l'information géographique et de l'environnement, Madagascar
- CGIAR, Consultative Group on International Agricultural Research, USA
- CICY, Centro de Investigación Científica de Yucatan, Mexico
- CIEPAC, Centre international pour l'éducation permanente et l'aménagement concerté, France
- CIFOR, Centre for International Forestry Research, Indonesia
- CIP, Centro Internacional de la Papa, Peru
- CIRDES, Centre international de recherche-développement sur l'élevage, Burkina Faso
- CIREN, Centre international de recherche sur l'environnement et le développement, France
- CNA, Centre national antiacridien, Madagascar
- CNEARC, Centre national d'études agronomiques des régions chaudes, France
- CNRA, Centre national de recherche agronomique, Côte d'Ivoire
- CNRE, Centre national de recherche sur l'environnement, Madagascar
- CNRS, Centre national de la recherche scientifique, France
- CNS, Centre national de séquençage, France
- CODEVASF, Companhia de Desenvolvimento do Vale do São Francisco, Brazil
- CONICYT, Comisión Nacional de Investigación Científica y Tecnológica, Venezuela
- CPAAF, Centro de Pesquisa Agroforestal da Amazônia, Brazil
- EHESS, Ecole des hautes études en sciences sociales, France
- EISMV, Ecole inter-Etat de sciences et médecine vétérinaire, Dakar, Senegal
- EMBRAPA, Empresa Brasileira de Pesquisa Agropecuária, Brazil
- EMI, European Membrane Institute
- ENGREF, Ecole nationale du génie rural, des eaux et des forêts, France
- ENSA, Ecole nationale supérieure agronomique, Senegal
- ENSAR, Ecole nationale supérieure agronomique de Rennes, France
- ENSIA, Ecole nationale supérieure des industries alimentaires, France
- EPHE, Ecole pratique des hautes études, France
- ESSA, Ecole supérieure des sciences agronomiques, Madagascar
- FAO, Food and Agriculture Organization of the United Nations, Italy
- FCR, Fonds de coopération régional, French Guiana
- FFEM, Fonds français pour l'environnement mondial, France
- FOFIFA, Foibe Fikarohana momba ny Fampandrosoana ny Ambanivohitra, Madagascar

- FRUTOTEC, Centro de Tecnologia de Hortifrutícolas, Brazil
- FUNDECITRUS, Fundo de Defesa de Citricultura, Brazil
- FUNAI, Fundação Nacional do Índio, Brazil
- GIS, Geographical Information System
- GTZ, Deutsche Gesellschaft für technische Zusammenarbeit, Germany
- IAC, Institut agronomique calédonien, New Caledonia
- IAM, Institut agronomique méditerranéen, France
- ICAFF, Instituto de Café, Costa Rica
- ICGI, International Cotton Genome Initiative
- ICRA, Institut centrafricain de recherche agronomique, Central African Republic
- ICRISAT, International Crops Research Institute for the Semi-Arid Tropics, India
- IEDES, Institut d'étude du développement économique et social, France
- IER, Institut d'économie rurale, Mali
- IFEN, Institut français de l'environnement, France
- IICA, International Institute for Cooperation in Agriculture
- ILRI, International Livestock Research Institute
- INA-PG, Institut national agronomique Paris-Grignon, France
- INIA, Instituto Nacional de Investigação Agronómica, Mozambique
- INIBAP, International Network for the Improvement of Banana and Plantain, France
- INRA, Institut national de la recherche agronomique, France
- INPA, Instituto Nacional de Pesquisa do Amazonia
- INRAB, Institut national de recherches agricoles, Benin
- INRIA, Institut national de la recherche en informatique et automatique, France
- INSAH, Institut du Sahel, Mali
- IOS, Institute of Sociology, Vietnam
- IPGRI, International Plant Genetic Resources Institute, Italy
- IRAD, Institut de recherche agricole pour le développement, Cameroon
- IRAG, Institut de recherche agronomique de Guinée, Guinea
- IRAM, Institut de recherches et d'applications des méthodes de développement, France
- IRD, Institut de recherche pour le développement, France
- IRRDB, International Rubber Research and Development Board, Malaysia
- IRRI, International Rice Research Institute, Philippines
- ISRA, Institut sénégalais de recherches agricoles, Senegal
- ISSCT, International Society of Sugar Cane Technologists, USA
- ISTOM, Institut supérieur d'agroéconomie internationale, France
- ITC, International Trypanotolerance Center, Gambia
- ITRAD, Institut tchadien de recherche agronomique pour le développement, Chad
- LEAD, Livestock, Environment And Development
- LEPSE, Laboratoire d'écophysiologie des plantes sous stress environnementaux, France
- LIAMA, Laboratoire franco-chinois d'informatique et de mathématiques appliquées, China
- LIRMM, Laboratoire d'informatique, de robotique et de micro-électronique de Montpellier, CNRS, France
- LRVZ, Laboratoire de recherche vétérinaire et zootechnique, Chad
- MINEF, Ministère de l'environnement et des forêts, Cameroon
- MPOB, Malaysian Palm Oil Board, Malaysia
- NIAH, National Institute for Animal Husbandry, Vietnam
- NIPP, National Institute of Plant Protection, Vietnam
- OAU, Organization of African Unity
- ODI, Overseas Development Institute, UK
- OIE, Office international des épizooties
- PACE, Programme africain de contrôle des épizooties
- PCR, Polymerase Chain Reaction
- PPZS, Pôle pastoral en zones sèches, Senegal
- PRASAC, Pôle régional de recherche appliquée au développement des savanes d'Afrique centrale, Chad
- PSAOP, Programme de services agricoles et d'organisations de producteurs, Senegal
- PT SMART, PT Sinar Mas Agro Resources and Technology Corporation, Indonesia
- QFRI, Queensland Forestry Research Institute, Australia
- QTL, Quantitative Trait Loci
- RFLP, Restriction Fragment Length Polymorphism
- RIFAV, Research Institute on Fruits and Vegetables, Vietnam
- RIVM, Rijksinstituut voor Volksgezondheid en Milieu, the Netherlands
- ROSELT, Long Term Ecological Monitoring Observatories Network
- RRIT, Rubber Research Institute of Thailand, Thailand
- SBL, Société des bois de Lastourville, Gabon
- SIUPA, Strategic Initiative on Urban and Peri-urban Agriculture
- SODECOTON, Société de développement du coton, Cameroon
- TANSAO, Taro Network for Southeast Asia and Oceania
- UCAD, Université Cheikh Anta Diop, Dakar, Senegal
- INICAMP, Universidade Estadual de Campinas, Brazil
- USP, Universidade de São Paulo, Brazil
- UTC, Université de technologie de Compiègne, France
- VASI, Vietnamese Agricultural Sciences Institute
- WECARD, West and Central African Council for Agricultural Research and Development, Senegal
- WTO, World Trade Organization, Switzerland

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