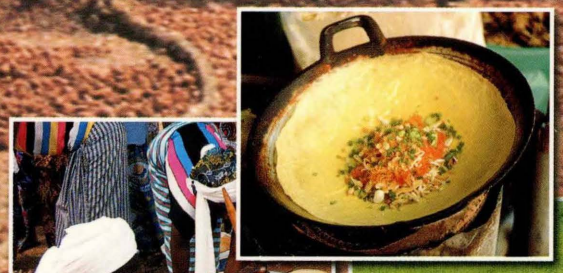
Cirad 2000



CIRAD 2000

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 persons, including 900 senior staff, who work in more than 50 countries. Its budget amounts to approximately French francs 1 billion (€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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CIRAD 2000

Contents

Message from the Chairman

In a world embroiled in fierce debate on development aid, environmental issues and the risks of globalization, CIRAD must define its position. In a world where some countries are emerging from poverty while others seem to sink deeper into it, CIRAD must ask itself difficult questions. And in a world where science is undergoing a revolution, CIRAD too is changing.

We have entered an important phase in the development of our new strategic plan. A process of consultation and debate on the major issues facing the international community and on global research trends has been accompanied by a critical evaluation of our existing projects and programmes. Both have led us to make important ethical and scientific choices. And both have thrown light on our operational options in terms of the geographical areas in which we work and the partnerships we enter.

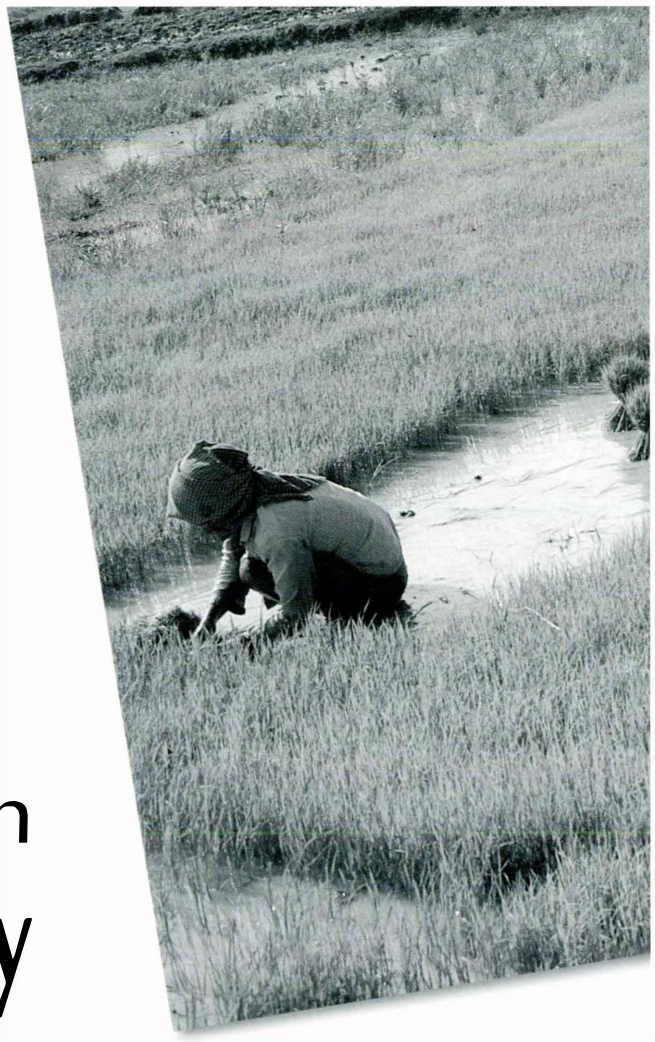
The renewal of our research is based on what we have learned from our failures as well as our successes. The programmes and projects that are an unqualified success have been strengthened and extended; many of the others have been redefined in some way; a few have been abandoned—but there are also many new activities. In the fields of genetics and information science and technology, we have decided to continue to be actively engaged in the revolutions currently under way and to build on the rapid progress we have already made. We acknowledge that this raises difficult questions, which we cannot answer by ourselves. But by taking carefully prepared positions arrived at through our own deliberations, we can contribute to a debate in which civil society is participating passionately.

Our partnerships in the countries of the South are also going through a period of considerable change. We remain very active in the least developed countries in which poverty eradication is the highest priority. This is fundamental to our mandate. But we have also decided to engage with the dynamic, emerging economies of the South, such as China and Brazil, with which scientific exchanges are proving highly fruitful.

Our alliances with overseas or international research groups should receive fresh impetus as new research objectives emerge and serve as a rallying point. As regards our partnerships with national institutions, our ambition is to collaborate more actively with basic research laboratories.

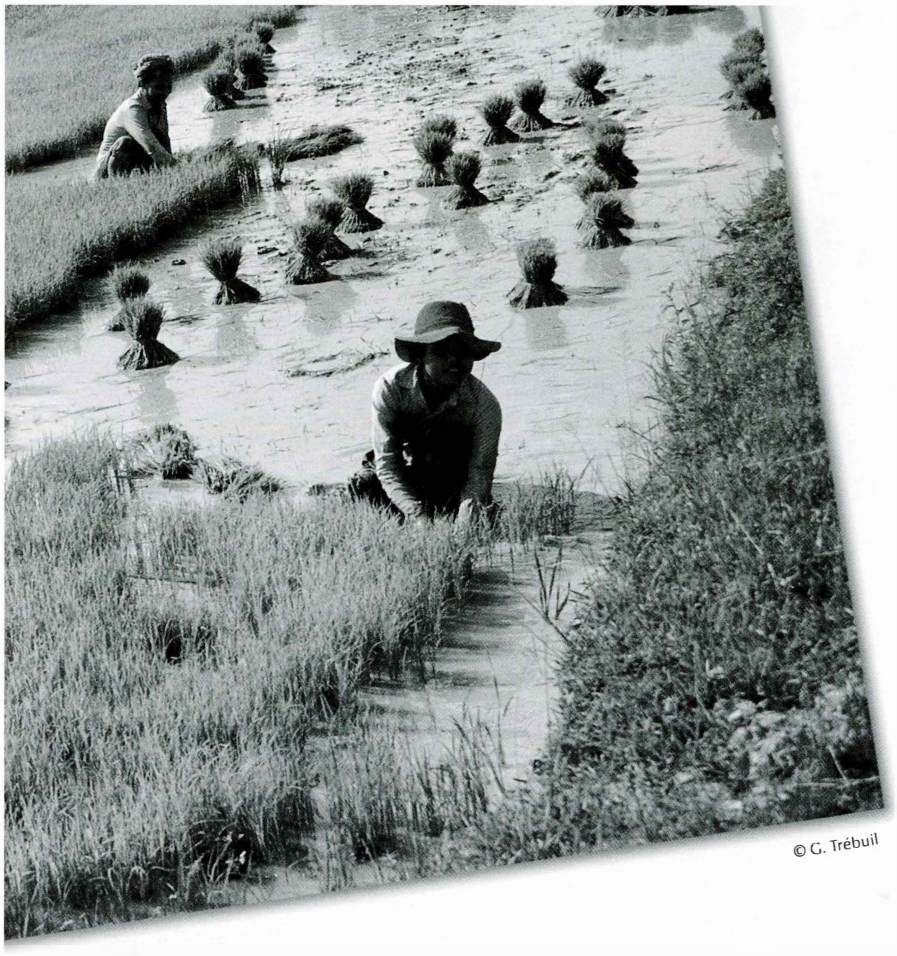
We have learned how to ask the right questions of ourselves and how to make the right decisions—decisions that will fundamentally renew our approach to development-orientated research. Now we must act on those decisions. Our strategic plan will be published and a draft contract with the French Government prepared by late 2001. Our planning process will undoubtedly equip us to meet the most urgent needs of our partners in the South even better in future than we do today.

Daniel Nahon
Chairman, CIRAD Board of Trustees



Towards an **environmentally friendly** agriculture

Loss of biodiversity, pests and diseases, pollution, climate change, desertification, water scarcity—these are some of the problems that threaten the future of the world's rural areas. CIRAD has acted boldly to redirect its research and adopt an environmental approach towards agriculture, livestock production and forestry. It aims to help producers create or recreate sustainable production systems in often difficult environments and to support decision makers in their efforts to design effective policies that will preserve our natural heritage.



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The international community now seems for the most part to have grasped the scale of the threats posed by global environmental degradation. International conventions, such as those on biodiversity, climate change and desertification, testify to its determination to tackle these threats, so as to ensure a viable environment for future generations. This is the background against which CIRAD must position its development-orientated research.

CIRAD has long taken natural resource management into account in much of its programme. However, the Centre's deliberations in preparation for its new strategic plan have profoundly altered our thinking. The environmental dimension will from now on be fully integrated in our research, the content of which may change considerably as a result. CIRAD is rethinking the priority fields in which it must invest its energies—those in which the end products of research have the best chances of protecting the environment and, thereby, of helping rural populations to earn a living under what are often extremely challenging conditions. This transformation of our research is accompanied by changes in our scientific capacity.

Analysing the natural resource base and assessing environmental risks allows us to develop sustainable production systems and tools to support policy making.

Resource analysis and risk assessment

Often it is the combined effects of human activity and natural phenomena that lead, or threaten to lead, to environmental decline or disaster. The main environmental themes addressed by CIRAD in its research to improve system sustainability are biodiversity, wastes and pollution, pests and diseases, climate change, desertification and water scarcity.

Reflecting its mandate, CIRAD approaches the issue of biodiversity mainly from the point of view of its importance for agricultural development. Agriculture as it is practised today—both in its intensive forms and in the expansion of cropped areas in developing countries—reduces genetic diversity within plant and animal species, as well as interspecific and ecosystem diversity. Understanding the interactions between agricultural activities and the evolution of biodiversity on different scales, from the plot to the ecoregion, has become a major objective of our research. But we also need to join forces with farmers and other stakeholders in development to invent, or perhaps re-invent, management practices that will enable them to sustain diversity by putting it to use. Among the priorities for this theme are animal biodiversity, including that of wildlife, the characterization of natural forest ecosystems and the biodiversity of major food crops.

Biodiversity


© M. Baumer

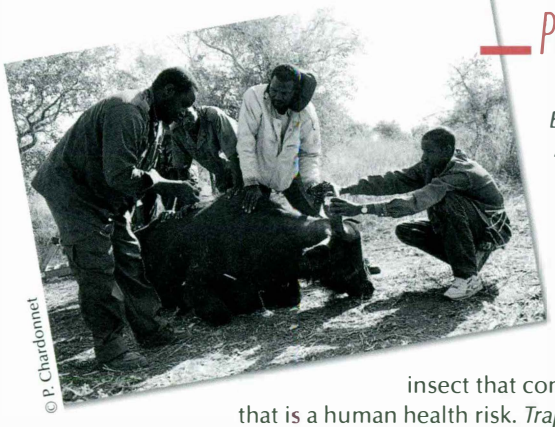
Repel the invader. Réunion's unique biodiversity is threatened by an aggressive introduced acacia. Proposals have been made for bringing it under control. *Invasive species in Réunion, p. 74.*

Understanding diversity. In collaboration with a leading French genomic research institution, CIRAD has used microsatellite markers to characterize a large number of tropical crops and their pathogens. Laboratories in the tropics and subtropics can be expected to take up the results. *DNA libraries enriched with microsatellites, p. 90.*

Exploring Andean passion fruits. With CIRAD support, national programmes in five Andean countries are studying wild and cultivated species with a view to enhancing diversity. Practical applications include the development of interspecific hybrids. *Passifloraceae diversity in the Andes region, p. 58.*

Integrating the wildlife perspective. Handing over the management of wildlife and the environment to local people offers the best chances of controlled, sustainable development. CIRAD and its partners have developed a training course for natural resource managers. *Training, p. 69.*

Pests and diseases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Emerging livestock diseases. A tropical viral disease transmitted by mosquitoes affects horses in the Camargue. How the crisis was managed. *Outbreak of West Nile fever in the Carmargue, p. 64.*

Beetles beware. New, patented technology allows mass trapping of an insect that contaminates coffee berries with a fungus that is a human health risk. *Trapping the coffee berry borer,* p. 47.

Resurgence of an old enemy. Rinderpest is on the move again in East Africa and is still present in Central and West Africa. Including sentinel wildlife species in epidemiological surveys can provide an early warning of outbreaks. *Epidemiological surveillance of rinderpest in wildlife, p. 64.*

Males to be eliminated. Various biological control methods, including sexual, visual and olfactory attractants and the introduction of a parasitoid, are being tested on fruit flies damaging a range of crops such as carambola, tomato and melon. *Flies damaging fruit and vegetable crops, p. 60.*

The risks of pests and diseases incurred by both crop and livestock production are considerable. CIRAD gives priority to integrated management and seeks to achieve a multiplier effect by combining epidemiology studies with early warning and better targeting of interventions. Biological research to open up new control options, the development of integrated control methods for crops, the search for natural bio-insecticides and work on the epidemiology and ecopathology of livestock pathogens are all choices that give high profile to environmental concerns.

The wastes and pollution resulting from human activity, including agriculture, are mounting rapidly, in the South as in the North, and agriculture is often required to find ways of dealing with them. This raises the vital question of how to preserve clean soil and water resources. Understanding the biochemical and geochemical pro-cesses that take place when wastes are released to the environment is essential in quantifying risks. Researchers are coming up with new ways of reducing the sources of pollution and of processing waste. They are also developing a set of methods, tools and indicators to aid decision making at different levels. Given the rapidly increasing demand for CIRAD's services in this field, we are strengthening our specialist teams based in Réunion and Montpellier. The Réunion team looks at the special case of how densely populated island environments should deal with waste.

The threat of climate change and its consequences—recurrent drought and desertification in some regions, flooding of coastal plains in others—has raised to the top of the international agenda

the challenge of reducing the greenhouse gas effect by changing human behaviour. Agriculture, livestock production and forestry all play an important if as yet an inadequately quantified part, by virtue both of their greenhouse gas emissions and of their ability to store these same gases. In other words they have negative effects, which can be reduced, and positive ones, which must be enhanced. The research conducted by CIRAD and its partners is responding to three challenges: first, how to measure and model gas emissions on different scales (particularly the carbon dioxide released by slash-and-burn agriculture, the methane produced by livestock and irrigated rice plots and the nitrates contained in fertilizers); second, finding ways of reducing these emissions and assessing the effects on them of changes in land use and agricultural practices; and third, identifying new policy options for rural development that will help attenuate climate change and promote the necessary changes in social behaviour. Among our more important projects let us cite by way of example: our studies on the part played by tree plantations and agroforestry systems in carbon storage; the development of a macroeconomic model for analysing the impact of climate change on agriculture and the environmental and equity effects of different policy interventions; and the development of strategies for monitoring greenhouse gas emissions, in collaboration with ten other research teams across the European Union.

Desertification results both from climate changes and from a mismatch between the natural resource base and the ways in which it is exploited. CIRAD possesses a wealth of knowledge on how to evaluate the risk of desertification and its consequences at the level of the plot and the cropping system. At the regional level, we know how to estimate biomass production in pastoral systems and how to model ecosystems and the way they operate. Various tools, including remote sensing, water-balance models and models for predicting crop yields, are used in conjunction with field studies to develop diagnostic and early warning systems, in addition to practical interventions and ways of measuring climate change. Most of our research efforts in this field focus on the agro-ecology of rainfed cereals in the arid zone.

Water scarcity, due both to the rising numbers of users and to the greater amounts used, can give rise to conflicts between different user groups and even between

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Wastes and pollution

Cleaning up the paper industry. Extracting lignins from eucalyptus wood for pulp manufacture is expensive and leads to pollution. The answer is wood with a low lignin content. Scientists have integrated lignin traits into genetic improvement programmes. *Biosynthesis of eucalyptus lignins, p. 74.*

Dealing with livestock wastes. A method for treating pig slurry is being tested by the Loire-Bretagne water authority in France. The residual compost is rich in nutrients. *On-farm treatment of livestock wastes, p. 43.*

Modeling can help. Opportunities for improving nutrient cycling can be identified through the development of models of manure management based on farmers' practices and agronomists' experiments. *Modeling the management of slurry in Réunion, p. 81.*

Climate change

© R. Oliver

A systems approach. Taking a fresh look at the management of Mediterranean and tropical production systems with a view to improving carbon storage. *SYSTEM, a new joint research unit, p. 90.*

Cutting carbon emissions. Carbon exchanges are being measured in a tree plantation in Congo, to aid implementation of the 'clean development' mechanism envisaged under the Kyoto protocol. *Measuring and modeling the carbon cycle, p. 73.*

Desertification

Towards stronger institutions. Building a regional research thrust with a Senegal-based institution mandated to combat drought in the Sahel. *Partnership with CERAAS, p. 89.*

Water scarcity

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Support to decision makers. Helping farmers' organizations and private-public partnerships meet the technical, economic and environmental challenges of water management. Experiences in Mali, Senegal and Brazil. *Towards better irrigation management, p. 81.*

A viable future for pastoralism. Preparing for the implementation of a pastoral water-points project in a transhumant production system in Chad. *Mapping of pastoral resources, p. 63.*

countries sharing the same resource. Agriculture is a key sector in the search for solutions, being at once a major consumer of water, especially for irrigation, a polluter of the water resource and a means of buffering the flow of water down rivers and streams. CIRAD has decided to strengthen its work on the biophysical processes that govern water availability in agrisilvopastoral systems, on the management of water and water use efficiency on irrigation schemes, and on the development of tools to support decision making and negotiations.

Applying the principles of sustainable agriculture

Sustainable agriculture and a 'doubly green' revolution—one in which yield increases go hand in hand with lower production costs and environmentally friendly management practices—are central concepts in CIRAD's current work, as in its deliberations about the future. At the level of the crop, livestock or tree-based production system, these concepts are applied in projects so many and so diverse as to defy discussion here. Instead, we will touch on a few themes that have recently come to the fore, sometimes in striking ways.

Zero tillage systems in which crops are sown directly into a mulch cover, of the kind studied and developed by CIRAD, are one of the best examples of the form a doubly green revolution could take. Now covering over 5 million hectares in Latin America, Africa and Asia, they represent a research breakthrough today and a beacon of hope for the future. The reduced erosion and gains in soil fertility to which they give rise are reflected in higher and more stable crop yields than those obtained in conventional cropping systems. At the same time the use of inputs is reduced, as also is the amount of hard labour required. These innovative systems are particularly attractive on environmental grounds, since they sequester more carbon than do conventional systems. We are currently quantifying this effect.

New cotton-based cropping systems are a response to the needs of African producers, who have expressed concern over the degradation of the natural environment that surrounds their crops at a time when the international market for cotton is depressed. In developing these systems, researchers and producers have sought to increase the competitiveness of the cotton component while taking into account constraints in the physical environment and farmers' strategies for coping with them. To complement farmers' strategies, they have come up with a number of new techniques, including a mulch cover, growth regulators, ripening agents and plant health components. The new systems are currently gaining ground elsewhere in the world.

The regional research thrust on sustainable agriculture, forests and the environment, based in Réunion, shows how the challenges of sustainable development—preventing soil erosion, recycling waste, sharing the water resource equitably, conserving biodiversity and maintaining a dense population of smallholders on the land—can be met at the level of a whole geopolitical unit.

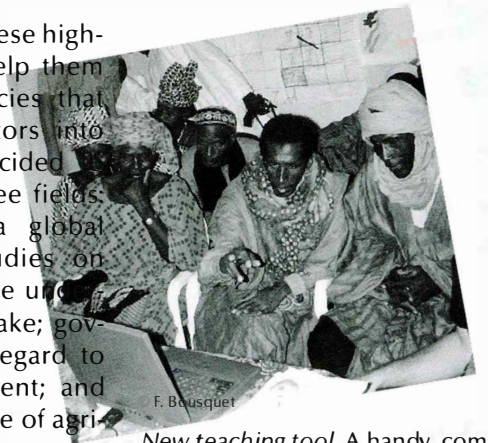
Supporting decision makers

Driven by the pace of global change, public policy towards agriculture and the environment is also changing rapidly. However, governments are seldom able to

master all the facets of these highly complex issues. To help them formulate effective policies that take environmental factors into account, CIRAD has decided to intensify its work in three fields: the development of a global model and *ex-ante* studies on policies, so as to improve understanding of what is at stake; government policies with regard to natural forest management; and the multifunctional nature of agriculture, with special reference to the new system of *contrats territoriaux d'exploitation*. These are contracts between farmers and the government, designed to reward farmers for non-productive activities.

The last of these three themes is highly topical. A seminar was held in Guadeloupe in November 2000 to study its implications for France's overseas departments. In Réunion, work on environmental law and on an information system to aid policy makers is supporting the introduction of these contracts.

CIRAD's strategic deliberations have revealed the areas in which it wishes to launch an ambitious drive to renew its research. The choices made by the Centre give high profile to the environmental aspects of agriculture. This is reflected in the recruitment of many new scientists in relevant disciplines and subject areas such as ecology, geography, law and geographical information systems (GIS). It is also reflected in the Centre's new or strengthened partnerships, both in France—with the National Agronomic Research Institute (INRA), the Institute of Research for Development (IRD), higher education colleges and private companies—and in other countries and internationally. ■



F. Bousquet

Sustainable agriculture and a doubly green revolution

Sharing the land. A multi-agent software programme has been developed to support negotiations between different groups of land users. The programme is linked to a geographical information system (GIS). *Tools for collective land management, p. 82.*

New teaching tool. A handy, computer-based update on the management of a fragile ecology, for professionals in research, education and development. *Amazonian savannas on CD-ROM, p. 42.*

Sustaining coconut production. Targeted fertilizer applications, the introduction of shrub legumes and the use of intercrops to restore soil fertility in Ghana. *Rehabilitation of African coconut plantations, p. 49.*

Public policy

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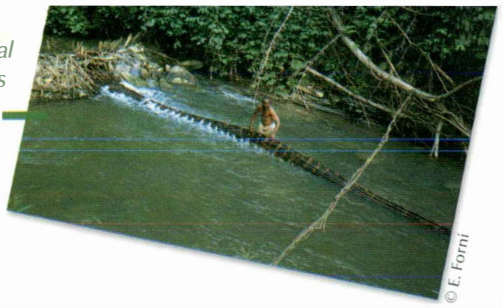
Environmentally sensitive. The debate on multifunctionality and how it feeds into policy making and local action in rural areas. *Multifunctional agriculture, p. 79.*

A price-tag on conservation. Policy instruments that protect the forest heritage at the same time as encouraging the development of an efficient timber industry. Cameroon sets an example. *Tropical forestry policy: devising an incentive system, p. 16.*

Profitability versus conservation. A textbook case of the dilemma facing policy makers. *Okoumé in Gabon, p. 73.*

Current research: Four case studies



Among the multiple ecological functions of forests are water management...

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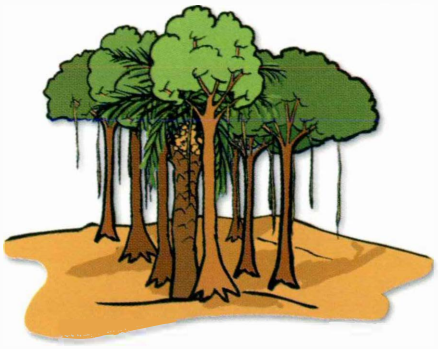

Tropical forestry policy: Devising an incentive system

Use or conservation? Economy or ecology? Tropical forests should no longer be arenas of hopeless dilemmas. Governments have it in their power to foster both the conservation of their forest resources and the development of efficient forest industries. A range of economic tools—taxes, quotas, public auctions, rights trading and so on—are persuading operators to change their behaviour in relation to the forest. However, these tools have to be selected carefully and used well. Cameroon is a forerunner in this field. The country is experimenting, adjusting its policies and institutions, sending out new signals to its forest industry stakeholders. The aim is to combine sustainable management with high-quality forest-based industries.

.....and wildlife conservation.

© D. Depommier


© M. Lemoigne

Cameroon is trying to conserve its forest resources and develop efficient forest industries.

The tropical forest was viewed until recently solely as a resource for producing timber. As the environment increasingly became a political issue during the 1990s, ecologists and economists entered the fray alongside foresters, the traditional administrators of these ecosystems. These new stakeholders claim that, if forests are degenerating and disappearing, it is because their multiple ecological functions are not sufficiently recognized and valued. Forests play a vital part in managing water resources, protecting wildlife, conserving biodiversity and reducing the greenhouse effect. As a rule these functions are not taken into account by governments or rural communities. Why not attach a price-tag to them? This would draw attention to their importance and value, and it would become more economically advantageous to manage the forest sustainably than to allow uncontrolled logging and forest destruction.

Cards on the table

How can this end be achieved? Because it is difficult to attach a cash value directly to these non-market functions, ecologists and economists have put forward various economic policy instruments that can be integrated with forestry reform.

Most forest management policy includes government regulations and technical recommendations. In addition, governments collect taxes and timber royalties. These, however, are primarily geared towards generating an income for the State and do not usually provide incentives of any kind to producers. If their amounts and distribution at different points in the sector were adjusted, these taxes could become economic instruments, designed to persuade operators to change their behaviour.

The public auction of permits to exploit the forest forces competing operators to put their cards on the table when they make a tender. The government is able to charge timber royalties on the basis of how operators are really likely to perform, while the operators themselves are motivated to reduce timber losses and make better use of the trees they cut down.

By restricting or prohibiting log exports, governments can promote the domestic timber industry and generate employment. However, overprotection can lead to waste, caused by inefficient wood processing plants—so protectionist policies need to be applied in moderation.

Cameroon, which in 1994 introduced a new Forest Law, is one of the first countries to experiment with new economic instruments. Its World Bank-supported reforms were enacted while a heated national debate was under way—one that confronted fairly and squarely the issue of unethical commercial practices.

At the request of the Cameroonian government, CIRAD, in collaboration with an international private-sector consultancy group, recently conducted an audit on the economic and fiscal aspects of the country's reorganization of its forestry sector. Despite the high hopes engendered by the 1994 reforms, there are still many uncertainties, partly because the theoretical models of economic outcomes found in the literature are no match for the diversity of real life, but mainly because it is difficult to obtain hard information, with the result that the government has no way of knowing the real costs and benefits of forestry activities. The theoretical models must be backed by a thorough practical understanding of the field and a great deal of common sense.

Common sense


© G. Blaha

Economic instruments can be used to persuade timber operators to change their behaviour.

A set of signals

The measures adopted or under consideration by the government following the audit show how a combination of economic instruments can be used to stop the harmful practices that frustrate sustainable forest use and the development of an efficient timber industry.

Since 1996, logging concessions have been allocated by competitive public tender. However, the government has been strongly criticized for the biased conditions attached to the tender, especially the procedures for selecting candidates. An independent observer has now been appointed to oversee the process and ensure transparency. The process has been improved considerably through such mechanisms as comparison of bids, bank guarantees and penalties to deter inflated bids that cannot subsequently be honoured.

Most logging companies were prepared for the ban on the export of raw logs, which was announced in 1994 and partially implemented in 1999. They responded by shifting the focus of their activities to wood processing. This is just what the government wanted, since its aim was to encourage development of this industry. The ban was a complete success from this point of view: the volume of sawn wood produced doubled between 1998 and 2000 and 2 600 new jobs have already been created in the forestry sector.

Unfortunately, the negative aspects of this accelerated development soon emerged. As noted in other countries of the South, such as Indonesia, Malaysia and Côte d'Ivoire, there are signs of overcapacity and overexploitation. Whereas the sustainable annual logging volume is estimated at 3.5 million cubic metres, the real volume produced is around 5.5 million cubic metres. The gap between the two figures is accounted for by illegal logging, which supplies a wide range of wood processing units. Many of these so-called 'processing plants'—often just small sawmills—handle high volumes of wood to which they add little value. It is now crucial to develop the sector by promoting initiatives in three areas: preventing wastage; diversifying the species used; and producing finished and semi-finished products with a higher added value.

Taxing raw logs as they enter the factory rather than processed products ready for export would provide an incentive for companies to reduce waste and make more efficient use of raw materials. In other words, innovation is the route to better performance. Because more government agents would be required on the ground to administer it, a tax of this kind could also be used to limit the volume of timber supplied to the factories and to prevent the supply of illegally harvested logs.

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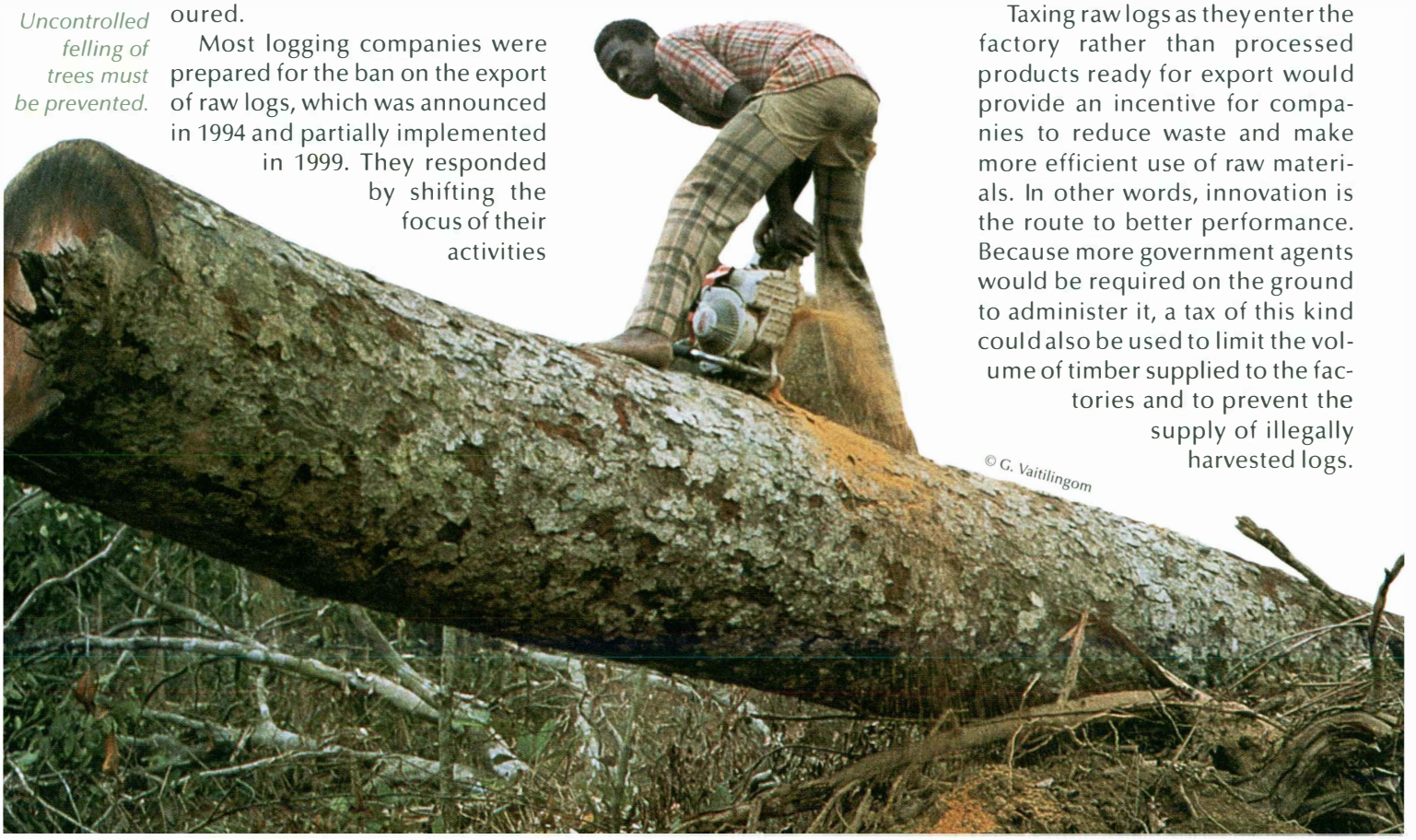
Banning log exports promotes domestic wood processing.



© G. Vaitilingom

Uncontrolled felling of trees must be prevented.

The government is also investigating the possibility of introducing a public auction system for rights to export logs on an annual quota basis. Competition between timber operators should ensure that the government is able to sell the rights at prices that correspond to their true potential in a market where prices fluctuate.

Through these economic instruments the Cameroonian government is sending signals to its forestry sector operators, in the hope of persuading them to adopt sustainable management practices and to redirect their enterprises towards the production of quality products with a high added value for the international market rather than the cheap, high-volume produce of today.

© J. Guisgafre

Many wood processing plants have recently been built in Cameroon. Signs of overcapacity are appearing.

Carbon storage

Trade in carbon represents another type of economic instrument—one that can be applied internationally. The industrialized countries intend to reduce their carbon dioxide and other greenhouse gas emissions. For instance, the European Union (EU) has decided to reduce these emissions by 8% (from 1990 levels) over the 2008-2012 period. The development of a market in carbon emissions would allow countries that exceed their quota to buy the right to emit more from more 'virtuous' countries. The market would determine the value of the carbon traded. Rights could be acquired either through what is known as the 'clean development mechanism' or via cooperative activities undertaken to develop clean technology.

Forests store carbon and in so doing reduce atmospheric carbon levels. Forests and plantations exploited on the basis of continuous renewal could thus become the focus of cooperation and exchange between countries of the South and the North, the former benefiting by investments on their land and the latter by emission rights. Combined with other economic instruments and regulations governing forest use, cooperative activities of this kind could have an impact on sustainable development reaching well beyond mere carbon storage. For example, it might become possible to reforest degraded land with a diverse range of species, so as to enhance biodiversity. In addition, rural communities could finance village plantation or agroforestry projects from investment funds to which enterprises in the North would contribute.

Despite the extreme complexity of interactions in the field of forest management and use, sometimes just a few strategically positioned levers, including economic instruments, can bring about a marked change in operators' attitudes. How to select these levers and orchestrate their deployment is a deserving topic for future research. ■

© D. Depommier

Carbon trading could benefit rural communties and promote village plantations.

To find out more, read:

Karsenty, A. 2000. *Economic instruments for tropical forests. The Congo Basin case.* CIFOR, CIRAD, IIED, 2000.

Also available in French: *Les instruments économiques de la forêt tropicale: Le cas de l'Afrique centrale.* CIRAD, Montpellier and Maisonneuve et Larose, Paris, 1999.

A Pangasius hypophthalmus (Ca tra) *breeder fish.*

© J. Lazard

Mekong catfish: Research leads straight to technology transfer

The artificial propagation of Mekong catfish, developed in 1995, has revolutionized aquaculture in Vietnam. National catfish production in floating cages has since increased from 15 000 to 50 000 tonnes per year. The sector is changing fast: fish rearing cages on the Mekong are proliferating, private fish hatcheries are being set up, processing industries are developing and producers are exporting to world markets. CIRAD and its Vietnamese partners are working on all aspects of this new industry, with the aim of building expertise throughout the commodity system.

Floating cages at Chau Doc on the Mekong River.

© J. Lazard

An important innovation

In Vietnam, freshwater fish farming accounts for three-quarters of the country's aquaculture production. In the early 1990s, the sector was ripe for growth in response to the high market demand for fish, but was held back by a number of constraints. In 1993, CIRAD, the French Institute of Research for Development (IRD) and the University of Agriculture and Forestry of Ho Chi Minh City began studies on various production systems: intensive floating cage cultures of catfish (*Pangasius bocourti* or *Ca ba sa*) on the Mekong River (in An Giang province), extensive rearing of catfish (*P. hypophthalmus* or *Ca tra*) in wastewater ponds (in An Giang and Dong Thap provinces) and intensive rearing of carnivorous fish in artificial lakes (around Ho Chi Minh City).

The initial results of these studies revealed the main bottleneck in the floating cage system, which was that fry had to be sourced chiefly from the wild (80% in Cambodia). These imports were illegal and fry prices were skyrocketing. In 1993, fry costs represented 55% of total production costs, which is an especially high share for intensive fish farming.

In 1994, as part of a PhD thesis, CIRAD began research on the artificial propagation of catfish. Breeding parents of the two main catfish species obtained from Can Tho University (CTU) and Agifish, a provincial fisheries company, were stocked in experimental cages and ponds. In 1995, catfish were successfully reproduced in captivity for the first time. In collaboration with IRD, CTU and Agifish, CIRAD produced 30 000 *Ca tra* and *Ca ba sa* fry.

CIRAD then supervised a second PhD thesis study, carried out by a Vietnamese teacher-scientist on methods for rearing fry of the two species. Both theses were defended in 1999 at INA-PG, a Paris-based higher education college. Agifish became a key partner and financed a third thesis, on improving broodstock management. This close partnership has helped consolidate Franco-Vietnamese relations. Some 10 field- or laboratory-based training courses have been organized, either for Agifish trainees in France or for French graduate students in Vietnam.

© J. Lazard

The Agifish fish hatchery.

Larval rearing and fish hatchery development

The two main *Pangasius* species have very different fecundity rates: a mature *P. hypophthalmus (Ca tra)* female produces 49 000 ovules per kilogramme of body weight, whereas a *P. bocourti (Ca ba sa)* produces only 4 700 ovules. The size and weight of ovules and eggs are inversely related to fecundity in the two species: 1 milligram per ovule for *P. hypophthalmus* and 4 milligrams for *P. bocourti*. This difference is explained by the much greater yolk material in *P. bocourti* eggs, which also affect larval feed requirements and survival rates. *P. hypophthalmus* larvae are smaller and more fragile, and are susceptible to the bacterium *Aeromonas hydrophila*. Moreover, they must begin feeding much earlier (20-25 hours after hatching) than *P. bocourti* larvae (48 hours). In addition, they are cannibalistic during the first few days after hatching. In controlled aquarium conditions, a diet of small live crustaceans leads to 90-95% larval survival for *Ca ba sa* but only 16-18% for *Ca tra* 10 days after hatching. *Ca ba sa* can also be fed a diet of inert feed, resulting in 80% survival. These results formed the basis for establishing the conditions for rearing juvenile Mekong catfish in floating cages. The low number of eggs produced by *P. bocourti*, combined with its high survival rates under intensive rearing conditions, facilitates rearing of fry of this species in artificial tanks. *P. hypophthalmus*, with its contrasting features, must be raised differently: 1 day-old larvae are stocked in large fertilised ponds where they find the micro-organisms on which they feed; 2 weeks later, they are given an inert feed made of fresh fish and snails. This type of nursery, which all local fish farmers can access, has been largely responsible for the boom in *Ca tra* fry production. In 2000, around 100 nurseries produced more than 100 million juvenile catfish.

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A small-scale hatchery: artificial tanks and (in the background on the right) egg incubators.


© J.Lazard

Harvesting fry in a private pond hatchery.

Rapid adoption

This research has led to a profound change in aquaculture in a Vietnamese region where fish farming is of major importance to livelihoods. Dynamic Vietnamese fish farmers showed how quickly they could adopt an innovation once they saw it as practical. Agifish constructed the first hatchery just 3 months after the first 30 000 fry had hatched under experimental conditions. The Mekong Company, another fisheries enterprise, followed suit. Many private hatcheries have now been set up with the technical support of Agifish technicians. Fry production has risen exponentially, reaching a total of 500 million *Ca tra* fry and 3 million *Ca ba sa* by 2000.

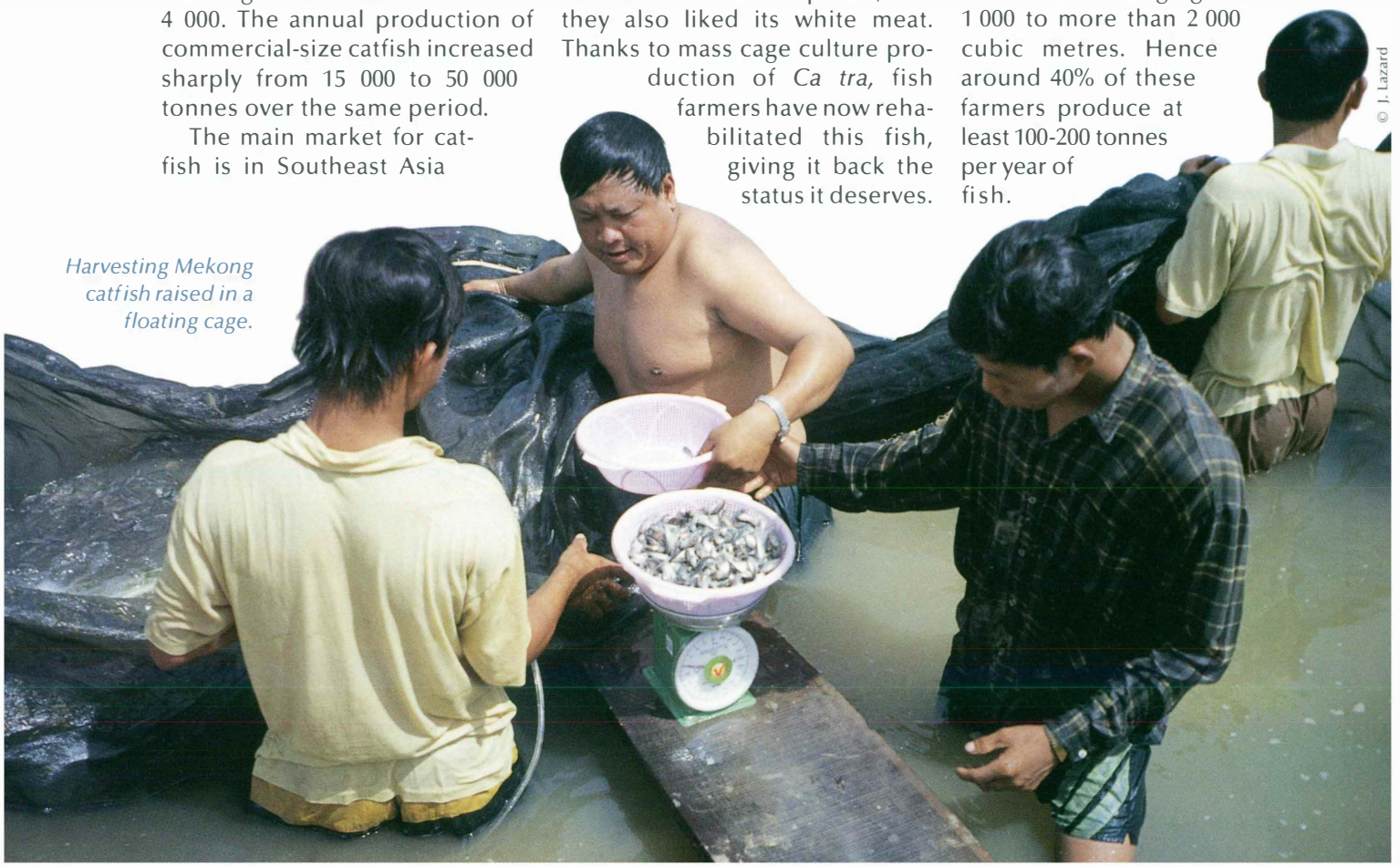
Between 1993 and 2000, the number of rearing cages in the Mekong Delta rose from 1 000 to 4 000. The annual production of commercial-size catfish increased sharply from 15 000 to 50 000 tonnes over the same period.

The main market for catfish is in Southeast Asia but demand is now growing in other parts of the world, including Japan, Europe and the USA. In response, Agifish is modernizing the fish filleting and freezing facilities in its processing plant, in compliance with the strict Japanese and European regulations on food safety. It has also just built a second fish processing plant.

Given the ready supply of catfish fry, fish farmers had no problems in adapting to these new species. Having at first reared only *Ca ba sa* in cages, they diversified their production and now rear 70% *Ca tra,* 20% *Ca ba sa* and 10% hybrids and other species. Before 1995, Vietnamese consumers preferred to buy *Ca ba sa* because this species was not reared in wastewater ponds, and they also liked its white meat. Thanks to mass cage culture production of *Ca tra,* fish farmers have now rehabilitated this fish, giving it back the status it deserves.

Industrial production by traditional methods

By the end of the production cycle, which lasts around 1 year, each cubic metre of cage contains around 100-200 kilogrammes of live fish. Three-quarters of all fish farmers in this region are rearing fish in a cage volume of more than 500 cubic metres, while half of them have volumes ranging from 1 000 to more than 2 000 cubic metres. Hence around 40% of these farmers produce at least 100-200 tonnes per year of fish.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Harvesting Mekong catfish raised in a floating cage.

By way of comparison, French fish farmers produce less than 100 tonnes of fish on average, and the 50 000 tonnes of fish produced in floating cages on the Mekong River is equivalent to the total rainbow trout production of France—the top ranking producer of this species in the world.

The profile of the average aquaculturist reflects this group's economic aspirations: 42% are under 40 years old, 70% have a secondary school education and almost 7% have been to university. Ninety percent of floating cages are owned by private family or small- to medium-sized enterprises, with the two large fisheries companies owning the rest.

Despite the industry's rapid growth, the rearing techniques used are still quite rudimentary. Fish farmers have an empirical approach to their discipline. They often rear excessively high densities of fish in their cages, apply blanket antibiotic treatments that are ill adapted to their needs, and use farm-made fish feed containing whatever byproducts are available at the local market (rice bran, fish meal, etc.). Indeed, their pragmatic management forms a marked contrast with the industrial scale of the output they achieve.

Endangered: knowledge of traditional fish feeding

The Mekong catfish producer's day begins early. Before dawn, fish farmers busily prepare fish feed on top of their floating cages. They may prepare more than 1 tonne of feed in a large pot. Once or twice a day, they feed their fish a moist dough consisting of rice, minced fresh fish and 'water spinach' (*Ipomoea aquatica*). This choice of ingredients is based more on cost considerations than on the real nutritional requirements of the fish, which are still poorly understood. Nevertheless, these fish farmers are practical people and, like the catfish species they raise, can readily adapt to changing conditions. The fish have a mean feed conversion ratio of 3.4 during the fattening period. There is thus considerable potential for improving feeding practices, which are critical to the success of this type of production system. Seventy percent of fish fatteners in this region still feed their fish in the small-scale traditional manner. There is a risk that economic pressures will endanger this practice by forcing a switch from farm-made feeds to industrially produced compound feeds. This transition should be managed carefully, since the results might not be entirely beneficial.

Feeding through a trap-door in the floor above the submerged floating cage. The dough mass is fed in the form of moist, individual balls.

How far can producers go without jeopardizing the future of the industry? The industry's major players fear that production could break down if the system fails to maintain a balance with the environment. Already, there have been several incidents of high catfish mortality due to sudden disease outbreaks. This concern was confirmed in a recent survey carried out by CIRAD in collaboration with Domenico Caruso Consulting, which revealed a link between rearing practices and fish mortality. The health status of caged fish is known to be an accurate indicator of the sustainability of the floating cage system.

Caged fish rearing practices could be enhanced by a strategy that takes account of the ecology of the fish and their pathogens. Stress would be reduce by improving the transportation of juvenile fish and making judicious use of therapeutic treatments. Diversifying the *Pangasius* species raised is also an avenue worth exploring, along with genetic improvement and optimizing reproductive performance and fry rearing. ■

Preparation and cooking of fish feed above the cage.

Food crop farmers were badly hit by a double crisis, ecological and economic. Some had to sell their farm implements, even their draught animals.

Indonesian **farmers** in crisis: Winners and losers

What is to become of Indonesia's farmers, as their country reels under the profound economic and political crisis brought on by the Asian panic of 1997?

For food crop farmers, the past few years have been a nightmare. Farmers who produce crops for export, in contrast, enjoyed a brief respite. Their produce could have helped put the Indonesian economy back on its feet, but the precipitous decline in world agricultural prices has wiped out the brief gains they made early on in the crisis. What measures should be put in place to spare the countries of the South the damaging effects of globalization?

In 1998, coffee smallholders, like most export crop producers, profited from the crisis. But the price of coffee, like that of most other agricultural commodities, fell sharply the following year and even further in 2000.

Huge windfall profits

A CIRAD research team has been working for more than 20 years in various Indonesian provinces. The team and its Indonesian colleagues, who witnessed the country's long period of steady growth before experiencing its sudden destabilization, seek to explain how farmers have coped with the crisis, why some have been able to take advantage of it and why others have fallen into even more abject poverty than before. What part did agriculture play in the Indonesian economy during the worst days of the crisis? And how could it help the country become prosperous again?

The financial meltdown that began in July 1997 in a number of Asian countries reduced the value of Indonesia's currency by two-thirds in less than 6 months. The US dollar, which was worth 2 500 rupiah in June 1997, had plunged to 15 000 rupiah 1 year later. It then stabilized at about 8 000 rupiah towards the end of 1998. Businesses went bankrupt and unemployment rose to alarming levels. At the height of the crisis, 100 million people—half Indonesia's population—were reduced to penury, whereas shortly before the crisis the country had achieved an enviable reputation for combating poverty.

The economic crisis produced a clear split between food crop farmers and farmers who grew crops for export. All of them, however, suffered from the terrible drought of 1997 caused by *El Niño*, then from the floods of 1998 induced by *La Niña*.

The crisis was an incredible but short-lived boon to most tree crop growers. The cocoa smallholders of southern Sulawesi, for instance, felt they were receiving manna from heaven. The harvests of 1997 and 1998, which were delayed by the drought, were quite good in the end because of the cocoa tree's short-term physiological response to such conditions. Earnings received an unexpected boost from the dollar exchange rate: the price of a kilogramme of cocoa, which had been 2 600 rupiah, began to rise in August 1997, reaching 6 000 rupiah by December, then soared in April 1998, culminating in an all-time high of 18 000 rupiah in July. These skyrocketing prices generated huge windfalls for growers. For a few months, they were able to sell cocoa on the world market at a price five to ten times higher than normal. Money abounded as never before.

Cocoa, coffee and pepper growers, and indeed all export crop growers, were the big winners during the crisis, although their profits varied. Even in cases where yields fell, profits were still high.

What did growers do with their windfall profits? Naturally, some began consuming frenetically, buying motorcycles or mopeds, cars, television sets and satellite dishes. They also invested in raising their social status by, for example, enlarging their houses or building temples. However, much of the windfall went into sound agricultural investments: growers bought large areas of forest or plantations, brought new land into production and replanted old plantations. To offset the devastating effects of the drought, they also increased their fertilizer purchases and, in some cases, acquired water pumps.

The increased resources of the 40 million people who directly or indirectly depend on export crops obviously had a beneficial effect on the country's economy, helping to maintain consumption and to keep the wheels of commerce turning while the crisis was at its worst for the majority of the population. The automobile and construction sectors, for instance, even though they were the first to be affected by the financial crisis, remained buoyant in areas where tree crops are grown. At this early stage of the crisis, it seemed as if the Indonesian economy could be put back together again by increasing export crop production.

© F. Ruf

Cocoa drying before being sold to a trader for subsequent export. In June 1998, the price of cocoa was five to ten times higher than a year earlier. In this Balinese village of Sulawesi, the windfall was used to build or improve temples and houses.


© P. Levang

Some families in transmigration areas lived on a single cassava-based meal a day.

However, these hopes were dashed by the sudden crash that followed. By the end of 1998, and especially during 1999 and 2000, as the rupiah slowly recovered, the international markets for agricultural commodities collapsed. A variety of factors were responsible: the currency devaluations in a number of developing countries, including the serious depreciations throughout the rest of Asia; the overproduction of the 1990s; the underlying poverty of governments and of smallholders, who have to plant crops regardless of market prices; and, in some commodity markets, the lack of competition among the few remaining agrifood companies, which probably drove prices down.

This was the real time of crisis for Indonesia's smallholder tree crop producers, especially since the drought had inflicted lasting damage on some plantations and yields had fallen sharply. Despite this, some traces of the boom times remain, and investments made during the brief period of prosperity are helping to support growers during the current critical phase.

The story is very different for food crop farmers and their families—some 80 million people. When the crisis struck, the prices of farm inputs tripled and markets were severely disrupted, giving rise to shortages. The lack of inputs, the drought and then the floods, as well as locust plagues in some provinces, substantially reduced production. Although close to self-sufficiency for some 15 years, Indonesia today imports huge quantities of rice.

Until the summer of 1998, the government—as it often had in the past—intervened to peg the rising prices of food crops, releasing public stocks in order to minimize imports. But when this stabilization policy could no longer be sustained, domestic food prices skyrocketed as the pain experienced by smallholders began to be felt by consumers too.

The impact of the crisis on food crop farmers varied considerably depending on the size and location of their farms.

The 10 to 20% of farmers with enough land to generate surpluses despite climatic fluctuations benefited from the price hikes and boosted their incomes.

Unfortunately, a far larger number of farmers have tiny farms that barely produce enough to feed their families. These farmers saw their off-farm employment opportunities, vital to supplement their incomes, vanish overnight. The crops they harvested were not sufficient for the family's subsistence. They sold first their non-essential assets, then their farming implements, even their buffaloes—and as a last resort borrowed money from loan sharks. It

Selling the farm implements


© F. Penot

Discussion with a group of Dayak farmers on rubber prices and the economic impact of the crisis in West Kalimantan.

Rice growers suffered not only a sharp fall in production but also from the pegging of food prices, held artificially low by government policy.


© E. Penot

Indonesia's agricultural diversity helped it survive the crisis.

will take years for these unfortunate farmers to recover from the penury to which they have been reduced. Many may have to give up farming altogether if they suffer another poor harvest.

How will agriculture be able to recover and re-establish itself as a driving force in the convalescing Indonesian economy? Some solutions are to be found within the country, while others depend more on the international community.

Over the past 30 years, Indonesian small-scale farmers have demonstrated their ability to work hard and to innovate, successfully achieving food self-sufficiency and substantially boosting exports. To capitalize on this ability, they should now be given increased access to land, credit, services and new technology. Indebted farmers must have access to the inputs they need to increase and stabilize their crop yields.

Need for regulatory mechanisms

However, the problems of Indonesia's farmers must also be seen from a broader perspective. In theory, one of the virtues of free markets is that they are self-regulatory. But what is actually happening? When Indonesia opened its doors at a time when the domestic economy was healthy, capital poured into the country. There was little interest in productive investments and a speculative bubble quickly formed, generating huge profits for a small group of businessmen.

Social justice

The 'Asian flu' that gripped the region's financial markets in 1997 triggered an economic and political crisis, which only exacerbated investors' lack of confidence. Indonesia's currency began to slide, triggering further problems and plunging the country into a deeper crisis. When they behave irrationally in this way, markets cease to play a regulatory role and an entire people may be penalized.

At the same time as it accepts liberalization, the international community should establish regulatory mechanisms that will attenuate temporary crises of this kind. In this way, the domino effect of a financial crisis precipitating economic and social crises can be avoided.

As regards the part played by international agricultural markets, demand is now concentrated in the hands of a few buyers who deal with a multitude of separate, unaffiliated smallholders—a situation that creates a serious imbalance of power. Cocoa traders, for instance, have almost all disappeared and three large processing companies control the world market.

For the time being, there is still keen competition between these groups, each of which aspires to increase its market share. This should normally lead to an increase in producer prices, but what the Asian economic crisis seems to demonstrate is that the general downturn in agricultural products is accelerated by globalization.

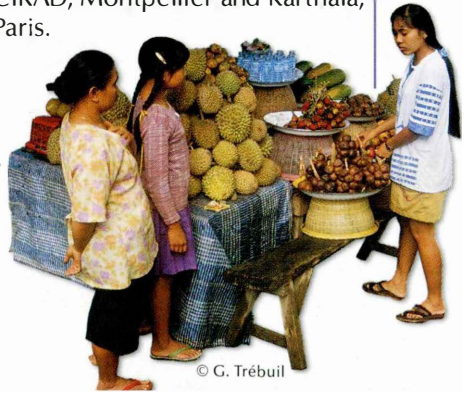
Although there is no need to assume any collusion between them, the reduced number of buyers has exerted a downward pressure on prices in a country whose currency has depreciated—and the entire world market has followed suit. This is almost certainly one of the factors that triggered the spectacular fall in commodity prices that has occurred since 1998. Just as Indonesian planters were beginning to help their country back on its feet, this slump in prices has stopped them in their tracks.

Establishing farmers' associations at national, regional and world levels could help to right the imbalance of power between producers and buyers. Is this idea merely Utopian? The Asian crisis has been a sharp reminder of just how crucial such associations are. We need to globalize social justice, not just markets. ■

To find out more, read:

Gérard, F. and Ruf, F. (eds). 2001. *Agriculture in crisis: People, commodities and natural resources in Indonesia, 1996-2000.* CIRAD, Montpellier and Curzon Press, UK.

Also available in French:
Agricultures en crise : populations, matières premières et ressources naturelles en Indonésie, 1996-2000.
CIRAD, Montpellier and Karthala, Paris.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Cocoa tree bearing fruit.

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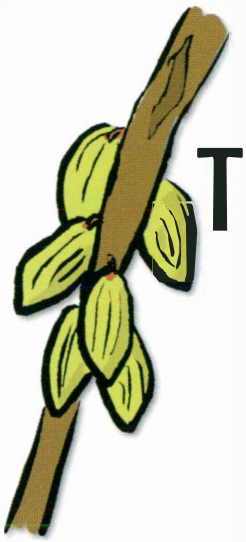


The fight against *Phytophthora*: Understanding and enhancing resistance in cocoa

Black pod disease, caused by *Phytophthora* fungi, is responsible for cocoa production losses averaging 30% worldwide and ranging from 50 to 80% locally. Breeding *Phytophthora*-resistant cocoa varieties is the major component of an integrated approach to disease management that will reduce the use of fungicides, ensure satisfactory incomes for growers and stabilize the cocoa market. Understanding the genetic basis of resistance is essential for developing breeding strategies, together with the molecular tools that will increase breeding efficiency.

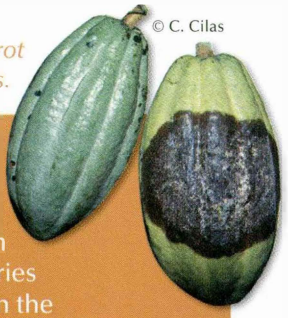
Phytophthora-infected cocoa pods.

© M. Ducamp

Cocoa resistance to *Phytophthora* is partial, polygenic and transmitted additively. This means that it is possible to improve cocoa yields by 'pyramiding' or combining resistance genes from different sources. Nevertheless, improving tree crops such as cocoa involves major constraints in terms of both time it takes years before yields can be assessed and space large areas are required for growing the trees. Are there any tests that can reliably be applied to assess resistance at an early stage of growth, thereby overcoming these constraints? How best to set about breeding varieties with better resistance? CIRAD and its partners have addressed these questions and achieved results that are now being applied in several international projects: they have developed an early leaf test, conducted preliminary screening of clones for their resistance to different *Phytophthora* strains and undertaken genetic mapping to pinpoint the genes for resistance. This latter initiative could eventually lead to marker-assisted selection.

A leaf test at the nursery phase

Resistance to *Phytophthora* in cocoa is assessed either in the field, by determining pod rot rates over several harvests, or in the laboratory, by artificially inoculating pods or disks of leaflet material obtained from 60-day-old plants. This latter test was developed using an experimental design that avoids bias from environmental effects. It can provide early estimates of inherited resistance in crosses or parents used in breeding programmes. In Cameroon, scientists have already planted families and hybrids pre-selected using the test. Field observations of black pod rot infestation will enable them to confirm resistance in these varieties, to recombine plants of interest and to guide research on the epidemiology of the disease. Once it is in use by CIRAD's partners, early leaf testing should considerably shorten the breeding cycle and hence the time taken to provide growers with improved planting materials that no longer require so many chemical treatments.



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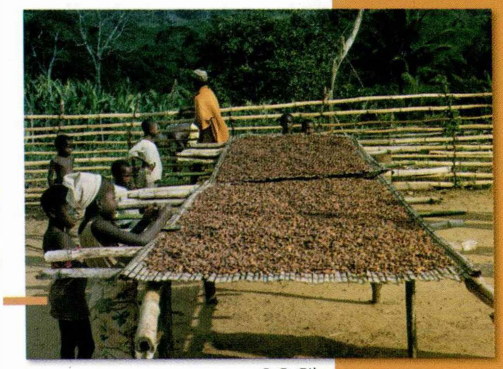
How the rot spreads.

Synergy through partnership and multidisciplinary research

Launched in 1995 with funding from the Association of the Chocolate, Biscuit and Confectionery Industries of the European Union (CAOBISCO), our project on the genetic basis of resistance to *Phytophthora* diseases combines strategic research with a strong focus on the needs of producers, processors and consumers. The countries involved are current or long-standing leaders in the cocoa industry: Côte d'Ivoire, the world's largest producer (1.2 million tonnes per annum), Cameroon, which has suffered the greatest losses due to pod rot, and Trinidad and Tobago, where the largest international collection of cocoa germplasm is located.

A highly successful scientific partnership was established between the Cocoa Research Unit of Trinidad and Tobago, Côte d'Ivoire's National Agricultural Research Centre (CNRA), Cameroon's Institute of Agricultural Research for Development (IRAD) and CIRAD's departments of Tree Crops and Advanced Methods for Innovation in Science. Among the factors that have led to success are the careful planning that has gone into the research—including definition of the roles of each partner, clear delineation of each project phase, regular meetings to coordinate activities and monitor progress, and responsive and competent involvement of CAOBISCO scientists—and the high degree of commitment among participating researchers to a long-term multidisciplinary project that combines cutting edge science with a strong emphasis on the application of results. Some of the project's results have already been published in international scientific journals, three PhD theses have been written and a synthesis of the project's findings will be published in English in late 2001.



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Natural drying of cocoa beans.

Resistant parents are now available to all the project's partners. These plants were selected for their good levels of resistance to several strains of *Phytophthora*. The selections were made on the basis of an early leaf test on 160 clones and 3 500 plantlets derived from 75 new crosses, and also by assessing field resistance in some 4 000 adult trees. They are now being maintained in nurseries or in the field in partner countries, where they represent an important resource for future research. Trinitario cocoa varieties generally show the greatest susceptibility to black pod disease, while upper Amazonian Forastero clones such as Sca 6, P 7, Pa 150 and T85/799 are resistant and will undoubtedly be used to breed varieties with improved resistance.

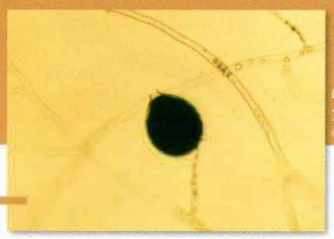

© D. Paulin

A harvest completely destroyed by Phytophthora.

The sharing of research results and planting materials should lead to more widespread progress in genetic enhancement in partner countries. Eventually, it may reduce the impact of *Phytophthora* diseases, which are a major cause of yield losses in cocoa. Whether resistance to *Phytophthora* is actually expressed in the plant depends on environmental factors and other biological traits, such as length of the pod ripening and harvest periods, in addition to inherited resistance. Inherited or true genetic resistance involves mechanisms that enable the plant to recognize the pathogen, to resist its invasion and to fight it off once it has invaded. These mechanisms raise several questions. What system does the plant have for recognizing and resisting the pathogen? How variable is this system? In clones with similar levels of resistance, are identical or different genes involved? What part is played by inherited resistance, as opposed to the other components of resistance? And are the same genes responsible for resistance to all *Phytophthora* species? Mapping the 10 chromosomes of cocoa and identifying the areas of the genome responsible for resistance could provide answers to these questions.

Phytophthora, an evolving pathogen

The main *Phytophthora* species that cause cocoa pod rot are *P. palmivora* (found throughout the world), *P. megakarya* (responsible for considerable pod damage in Africa) and *P. MF4 capsici* (prevalent in the Americas). The project included a detailed analysis of the virulence of many pathogen strains using the early leaf test, and of the evolving genetic diversity of these strains, which was determined using isoenzyme markers and random amplified polymorphic DNA (RAPD) analysis. Two distinct *P. megakarya* populations were identified, one from West Africa and the other from Central Africa, along with a number of highly virulent hybrids in the Nigeria-Cameroon border area. Regional infestation patterns can change rapidly, as already noted in cocoa plantations in Ghana, where *P. megakarya* replaced *P. palmivora* between 1989 and 1998, leading to an increase in virulence. Côte d'Ivoire may soon be similarly affected. Few specific interactions were noted between the different cocoa clones and pathogen strains, but there were some cases (three strains from West Africa). The results of the project's analysis did not, therefore, change the established classification of cocoa clones for resistance to isolates of the two pathogen populations and to *P. megakarya* hybrids. No specific interactions were observed with respect to *P. palmivora*, so any isolate can be used in inoculations to assess tree resistance provided its virulence is suited to the situation in the region where the pathogen is present. Studies on interactions between *P. palmivora* and *P. megakarya* are still under way, but the initial results suggest that clones bred for resistance to *P. palmivora* could also be effective against *P. megakarya*, at an equivalent virulence level.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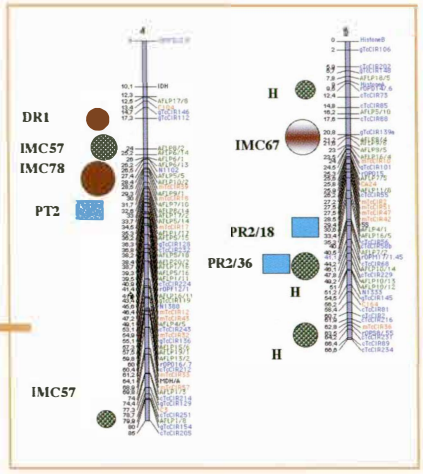
A Phytophthora megakarya *sporocyst.*


© M. Ducamp

Early leaf test to assess the resistance of cocoa clones, scored on a disease susceptibility scale of 0 to 5. Leaf disks (15 mm in diameter) are placed in trays and inoculated with Phytophthora *spores. Symptoms are checked after five and seven days of incubation at 25°C.*

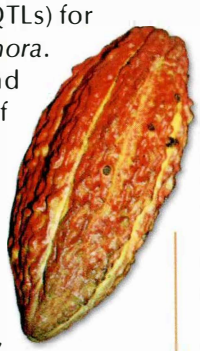


The cocoa genome's chromosomes 4 and 5, on which QTLs for resistance to Phytophthora were detected. Candidate resistance genes were also located in the same regions as QTLs associated with resistance in other crops: PT2 is homologous to the rust resistance gene in wheat and the Pseudomonas syringae resistance gene in tomato, while PR2 QTLs correspond to defense proteins (glucanases).

Genetic mapping reveals the secrets

A genetic map of cocoa was made using various kinds of molecular marker, including restriction fragment length polymorphism (RFLP), amplified fragment length polymorphism (AFLP), isoenzyme and microsatellite markers. The map is now saturated with these markers, which are being used by scientists at CIRAD and a French national gene sequencing centre to identify the genes that code for relevant traits. The scientists are developing as many microsatellites as possible, since these markers are relatively easy to use and can be handled by most laboratories, including those based in the tropics.

A study of about 10 progeny, whose resistance had been confirmed in the field or by leaf tests, led to the identification of several quantitative trait loci (QTLs) for resistance to *Phytophthora*. These QTLs are found in different parts of the genome in different cocoa clones. For example, one QTL linked with field resistance was located on chromosome 1 in clone UF676, another on chromosome 10 in T60/887 and a third on chromosome 4 in IMC78. Inoculating the same progeny with different *Phytophthora* species revealed QTLs that are common across species and others that are species-specific. These results are important for breeding clones with multiple resistance to *Phytophthora* species, even if not all the species are yet present in the area targeted for planting.



The fact that different *Phytophthora* resistance genes were detected in different clones indicates that resistance genes could probably be pyramided to provide improved resistance. Improved varieties could be developed quickly and with a high degree of accuracy, using the markers developed for QTLs associated with black pod resistance. After controlled crossing, plants containing resistance genes pyramided from different parents can be identified at the nursery phase, again using markers. Marker-assisted selection of this kind will greatly enhance breeding for resistance to *Phytophthora*.

Our genomic approach was further refined through the use of cocoa DNA segments containing homologues of genes known to code for disease resistance in other crop species, such as tomato, rice, tobacco and wheat. Some of these genes are located in the same areas of their respective genomes as are the QTLs associated with resistance to *Phytophthora* in cocoa. These homologous DNA segments may well contain candidate genes for *Phytophthora* resistance. They may also be implicated in resistance to other cocoa diseases, such as witches' broom and monilia pod rot. These lines of research could shed further light on the mechanisms involved in resistance to *Phytophthora*. ■

© C. Cilas

A cocoa plantation.

Homology between a rust resistance gene in wheat (LRK10) and a cocoa DNA segment. Vertical bars link homologous regions in the two DNA sequences (there is 62% homology between them). This segment was mapped in the same chromosome region as several QTLs for resistance found in the cocoa progeny. It may well contain a candidate gene accounting for the share of resistance associated with this region.

Departments and programmes: Major achievements

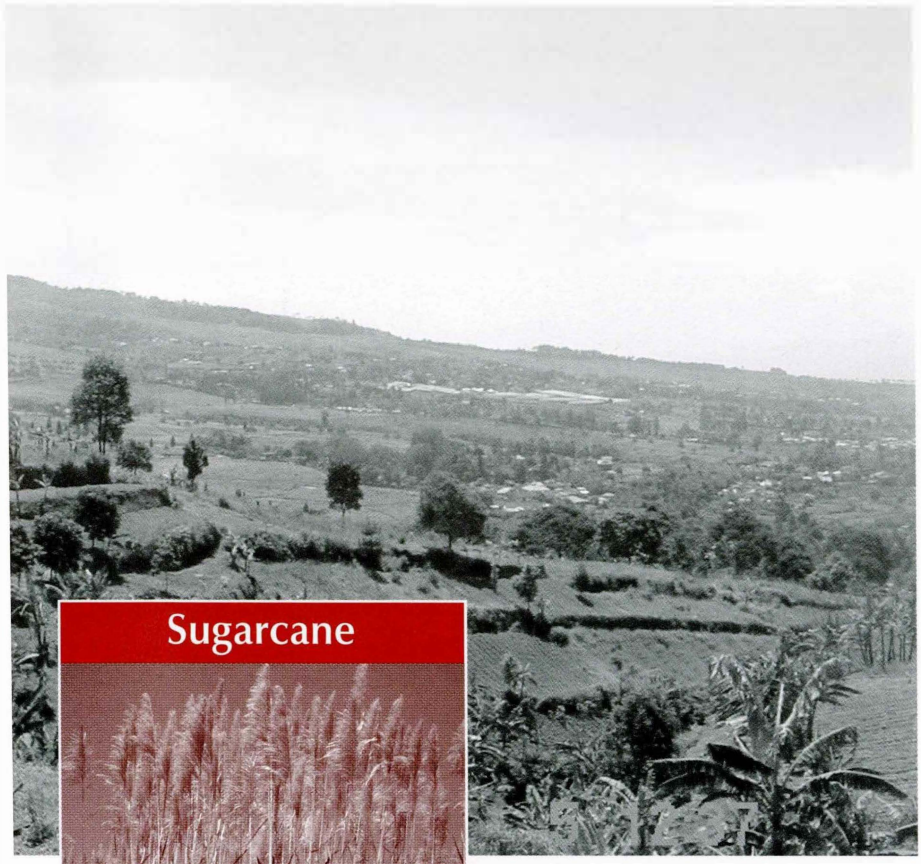
Annual crops

Agricultural landscape near Bogor, Indonesia.

© F. Forest

The research on food security undertaken by CIRAD's Annual Crops Department in 2000 focused on several crops: rice and so-called secondary cereals—millet, sorghum and fonio—in addition to edible groundnut, yam and taro. It covered smallholder production, the quality of crops grown for local consumption and for export, and storage and processing methods. It addressed issues throughout the commodity system, through projects ranging in scope from genome analysis to the organization of marketing in a specific cropping area. Work was conducted on plant breeding, field production, crop collection after harvesting, and marketing. Product quality assessment and research on new products provided further support to individual commodity systems and their markets. The department is also conducting research on the sustainability of production, notably on sugarcane farms in the French overseas departments. The need to boost crop production in the countries of the South receives equal emphasis to the environmental concerns raised by production: we conduct work on the development and extension of cropping systems based on direct seeding into a permanent mulch cover, and on preserving biodiversity by introducing a wider range of materials into highly productive cropping systems.

CIRAD's scientists have been posted at several centres of the Consultative Group on International Agricultural Research, where they work in close collaboration with the international research teams of the host centre. New or strengthened collaborative arrangements with various national agricultural research systems have enhanced the potential for multidisciplinary research on cropping systems and for regional networking. An increasing number of the department's scientists are involved in projects outside mainland France, especially in Africa and Southeast Asia. Partnerships with the private sector have been strengthened, especially with the creation of an African sugar producers' network.



Sugarcane

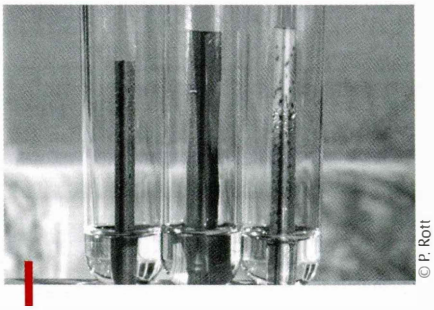
© R. Fauconnier

Our sugarcane programme was restructured around specific themes—genome analysis, breeding, crop protection and production systems—so as to strengthen our research and support activities and to diversify our international partnerships. Productivity-orientated projects were consolidated through the signing of research agreements with a number of French overseas departments. New partnerships were launched in Africa and in Latin America, with CIRAD scientists being posted to genomic research laboratories, research centres and large-scale sugarcane plantations. Foreign scientists are also now working for the programme.

Identifying genes for agronomic characters

The genetics of sugarcane is complex because of the high number of chromosomes in the genome (100-130) and its interspecific hybrid origin. The genetic factors responsible for desirable traits are still poorly understood, so molecular marker studies are particularly useful as a means of improving our understanding of heritability. In 1995, evaluation and molecular mapping of the progeny of the R570 cultivar led to the first ever identification of a major sugarcane gene. This gene confers resistance to rust, a disease caused by the fungus *Puccinia melanocephala*. Accurate markers are being developed and gene cloning is under way, with financial support from the International Consortium for Sugarcane Biotechnologies. Molecular resources are being used for this purpose, namely libraries of large DNA segments of sugarcane and also of sorghum and rice—model species with a simpler genome that is similar to sugarcane in its basic structure.

Studies on the genetic determinants of quantitative traits in sugarcane require sophisticated analytical tools because of the many chromosomes potentially involved and the extent of genotype x environment interactions. The first large-scale study of this type was undertaken by CERF, a sugarcane breeding centre in Réunion, and by CIRAD, using cv R570. For each of the components of yield studied—sugar content, plant height and diameter—between 7 and 12 quantitative trait loci (QTLs) were identified, each having a relatively weak effect on the expression of the relevant trait. Further studies are required to confirm the presence of these QTLs and to narrow down their locations. These will include large studies on expressed sequence tags, such as the one carried out by FAPESP, a foundation that supports research in São Paulo State of Brazil, with CIRAD's active involvement. The studies will identify many candidate genes for further testing.



© P. Rott

Rust spores on sugarcane foliage inoculated with Puccinia melanocephala.

Sugarcane production in the highlands of Réunion

Sugarcane production in Réunion's highlands has never been widespread. According to the literature, a quarter of the island's area under sugarcane is in the highlands, which account for one-fifth of total production. The area is, however, shrinking rapidly, with fields being returned to fallow due to the lack of varieties adapted to the harsh conditions of the highlands.

Developing highland sugarcane production implies improving roads and transport, mechanization, farm management and supplies to sugar factories. Labour productivity and crop yields must also be increased. Supplementary irrigation and organic fertilizers can boost yields, but they require the use of scarce resources generally reserved for high added-value crops.

In contrast, better management during the critical period before canopy closure is a more rewarding line to pursue. This period ranges from 2-3 months at sea level to 7-8 months in the highlands. Weed infestation increases with altitude, to such an extent that it becomes the main constraint mentioned by farmers. Further, the risk of erosion increases and the yield potential decreases as the productive phase of canopy cover is reduced. Two complementary techniques—reducing the distance between rows and increasing the period between harvests—could alter the length of this phase. An initial series of trials revealed that inter-row spacing, which had no effects at low altitudes, was negatively correlated with yield at 500 metres elevation, with a mean annual increase of 25 tonnes per hectare when it was reduced from 1.5 to 0.9 metres.

© R. Fauconnier

Réunion's highlands account for one-fifth of the island's production.

An experiment to compare yields of 12-, 18- and 24-month crops is under way. Trials on reduced inter-row spacing and the length of the cropping cycle have been established on smallholdings to assess the feasibility of these techniques and the perception of the risks associated with them. The results are being fed into the sugarcane growth model developed in Réunion, with the aim of applying the techniques to the island's other main sugarcane growing areas.

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Tillers of sugarcane variety FR80, in Côte d'Ivoire.

African sugarcane breeding network

At the first Regional Workshop on Sugarcane Breeding in West and Central Africa, held in October 1999 at Yamoussoukro in Côte d'Ivoire, sugar industry representatives from the region's French-speaking countries, private-sector companies and research institutes asked CIRAD to coordinate preparatory activities and to formulate concrete proposals for the establishment of a sugarcane breeding network.

Several sugarcane breeding centres would welcome the opportunity to promote their new varieties through a network, including CIRAD in Guadeloupe, CERF in Réunion, the Mauritius Sugar Industry Research Institute and the West Indies Sugar Cane Breeding Station in Barbados.

Data from variety trials carried out at various locations in the region over the past 15 years were collected to analyse the effects of genotype x environment interactions in different zones. Results obtained by SN-SOSUCO, a new sugar company in the Banfora sugar belt of Burkina Faso, and by SUCRIVOIRE, in the Zuénoula

sugar belt of Côte d'Ivoire, indicated that breeding is best conducted initially in the area where the varieties are to be grown.

As requested by its members, the network will be hosted by a producers' association, which will pool members' resources to create a regional breeding programme. A network charter and operational guidelines have been drawn up and will soon be presented to members.

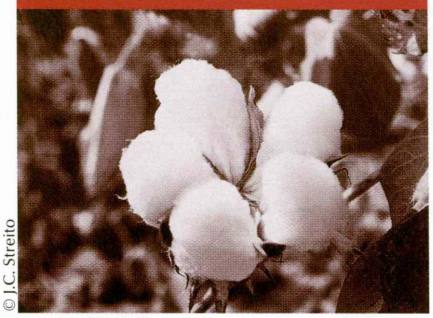
Sugarcane pathology

In 2000, CIRAD and the Mauritius-based International Society of Sugar Cane Technologists (ISSCT) copublished a new book and CD-ROM on sugarcane diseases, entitled *A guide to sugarcane diseases*. The book, which is in CIRAD's *Repères* series, was edited by P. Rott, R.A. Bailey, J.C. Comstock, B.J. Croft and A.S. Saumtally.

The book provides up-to-date information on research findings and practical aspects of sugarcane disease control, while the CD-ROM contains an electronic version of the book, together with multimedia software to support disease diagnosis and control, illustrated with many photographs.

CIRAD's new book on sugarcane diseases.

Cotton



© J.C. Streito

Our cotton programme aims to bring about lasting improvements in the competitiveness of the cotton sector. This involves adapting crop management practices and planting materials to meet growers' increasingly diverse needs and developing high-quality products and byproducts for different markets. Given the formation of new cotton growers' groups, it also involves gaining a full understanding of the enterprises involved and assisting them in their organizational and institutional development.
Research projects are developed collaboratively at regional level in Africa and Latin America. They include new partners alongside long-standing ones.

New cotton cropping strategies

In 2000, partners from the South became involved in a new drive to promote interdisciplinary research on cotton. The challenge was to bring together researchers' expertise in different fields in ways that would allow the development of technical recommendations appropriate to the diverse conditions encountered in cotton cropping areas.

Three multidisciplinary regional research thrusts were established or strengthened with the support of partners from the South and of the French Ministry of Cooperation. In Latin America, a team of four researchers (an agronomist, two cotton breeders and an entomologist) is working with COODETEC, an association of cooperatives in Paraná State in Brazil, and with the Ministry of Agriculture in Paraguay. In Benin, a three-member team (an agronomist, a cotton breeder and an entomologist) is collaborating with INRAB, Benin's agricultural research institute. And in Cameroon, a team of four (a general agronomist, an agronomist specialized in cotton cropping systems, a breeder and an entomologist) is collaborating with IRAD, the Cameroonian agricultural research institute. A fourth team (consisting of an agronomist, an environmental economist and an entomologist) is to be hosted at IER, the Malian institute of rural economics.

© M. Fok

The new approach to cotton production is also influenced by other management models: here, a topped plant in China.

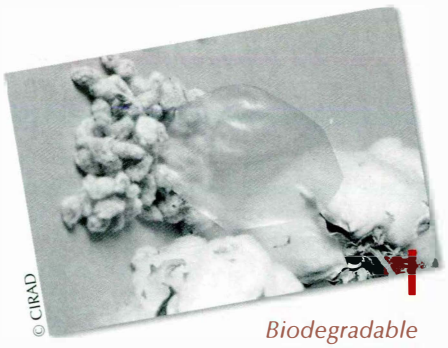
By way of example, the team in Benin is proposing a package of interventions designed to address the problems associated with the sector's changing structure, the reduced availability of labour, the decline in the use of inputs and the increasing crop losses caused by pests. Results have been

obtained in various fields, including environmentally targeted breeding, sustainable pest control, rational fertilizer application, the use of growth regulators, labour-saving herbicide applications and no-till cropping. These results will be used to develop new crop management practices in collaboration with SYSTEM, a joint research unit on tropical cropping systems.

With the exception of the initiative in Brazil, the regional thrusts are dealing with the technical problems faced by smallholders as the cotton sector is integrated following market liberalization. The Brazil initiative, in contrast, is extending a 'new approach to cotton cropping' to highly mechanized farms consuming high levels of inputs and more directly exposed to the pressures of globalization.

New uses for cottonseed

Our cotton technology laboratory is attempting to develop biodegradable packaging based on cotton proteins. Like synthetic polymers, these thermoplastic proteins can be shaped using techniques such as extrusion and thermoforming. A study is under way, in collaboration with a French higher engineering school, to assess the thermomechanical behaviour of raw cottonseed. The development of biodegradable films made from raw cottonseed meal would mean that short shelf-life materials such as single-use bags, mulching sheets and agricultural packaging materials could ultimately be produced on an industrial scale at competitive prices to meet specific market needs.



© CIRAD

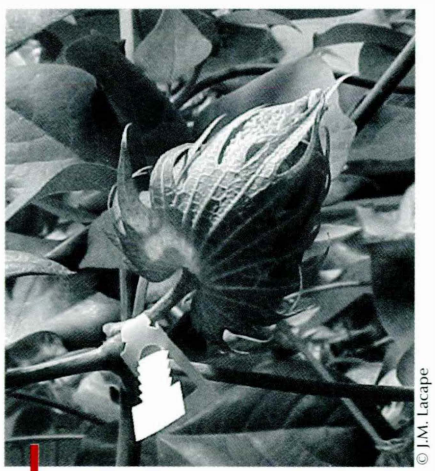
Biodegradable film obtained from cotton meal.

Research is also being carried out on 'active' cottonseed coatings based on cotton proteins. These coatings are themselves derived from cottonseed and can be supplemented with substances such as fertilizers or pesticides to enhance plant growth. Pesticides in such coatings are released gradually when the seed is moistened. The performance of coated cottonseed when challenged by pests and diseases is currently being field tested on large farms in Brazil and Thailand. The coatings have a targeted, slow-release effect that is limited to the immediate vicinity of the seed, making them more environmentally friendly than conventional pesticide treatments.

This research and its results have led to new joint research activities with partners in Brazil, Argentina and the Netherlands. These partners have developed a large research project on industrial-scale manufacturing of bio-degradable materials for agricultural applications—mulching sheets, packaging, composite materials, seed coatings—from cottonseed and cottonseed cake. This project will be launched in 2001.

Mapping the cotton genome

DNA markers are being used to support the transfer of fibre-enhancing alleles into the genome of *Gossypium hirsutum*, the main cotton species grown in the world. These alleles are derived from *G. barbadense*, the second most commonly grown species. This research should result in the creation of *G. hirsutum* lines with high fibre quality for use in breeding programmes. The method used consists of first crossing a *G. hirsutum* variety with a *G. barbadense* variety, then backcrossing repeatedly to the *G. hirsutum* parent. Individual plants from populations obtained from backcrossing are selected on the basis of QTLs for fibre quality identified in an earlier generation.



© J.M. Lacape

A cross between G. hirsutum and G. barbadense.

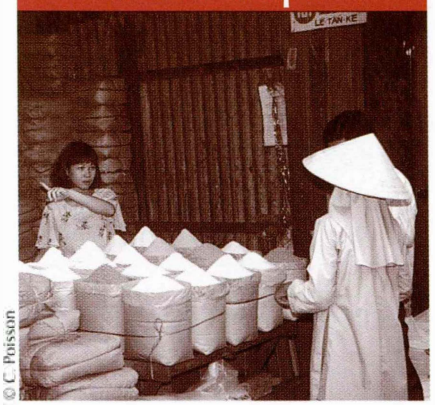
The first step was to analyse the population obtained from the first backcross. A map of the cotton genome was made, using 1000 molecular markers. The second step will be to select individual progeny of the backcrosses on the basis of molecular analyses. Actual breeding can begin once QTLs

associated with fibre quality have been identified, following the second backcross. Using the markers for these QTLs, it will be possible to track the introgression of segments of the *G. barbadense* genome in subsequent generations. The other markers shown on the map will help detect individuals that are genetically similar to the *G. hirsutum* parent.

One outcome of this research is the creation of the first integrated and saturated genetic map of the tetraploid cotton genome. The map shows 900 loci scattered over a total distance of around 5 500 centimorgans. This map is integrated in the sense that different types of molecular markers—restriction fragment length polymorphism (RFLP), amplified fragment length polymorphism (AFLP) and microsatellite markers—are used together for the first time, allowing comparisons with maps developed by other research teams in the USA. The saturated map covers all 26 chromosomes of the genome.

Partnerships have been established with universities in Belgium and the USA, with the aim of pooling map data and exchanging markers for the benefit of the whole international scientific community. A new international consortium, the International Cotton Genome Initiative, has been formed with the active involvement of CIRAD to facilitate exchanges and share results.

Food crops



© C. Poisson

In 2000, three main challenges were addressed through the research and other activities conducted by our food crops programme in partnership with local research organizations. The first is to increase smallholder crop production, through the development of improved varieties and agronomic practices adapted to local conditions. The second is to improve processing techniques throughout the commodity system, so as to adapt products to market demand. The third is to strengthen our understanding of commodity systems and markets in order to aid decision making by stakeholders.

New sorghum varieties: high quantity, high quality

Sorghum is a staple food crop in the Sudano-Sahelian zone of West Africa, where it is mainly used to prepare *tô*, a thick gruel. Traditional varieties, mainly belonging to the guinea race, have ideal grain characteristics for making high-quality *tô*, but their yield potential is limited by their low harvest index. Recently developed varieties, mainly belonging to the caudatum race, have a higher yield potential but their grain quality is considered poor for making *tô*.

Sorghum improvement programmes have long focused on the difficult yet important task of breeding varieties that combine good agronomic traits with quality grain that satisfies consumers' tastes. Preparatory strategic research was necessary, to understand the physical and chemical properties and other characteristics of quality grain for making *tô* and to identify the genetic bases of grain yield and quality. The factors responsible for *tô* quality have now been identified and simple reliable tests have been developed to assess varieties for them during the breeding process. Several regions of the genome governing the main quality and productivity traits have also been located.

Using these results, together with the new tools of molecular biology, three breeding strategies have been developed: improving grain quality for *tô* in caudatum varieties, while maintaining or even increasing their yield potential; improving the yield potential of guinea varieties, while preserving their grain quality; and recombining traits of interest from both races through guinea x caudatum crosses. These strategies, pursued in partnership with national

© G. Trouche

Selection from a caudatum sorghum in Burkina Faso.

research groups in Senegal, Burkina Faso and Mali, have led to the development of new varieties that combine adaptation with good grain quality and high yield. These varieties, including CEF 322/53-1-1 (CIRAD 437) and CEM 326/11-5-1-1 (CIRAD 406), are being extended to farmers in Mali and Burkina Faso, while being tested in a further 15 African countries through the West and Central African Sorghum Research Network.

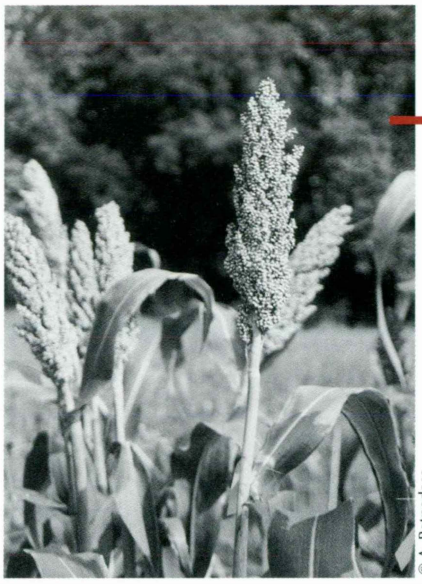
Integrated pest management in sorghum

Our project on integrated pest management in sorghum ended in December 2000. It was launched in September 1996, funded by the European Union (EU) and coordinated by CIRAD, with the collaboration of the University of Heidelberg in Germany, the Agricultural Research and Environment Institute (INERA) in Burkina Faso and the national Centre for Solar and Renewable Energy and the IER in Mali. The research carried out by the project aimed to reduce the high yield losses in sorghum caused by insect pests.

CIRAD was involved in research on plant-derived insecticides. In particular, the Centre characterized the toxicity of *Jatropha curcas* seed extracts against armyworm *(Helicoverpa armigera),* which attacks sorghum panicles but is also a well-known pest of cotton and vegetable crops.

The efficacy of pheromone trapping as a means of monitoring the population dynamics of the sorghum stemborer, *Busseola fusca,* was confirmed. The results obtained suggest that this technique may also be suitable for direct control of this pest.

However, the main emphasis of CIRAD's research was on varietal resistance. Since the genetic basis of sorghum resistance to head bugs was unclear, a genetic map of the crop was made using molecular markers derived from a cross between Malisor 84-7, which is resistant, and S34, which is susceptible. QTLs were detected for grain traits affected by bug attack, as measured in trials in Mali conducted on the progeny of a cross challenged by artificial infestation.



© A. Ratnadass

Selection from sorghum line CCAL 1/13, resistant to head bugs and midges, Mali.

Five promising sources of resistance to sorghum midges were found in 184 ecotypes from Burkina Faso, Cameroon, Mali, Niger and Senegal. New varieties resistant to midges, bug-mould complexes and leaf diseases were developed by pedigree selection.

Following evaluation on the research station and then in farmers' fields, CCAL 1/13-1-1 (CIRAD 441), a variety bred by CIRAD at the International Crops Research Institute for the Semi-Arid Tropics in Mali, was found to be of interest for eastern Burkina Faso on account of its dual resistance to midges and bugs and its excellent yields.

Recovering from crisis: rice in Madagascar

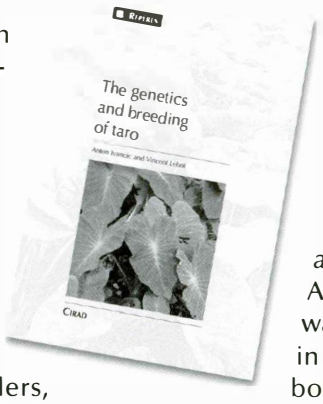
Rice production, a driving force in Madagascar's economy, has been in crisis for several years: production increases have been inadequate, per capita rice availability has fallen, imports have risen, yields have plateaued at a low level and there is poor market integration.

In response, the Malagasy Ministry of Agriculture and the Food and Agriculture Organization of the United Nations (FAO) asked for

© M. Barale

Rice trader in Madagascar.

CIRAD's support in developing a new policy towards the crop. A study of the sector, in the form of a large survey, was undertaken in six regions. Over 2 300 rice growers, rural and urban consumers, traders, large- and small-scale millers, wholesalers and retailers were interviewed.



Constraints and market failures were analysed from technical, economic and institutional perspectives. The results highlighted the inefficiency of rice markets, due to poor organization and the lack of roads and marketing infrastructure. The survey also confirmed the importance of rice in the Malagasy economy: the crop accounts for 12% of gross domestic product (GDP) and 43% of agricultural GDP, while 10 million people or two-thirds of the country's population are directly involved in its production.

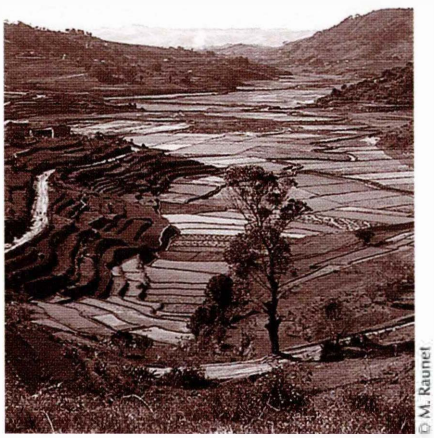
To help the Malagasy government define its rice development policy, two major strategies were outlined: intensifying production by efficient, specialized farmers in key high-potential areas; and poverty alleviation among subsistence farmers in less productive areas. Specific technical and economic proposals were put forward for each of these strategies. As one result of the study, a 35% tax was levied on rice imports in 2000 to help protect local production.

Taro genetics

Taro *(Colocasia esculenta)* is a starchy plant consumed by more than 400 million people worldwide. It is grown in a wide range of habitats for its starch-rich corm, for its leaves, which are eaten like spinach, and sometimes for its ornamental qualities.

In 2000, *The genetics and breeding of taro*, by A . Ivancic and V. Lebot, was published by CIRAD in its *Repères* series. The book covers the crop's taxonomy, botany, origins and distribution—and its genetic improvement.

Agrosystems



© M. Raunet

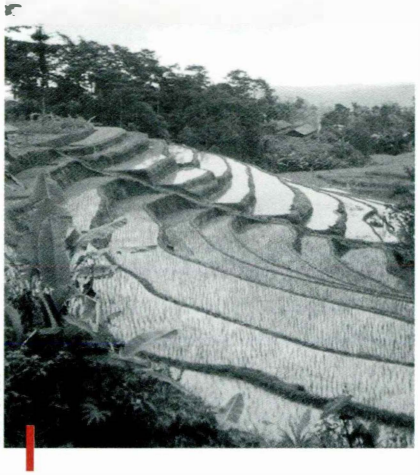
Our agrosystems programme adopts an approach that is firmly rooted in the practical problems faced by farmers while at the same time conducting methodological research with a range of stakeholders. This approach has given rise to major innovations, such as the design of sustainable cropping systems based on direct seeding into a permanent mulch cover, with minimum tillage. Decision support tools and crop management practices have also been developed to meet farmers' needs as they strive to increase their profitability.

Rural development in Laos

An initiative to promote rural development in Laos through studies on three toposequences is addressing the physical and socio-economic diversity of Sayaboury province. Sixteen farms covering a total area of 3 hectares have been studied. Research focuses on developing new ways of sowing crops that will reduce damage to the environment, on varietal trials and on the introduction of new planting materials.

Sorghum, millet and maize were sown at various dates between 20 August and 10 October to assess the ability of these crops to cope with fluctuating conditions at the end of the rainy season and to produce enough biomass to protect the soil at the onset of the next rainy season. A sorghum variety developed many years ago (IRAT 203), which combines high grain quality and drought tolerance, was introduced and appears promising for late sowing. Sorghum and millet sown at the end of the rainy season could be used to quick-fatten pigs and chickens and to supply factories producing livestock feeds. These crops, which have multiple uses as forage supplements, in fattening enterprises and as cover plants, and can easily be grown as a second crop in some production systems, are an attractive option for many farmers and traders.

A fourth toposequence will provide a basis for designing and studying new cropping systems based on direct seeding into a mulch cover. Programmes on paths and roadsides, and on diversification in rice growing areas, are also planned. The main varieties and plant cover techniques introduced will be showcased at the principal research station of the Laotian Agricultural Research Centre.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Rice terraces in Laos.

Amazonian savannas on CD-ROM

With EU funding, CIRAD and partners at the University of Londrina State in Brazil have developed an interactive CD-ROM entitled 'Savannas', on the sustainable management of tropical savannas in the Amazonian region. The CD-ROM will be disseminated to professionals in research, teaching and development in Amazon Basin countries, to provide an up-to-date source of knowledge as well as a new training tool. The French version, which was developed first, is currently being translated into Portuguese and Spanish. The CD-ROM includes a glossary of around 100 words, along with multiple choice questions at the end of the main chapters to assess the user's knowledge.

Navigation is facilitated by specially designed search systems. Users can consult cross-cutting themes or explore the CD-ROM at will, following a personal route that can be saved and even shared with other users. These new systems, developed in collaboration with a multimedia design agency, could be integrated in other products developed to promote scientific knowledge.

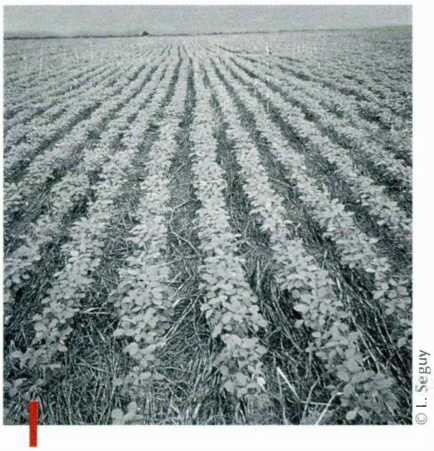
The CD-ROM is distributed by CIRAD, the University of Londrina State, and institutions belonging to PROCITROPICOS, a network of agronomists in the Amazonian region.

Promoting no-till cropping systems

At a meeting held in Paris in January 2000, agronomy research coordinators from CIRAD, the International Maize and Wheat Improvement Center (CIMMYT), the International Center for Agricultural Research in the Dry Areas, and FOFIFA, the Malagasy agricultural research institute, decided to create a network to promote no-till cropping systems: the Global Program on Direct-Sowing, Mulch-Based Systems and Conservation Tillage (GP-DMC).

The objective of the new GP-DMC network is to disseminate the innovative technologies developed to date and to provide farmers—especially the poorest ones—with options that will sustain and improve their agriculture by enabling them to generate resources on-farm, to reduce their use of inputs, to reduce the demands on their labour and to lower their investment costs.

In May 2000, the GP-DMC network was officially launched at a conference on sustainable agriculture held in Dresden, Germany and attended by representatives from 80 research institutions, non-government organizations (NGOs) and other professional bodies in agriculture. CIMMYT was asked to convene an *ad hoc* initial steering committee.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Soybean crop sown direct into millet straw, Brazil.

The network promotes the practical application of technical and scientific knowledge, while drawing and sharing lessons from experiences in the field. Any field initiative leading to applicable technical solutions that will facilitate carbon sequestration and enhance the cost-effectiveness of land and natural resource management will be considered by GP-DMC. In addition, interactions between smallholders, large-scale producers and institutional and political decision makers will be promoted to speed up the adop-


© F. Forest

Mechanized direct sowing of maize into soybean residues.


© R. Pirot

Direct sowing into a straw mulch using animal traction, Brazil.

tion of technical innovations and the implementation of appropriate policy interventions.

The GP-DMC network aims to instigate and support the development of a few testbed sites around the globe that will showcase sustainable agriculture practices and serve as a springboard for more widespread innovation.

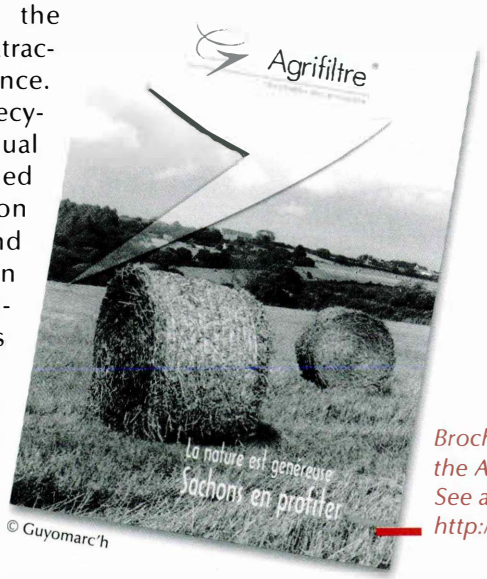
In 2001, CIRAD will take its turn at coordinating the network steering committee, establishing an international secretariat that will be based in Montpellier for an 18-month term.

On-farm treatment of livestock wastes

In 2000, the Agrifiltre process was adapted for the on-farm treatment of pig slurry, on the basis of research carried out over several years by CIRAD in collaboration with an animal feed company. This technology has two main components: the Agrifiltre reactor, a biofilter loaded daily with fresh straw, which traps suspended matter and phosphorus; and a standard nitrification-denitrification biological reactor, which eliminates nitrogen by releasing it to the atmosphere. Slurry processed through this system produces a solid compost that is easy to transport and has a high agricultural value, and a liquid suitable for spreading on local crop fields. The process has the added advantages of being performed at ambient temperature and of consuming only straw and a small amount of energy. Current average performances for reducing nitrogen and phosphorus concentrations in the liquid phase are around 83% for nitrogen and 60% for phosphorus. Investment and operating costs are around FF 6777 (€ 10.2) per cubic metre of processed slurry, for a quantity of around 5 500 cubic metres per year of raw slurry.

The industrial version of the process, as presented on the company's website (http://www.agrifiltre.com), will be installed for the first time at farms in Brittany as soon as the Loire-Bretagne Water Authority, which is responsible for controlling this form of pollution, gives its permission.

The process has also been modified to improve the phosphorus extraction performance. This involves recycling the residual sludge obtained by decantation in the second nitrification reactor. The initial test results suggest that nitrogen and phosphorus concentrations can be reduced by around 90% without increasing processing costs. This new version of the technology will also soon be evaluated by the water authority. ■



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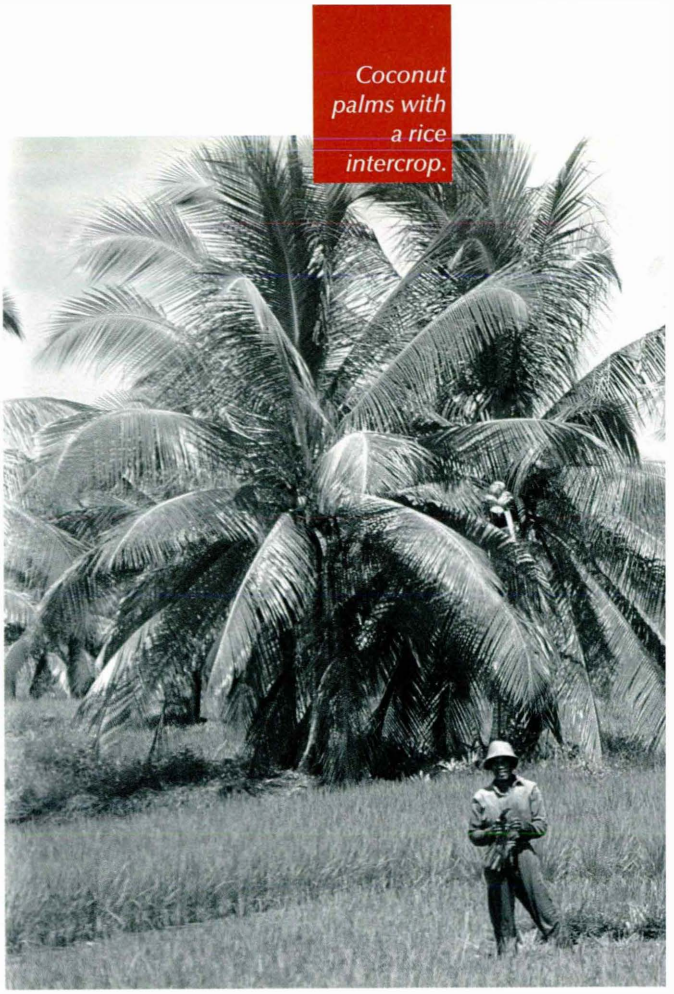
Brochure presenting the Agrifiltre process. See also the website http://www.agrifiltre.com

Tree crops



Coconut palms with a rice intercrop.

The new global context in which cocoa, coffee, coconut, oil palm and rubber are traded is marked by competition between different production systems and by considerable economic instability resulting from the deregulation of markets. In view of these trends, research at CIRAD is no longer geared towards developing standard cropping systems aimed at optimizing yields but rather towards helping farmers make the transition either to more intensive, specialized farming, in response to market demands and social and technical opportunities, or to a more extensive and more diverse system. With support from CIRAD's training service and from France's National Institute of Agronomic Research (INRA), we have developed a new approach to our research. We aim first to characterize farmers' existing practices accurately—the sequence of operations they follow and how they manage genetic diversity. This characterization is based on agronomic and agro-ecological diagnostic studies and on the development of simple conceptual models, which in turn allow researchers to model the transition from one management system to another.

Our new approach focuses primarily on family farms in developing countries, which account for over 85% of world cocoa, coffee, coconut and rubber output in volume terms. However, the decision support software that we develop can also be used to manage large plantations. We also pay special attention to four research themes with a strong potential for practical applications: food safety and quality control in cocoa and coffee; the commercialization of a mass trapping method for the coffee berry borer; the use of ethylene gas to stimulate latex production; and—a long-term project—genome mapping as a basis for marker-assisted selection in oil palm and coconut.

© D. Montange

Cocoa

© Projet cacao Equateur

Our cocoa programme focuses its research on five main issues: the sustainability of production; the integrated control of pod diseases; fine cocoa development; maintaining quality throughout the commodity system; and germplasm exchanges. For each of these issues, we operate by collaborating with other research groups (at universities or in national research institutes) and by involving stakeholder groups throughout the commodity system (producers, processors, exporters, chocolate manufacturers, quality control bodies, professionals in the industry and international organizations).

Agricultural systems analysis

At the Institute of Agricultural Research for Development (IRAD) in Cameroon, CIRAD supported a shift in the focus of coffee and cocoa research from the plant to the farming system. This shift has led researchers to take greater account of the factors that determine the decisions made by cocoa growers when developing innovations. Diagnostic surveys, off-station trials and action research are now their preferred tools. For example, a survey conducted in 1999-2000 in cocoa growing areas confirmed the existence of different cocoa production systems in different regions—pioneer fronts in Mbam and parts of the Southwest, rehabilitated orchards and diversified farms in parts of the South Central region. It also helped researchers identify the technological innovations needed by producers, particularly the characteristics of new varieties. A network of on-farm trials has been established to study the intercropping of cocoa with forest and fruit species. This is another example of the shift in methods made by IRAD's researchers.

© C. Cilas

Cocoa palms with a banana intercrop.

Improving Ecuadorian fine cocoa

CIRAD has now completed a project in Ecuador aimed at revitalizing the production of Arriba, an aromatic cocoa. Launched in 1995 in collaboration with the European Union (EU) and the Ecuadorian Ministry of Agriculture, the project has had an impact in three fields: research, rural development and the way the commodity system is organized. Over 100 genotypes, selected for their aromatic beans, have been collected. Postharvest processing techniques suitable for the Nacional variety, which is responsible for the scented taste of Arriba, have been developed and disseminated. For the past

year, producers' associations and cooperatives belonging to a national umbrella organization (UNOCACE) have been exporting their improved cocoa directly to major European chocolate manufacturers. Direct exports of this kind mean that producers are no longer dependent on the prices offered by local exporters and middlemen and they also receive the quality premiums paid to those who invest in rehabilitating their plantings. Lastly, the project has had an impact on all the stakeholders in the Ecuadorian cocoa market, who have now realized both the importance of quality in maintaining competitiveness and the need to cooperate with each other to protect their product. CIRAD has been asked to apply the same approach in other cocoa-producing countries, among them Venezuela.

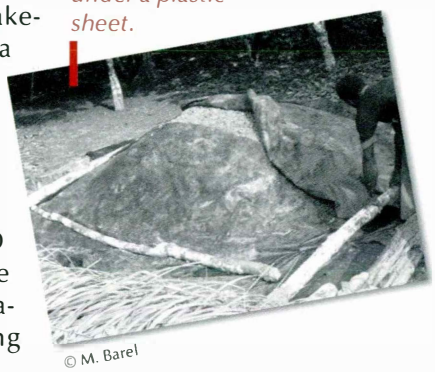
© B. Decazy

The Nacional cocoa variety in Ecuador.

Estimating fatty acid content

In Côte d'Ivoire, CIRAD has been asked to investigate the causes of a periodically occurring defect of cocoa butter, namely an increase in the free fatty acid (FFA) content over the permitted level of 1.75%. This research programme, launched at the end of 1999, involves the Ivorian private sector—particularly exporters and processors—and several CIRAD departments. Amongst other results obtained in 2000, the seasonal nature of the defect was confirmed, prompting several hypotheses as to its causes. These hypotheses will be tested during the 2000-2001 season. At the same time, work on the rapid appraisal techniques for measuring FFA contents revealed that there was a risk of overestimating the defect. Recommendations were subsequently made to the local buyers and exporters who carry out the tests. The quality of the approach used in Côte d'Ivoire prompted the European cocoa manufacturers' association (CAOBISCO) to entrust CIRAD with another research project, on the causes of ochratoxin occurrence in cocoa.

Fermenting cocoa beans under a plastic sheet.



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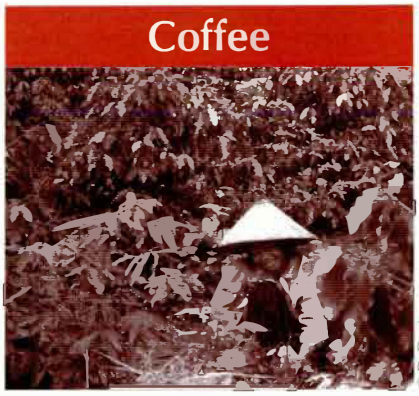
Coffee



© D. Durrs

Production constraints and difficult market conditions mean that coffee producers need to manage their crop flexibly in ways that will improve profitability. To respond to this challenge, studies are needed on the conditions under which innovations are successfully transferred to producers and accepted by them. The management of pests and diseases also needs to be improved. Specifically, there are plans to improve Robusta coffee-based systems by supplying growers with new hybrids tested for their quality characteristics. New hybrids are also a way forward for Arabica-based systems, where there is a need to combine sustainability and productivity.

Promoting new coffee varieties

CIRAD recently signed an agreement with several partners in Central America to test and distribute 19 Arabica hybrid and Nemaya rootstock varieties developed by a regional genetic improvement programme. The other signatories are the Tropical Agronomy Research and Training Centre (CATIE), the Ministry of Agriculture of the Dominican Republic and a number of national coffee organizations, including ANACAFE in Guatemala, ICAFE in Costa Rica, IHCAFE in

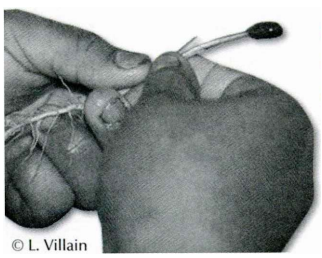
© D. Duris

Damage caused by the coffee leaf miner.

Honduras, PROCAFE in Salvador and UNICAFE in Nicaragua.

The agreement recognizes the co-ownership of these hybrid varieties and describes how they should be evaluated and distributed. Regional multi-location trials have been established and an application is being made for a certificate of variety protection for the most promising genotypes. Once the trials have been completed, in 2003, the signatories of the agreement will jointly promote the use of the material.

These hybrid varieties were developed by crossing commercial *Coffea arabica* varieties and Ethiopian wild genotypes. They have a higher yield potential than the commercial varieties grown at present. Their cup quality has been evaluated. A new rootstock variety, known as Nemaya, produced by crossing two *C. canephora* var. *robusta* genotypes, has been bred to provide grafted plants with nematode resistance.



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Grafting coffee plants.

Genetic modification for leaf miner resistance

A trial was planted in French Guiana in May 2000 to test a variety that has been genetically modified for resistance to leaf miners. The trial has two objectives: to compare the performance of adult modified trees and control plants, and to test the plants' actual resistance to leaf miners, which are the major coffee pests in South America and occur naturally in French Guiana.

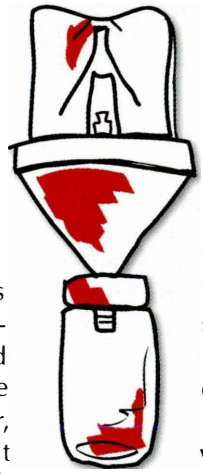
The choice of a site in French Guiana was prompted by this country's favourable soil and climatic conditions for coffee and the fact that the crop is very little grown there at present. Moreover, since coffee originated in Africa, it does not naturally hybridize with any of the plants found in Guianan forests. The initial results of the trial suggest that plant development is normal and that some plants do indeed have effective resistance against leaf miners. The trial will also throw light on gene flows and the interactions between these coffee trees and the Guianan environment.

The trial will continue until 2004, when the plants will be pulled up and burned. The coffee harvested will not be sold or distributed, as the variety has not been approved as safe for human consumption.

Trapping the coffee berry borer

Coffee berry borers are the main pest in all coffee-producing countries. Recent work showed that the damage they cause can encourage bean contamination by fungi that produce ochratoxins, which are highly poisonous to man.

Following 3 years' joint research on mass trapping of the insect and the development of a special trap, CIRAD and the Salvadorian producers' association, PROCAFE, have signed a contract to develop and market the trap, under the trademark Brocap®. The technology has been tested on a small scale to assess the impact of trapping on coffee production. This pilot phase, which took place in El Salvador, confirmed previous experimental results and led to some further modifications to the trap. The conditions for scaling up trapping and for mass-producing the trap successfully are now clear and will be used as the basis for a new agreement between the two organizations on how to market the technology.



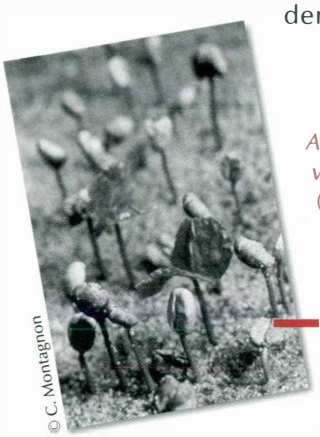
The new Brocap® trap.

High-yielding, uniform *Coffea canephora* hybrids

One of the main constraints to the production of *C. canephora* in Africa is the limited use of improved planting material—only around 10% in Côte d'Ivoire, for example. The main reason for this is that distributing clones in the form of cuttings is both complex and costly, whereas seedlings, which are also more familiar to farmers, are easier to produce and distribute. Nevertheless, hybrid varieties grown from seed typically yield 30 to 40% less than clones.

By applying the techniques of reciprocal recurrent selection to *C. canephora* in Côte d'Ivoire, scientists have identified new intergroup hybrids (Guinean x Congolese) that are as productive and uniform as clones. Indeed, the best hybrids can produce up to 40% more than clones. This revolution in the varietal improvement of this species opens the way for the distribution of hybrid varieties in the form of seeds produced in propagation plots.

In addition to their higher yield potential, the new hybrids have a bushy, branched habit that reduces the ratio between yield and the number of fruiting branches. This should allow farmers to switch to higher cropping densities.



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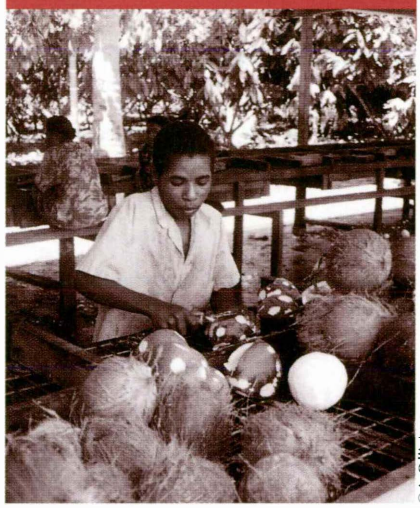
A hybrid coffee variety (C. canephora) raised from seed, shortly after emergence.

Coconut



© J. Ollivier

The coconut sector faces serious problems that cast a shadow over its future: ageing plantations, pest attacks, lethal diseases and a plateau in copra prices. CIRAD works to improve the profitability of the crop for smallholders, millions of whom rely on it for their livelihood. Our current research focuses on using biological control to protect plantations against insect pests, exploiting coconut genetic diversity, developing techniques for rehabilitating old or degraded plantings and improving small-scale processing techniques.

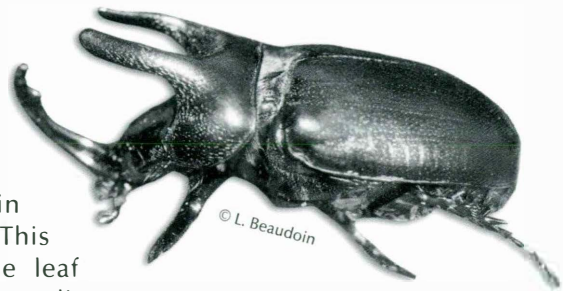
Control of *Scapanes australis*

In Papua New Guinea, *Scapanes australis* causes considerable damage in young coconut plantings. This beetle bores through the leaf stalk, causing growth abnormalities and often killing young palms.

Under an EU project conducted in partnership with the Cocoa and Coconut Research Institute in Papua New Guinea, the discovery of a calling behaviour in males allowed scientists to identify a pheromone that is secreted abdominally and attracts both males and females.

Gas chromatography analyses, combined with mass spectrometry, identified two compounds present in the pheromone: 2-butanol and acetoine (3-hydroxy-2-butanone). A synthetic mixture of these compounds was found to attract the pest into traps comprising a plastic bucket with two large holes in the side. The mixture is placed in a diffuser that is hung from a box containing a plant that acts in synergy with it. Over the past 2 years, experimental mass trapping has resulted in the capture of over 3 000 adults in 14 traps, thereby reducing both the insect population and the damage it causes.

These promising results are now being verified in the field. Trials have been established in new plantings of high-yielding coconut hybrids in severely infested areas. Additional studies are under way on the insect's migratory patterns, with a view to increasing the effectiveness of mass trapping still further.



© L. Beaudoin

Male Scapanes australis.

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A rehabilitated coconut palm grove.

Conserving and using coconut genetic diversity

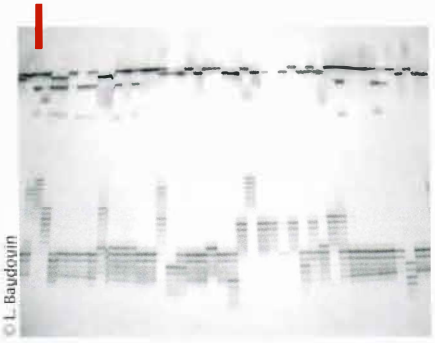
Cultivated varieties of coconut need to be productive, adapted to their environment and in line with consumers' needs. Genetic improvement must seek to meet these requirements by making the most of the diversity found in traditional varieties.

However, managing and conserving coconut genetic diversity, like genetic improvement itself, runs into the constraints imposed by the time and space required to grow the crop. In both cases, molecular markers can provide efficient and cost-effective solutions.

Microsatellites were deemed to be the most suitable kind of marker for our purposes. They are expensive to develop, but highly polymorphic, reliable and easy to use. CIRAD has already identified 85 of these markers, some of which will be included in a molecular tool-kit being developed for the Coconut Genetic Resources Network (COGENT) for use in characterizing coconut populations. For allogamous species such as coconut, such kits need to be used in conjunction with appropriate statistical methods, which CIRAD is also developing.

The first genetic linkage map of coconut has been produced as a result of work instigated by the Bureau for the Development of Research on Tropical Perennial Oil Crops (BUROTROP), with the Long Ashton Research Station and the Scottish Crop Research Institute in the UK and with Neiker, a research foundation in Spain. The map was made using an adult population derived from a cross. Meanwhile, observations of the production of individual trees, made by the National Agronomic Research Centre (CNRA) in Côte d'Ivoire, have led to the identification of several quantitative trait loci (QTLs) associated with production characters.

Polymorphism in two microsatellite markers for coconut palm.



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Rehabilitation of African coconut plantations

To support coconut rehabilitation in Africa, CIRAD has developed a strategy based on replanting old plantations, sustaining yields in ageing plantations and promoting the production and marketing of coconut products and byproducts.

Under a project implemented by the French Development Agency (AFD), the strategy has been applied in Ghana, where initial results have been obtained on the adjustment of fertilizer applications to palm condition. After 2 years of applying 3 kilogrammes of fertilizer per palm, production in one 10-hectare plot was up from 50-55 to over 120 nuts/palm. In 2000, around 400 hectares of village plantations, each averaging 3 hectares, were rehabilitated following the strategy, which is to be extended to a further 1000 hectares in 2001. Soil fertility in coastal coconut plantings was restored by introducing shrub legumes (*Cassia siamea* or *Acacia mangium*), which also produce large amounts of the fuel wood villagers need to dry fish. Intercropping coconut with food crops, such as maize, groundnut, veg-

etables, yam, cassava, taro and other tubers, provides farmers with additional income. Over 350 hectares of these intercrops were planted in 2000. The traditional oil extraction process has also been improved: a study of micro-oil mills in Western Region, which produces 90% of Ghanaian coconut oil, identified the defects to be corrected and the required capacity of the pilot unit to be tested. Prototype hand presses and improved copra ovens have been designed by CIRAD and built by local craftsmen. They have been installed at a demonstration site so as to train small-scale oil producers and producer groups in how to use these new tools.

Rubber

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The recent Asian economic crisis has slowed the growth in world consumption of natural rubber. Indeed, unfortunately for producers, it has led to a prolonged decline in international prices. This has discouraged replanting and there are now fears of a shortage. CIRAD's rubber programme has therefore geared its research towards increasing productivity throughout the sector but particularly on smallholdings, which account for over 80% of world natural rubber production.

Possible futures for rubber

In 2000, CIRAD conducted a foresight exercise on the rubber sector with a view to gaining a clearer picture of its future. The study was recently presented to the International Rubber Study Group.

For many years now, the natural rubber market has been in turmoil, a fact reflected in the low prices paid to producers and the demise of the International Natural Rubber Organization and its buffer stock. Despite these difficulties, and competition from other crops and activities, rubber production continues to rise slowly. However, the increase in demand for natural rubber has not been sufficient to persuade growers to extend or renew their plantations, and little is known about the potential for intensifying production in the areas already planted or the possible existence of reserves that have not yet been tapped. Professionals in the sector are concerned that there may soon be a shortage of the product.

The study revealed the diverse functions of rubber in smallholder production systems, where it accounts for 85% of the area planted. The crop has an economic function, reflected in the production of natural rubber and wood and in its contribution to jobs, incomes and diversification, but also a social one, related to land tenure, and an ecological one, since it helps to control soil erosion, maintain soil fertility, save fossil fuels and store atmospheric carbon.

The study also showed that the international market for rubber is becoming more complex: some producing countries have become consumers, while some importing countries are also producers.

© E. Penot

Improved agroforestry system with clonal rubber.

It is essential to quantify future supply and demand, not only for natural rubber but also for other products such as rubber wood. However, it is also necessary to take into account the increasing importance of quality and marketing services, together with the emergence of environmental regulations and standards.

The results of this CIRAD study will be used to identify the research strategy that will best contribute to the sustainable development of this sector.

© T. de Rebaul

A well-maintained plantation of old rubber trees.

Support for rubber smallholders

Several CIRAD departments have launched a programme in four countries to develop and transfer suitable rubber-based production systems for smallholders.

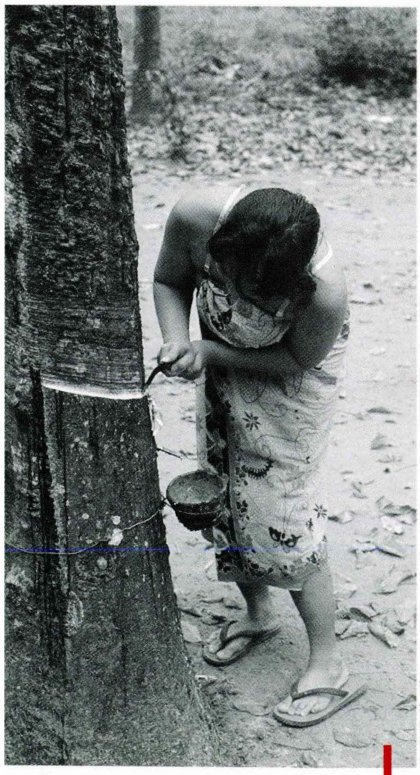
In Indonesia, the Smallholder Rubber Agroforestry Project is being implemented in collaboration with the Indonesian Rubber Association (GAPKINDO), the International Centre for Research in Agroforestry and the International Rice Research Institute. Researchers have demonstrated that improved planting material can perform well under traditional agroforest management conditions. The characterization of smallholder production systems has revealed the opportunities for extending the technical innovations that have been defined by the project, together with the constraints on their adoption. In Vietnam, where the national Rubber Research Institute (IRCV) is collaborating with the adaptive research unit of the Agriculture Diversification Project, initial activities have included a rapid rural appraisal, the identification of research themes for smallholders in the coastal provinces, and trials of productive rubber-based farming systems that can be widely replicated.

In Latin America, Colombian development agents have been offered training in rubber agroforestry techniques and research on smallholder systems. A socio-economic study has also been carried out as a prelude to a rubber smallholder development project in Guatemala.

Stimulating latex production using ethylene gas

Since 1969, stimulation with ethephon, which was a major innovation in its time, has made it possible to reduce tapping frequency without significantly reducing production. However, leaving more than 5 days between tappings still reduces profitability.

For this reason CIRAD has embarked on a multidisciplinary research project aimed at replacing ethephon, which generates ethylene, with ethylene gas itself. The initial results suggest that, when ethylene is used, the latex flow period after each tapping is much longer and the area of bark effectively tapped is greater, without the toxic effects associated with ethephon. A start has been made on analysing tree performance, trends in wood starch reserves and rubber quality. Provided this new stimulation method can be fitted into existing management systems, tapping frequency could be reduced. Gas stimulation might also allow tapping to be intensified more effectively before felling. This research has prompted keen interest on the part of the French Rubber Institute and several planting companies.



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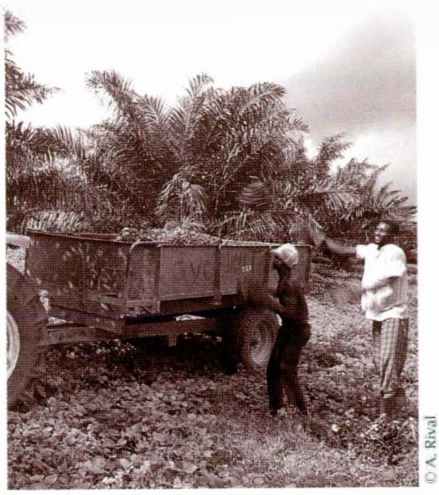
Rubber tapping.

Oil palm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The oil palm sector has special characteristics that have prevailed for several decades now: the predominance of large agribusinesses, the major role played by Malaysia and Indonesia and, for large-scale plantations, growing problems in obtaining land.

The withdrawal of the State and the privatization of production have revolutionized the commodity system. Producing countries have seen considerable growth in the smallholder sector. Market liberalization has made African plantations particularly vulnerable, due to their poor management, lack of access to high-quality planting material and low product prices. In Latin America, in contrast, a boom in planting has resulted in strong demand for improved seeds.

Lastly, the sector has had to cope with a dramatic slump in world prices. The resulting crisis has had a marked impact on investment and research policies among our partners.

The role of oil palm on family farms

In Cameroon, CIRAD has been working with IRAD to define a typology of the farming systems that include oil palm. A survey of around 100 smallholders has been conducted and sophisticated computer-based tools have been used to analyse the results.

In Côte d'Ivoire, CIRAD is characterizing smallholders' organizational needs following the privatization of the sector, under a research agreement with the University of Bouaké.

This new initiative encompasses all the socio-economic factors governing the growth of oil palm cultivation around the edges of the main agro-industrial plantations. It is also leading to an intense process of questioning among all the disciplines involved in the sector.

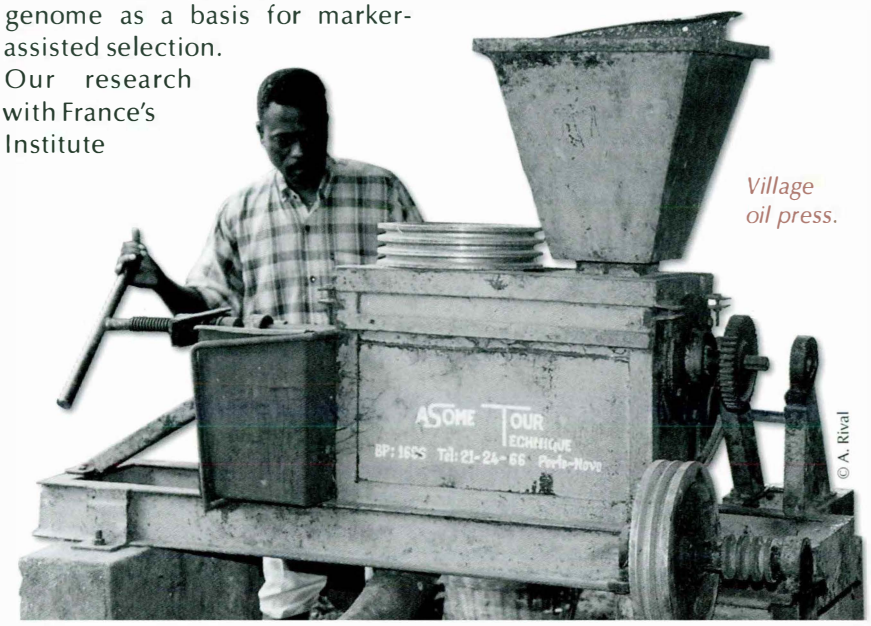
Planting materials that meet planters' needs

CIRAD is gradually building a reputation as a world leader in the use of biotechnologies to improve oil palm. We have made substantial progress in mapping the crop's genome as a basis for marker-assisted selection.

Our research with France's Institute

of Research for Development (IRD) on the genetic basis of somaclonal variations has produced important results. Thesis work has shown that DNA methylation is involved while several markers that can identify such variations at an early stage of *in vitro* regeneration have been isolated in partnership with the Palm Oil Research Institute of Malaysia. Our efforts to transfer the recent progress made in mass micropropagation through embryogenic suspensions continue, with the hosting of a researcher from the Indonesian Oil Palm Research Institute.

The initial results of tests on parents obtained in Indonesia with support from the private-sector company SOCFINDO have shown the potential for significant genetic gain in the near future. This gain can be transferred to producers by cloning the best individuals.



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Village oil press.

© E. Lamade

Measuring leaf density.

In partnership with the company PT SMART in Indonesia, new findings were obtained on the use of oil mill byproducts, such as empty bunches and effluent, as fertilizers. Recycling is not only economically worthwhile, it is also a necessary response to the tightening of environmental regulations in producing countries.

Also in Indonesia, a major integrated research programme has been launched in collaboration with the private sector on the control of *Ganoderma*, a fungus that causes substantial losses in Southeast Asia. ■

To strengthen CIRAD's position on the international market for improved seeds, we have proposed a number of joint ventures with the private sector. These proposals envisage the establishment of development-orientated seed gardens containing a genetic block.

Oil palm development in Latin America

Although the oil palm sector is growing rapidly in Latin America, bud rot has become a major constraint. Considerable progress has been made in breeding tolerant material: 200 clones of embryos obtained from a backcross are being produced *in vitro*. These will be evaluated in an infested area, as a basis for identifying molecular markers for tolerance.

Several trials have been planted in partnership with companies in Colombia and Ecuador. Some of these are already producing usable results. The aim is to test the tolerance and growth characteristics of materials of different genetic origins: pure *Elaeis guineensis*, *E. guineensis* x *E. oleifera* hybrids, and genotypes obtained from backcrosses.

Improving plantation management

The provision of support to plantation management is a major part of CIRAD's advisory services. The relevance of these services, in agronomy as in other fields, hinges on the development of innovative research programmes in partnership with French and international research centres.

A science-based approach to intensifying production systems must now encompass fields such as remote sensing and ecophysiology, data from which can enrich the models used to predict future production.

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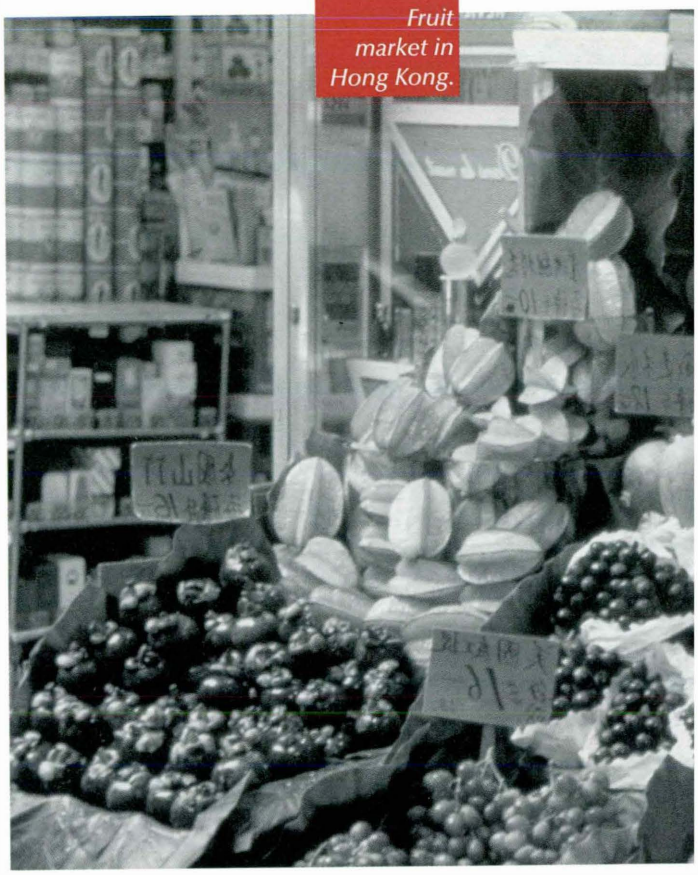
Clonal micropropagation of improved oil palm genotypes by somatic embryogenesis.

Fruit and horticultural crops



Fruit market in Hong Kong.

More than ever, CIRAD's Department of Fruit and Horticultural Crops needs to work closely with the users of its research to adjust its programme to the new challenges facing the fruit and vegetable sector. The essence of the department's strategy is to promote efficient production that meets market demand and consumers' needs while protecting the environment.

Against this background, a key target of research is risk management—anticipating problems and coming up with timely and appropriate solutions. The aim is to provide support for all stakeholders in the sector, whatever the risks they face. Examples are new or evolving pests and diseases, environmental hazards associated with specific farming practices, food safety hazards, changes in the regulatory framework, and sudden changes in the market, occurring as a result of liberalization and globalization.

In both the North and the South, the fruit and vegetable sector is especially susceptible to such risks. The produce is generally fragile and perishable and may be subject to heavy attack by pests and diseases, while markets are highly competitive. At the same time, it must convey the image of being healthy and of high quality.

We must establish a dialogue with users if we are to address their needs effectively. Round-table conferences or specialized seminars—such as the September 2000 banana and plantain meeting—provide opportunities to promote interaction and decide on research priorities in the light of the needs expressed.

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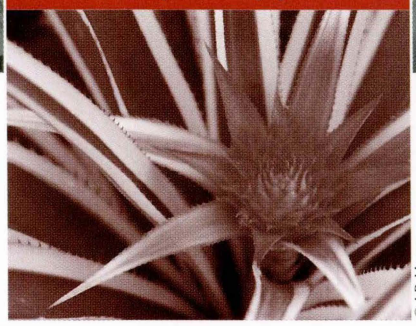
Banana, plantain and pineapple



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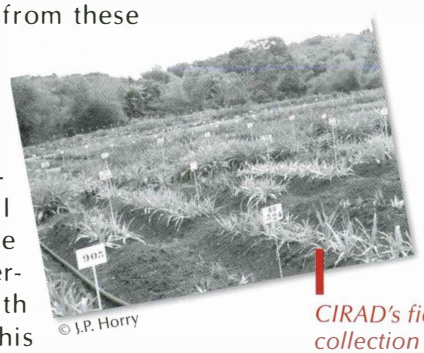
Our banana, plantain and pineapple programme focuses both on production for export markets and on smallholder production for domestic markets and subsistence consumption. Its research integrates consumers' needs and market constraints with environmental concerns, in order to develop appropriately adapted production and marketing practices. The programme seeks to develop economically viable and sustainable production systems with a low environmental impact. Good farming practices, detailed technical specifications, ecolabels and new varieties are all tools that are made available to farmers and other stakeholders to help them meet the challenges of the sector, both now and in the future.

Pineapple collection in Martinique

The pineapple germplasm collection in Martinique was assembled for the purposes of characterizing and using the genetic diversity of a species that would otherwise be endangered due to the low number of varieties cropped and the genetic erosion occurring in the Amazon Basin, its centre of origin. This collection was created in the 1950s from earlier collections and has since been enhanced with accessions collected in specific locations, such as Hawaii, South America and Asia. Especially beneficial were the 500 new accessions added as a result of collection missions carried out between 1988 and 1994 in Venezuela, Brazil, Paraguay and French Guiana, with the participation of the International Plant Genetic Resources Institute (IPGRI) and financial support from the European Union (EU). The collection, which is one of the world's largest, now contains 600 clones belonging to six *Ananas* and *Pseudananas* species. Accessions are added to the collection after an *in vitro* phase and maintained under field conditions with protection from *Fusarium* infection and fruit borers *(Thecla basilides)*.

The accessions are assessed and characterized using morphological and molecular markers. Ninety-five descriptors were identified and classified as part of a European project carried out in collaboration with Brazilian, Venezuelan and Portuguese partners. To assess the genetic diversity, cleaved amplified polymorphism (CAP) analysis was undertaken in Brazil, following analysis using restriction fragment length polymorphism (RFLP) in Montpellier, France.

Besides enhancing CIRAD's own database on pineapple genetic resources, the information obtained from these analyses is being used to develop a new international database in partnership with IPGRI. This will soon be accessible on-line.



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CIRAD's field collection of pineapple, in Martinique.

CIRAD has also used the information to draw up guidelines for the genetic assessment of


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Anthracnose damage on bruised fruit.

pineapple varieties for the purposes of having new varieties registered and certified by the International Union for the Protection of New Varieties of Plants.

Highland banana plantations in Guadeloupe

With regard to highland banana, the introduction of new contracts with growers should ensure efficient production that minimizes environmental damage and maintains soil fertility. This EU-funded initiative is part of the *contrats territoriaux* scheme now operational in Guadeloupe, where the first five contracts were signed in late 2000.

A project to apply various diagnostic and monitoring tools was developed by CIRAD and Agroservice, a non-governmental organization that serves as an intermediary between the project and the banana industry. The health and nutrient status of the first plantations has already been assessed jointly by CIRAD, Agroservice and a specialized laboratory. Banana growers participating in the initiative must use traditional cropping practices, without tillage or replanting, so as to reduce the risks of soil erosion in these highland areas, which have high rainfall and steep slopes. Plantations are assessed to determine whether new canals, windbreaks or access roads need to be built. The collection of waste plastic bags and of pesticide and herbicide packaging is being organized.


© M. Dorel

Highland banana grove in Guadeloupe.

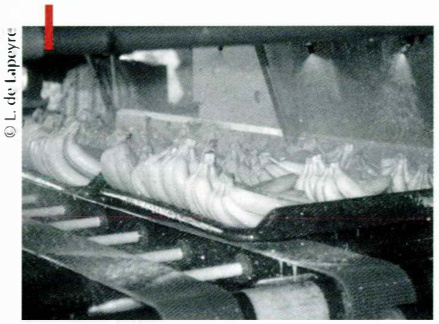
A further 30 contracts are being drawn up for 2001 to ensure the sustainability of highland banana plantations. The project's ultimate aim is to encourage contracted growers to form a group through which to apply for a quality label for bananas produced in the highlands of Guadeloupe.

Protecting bananas without chemical control

Stopping post-harvest fungicide treatments for export bananas could yield substantial benefits, enhancing the food safety of edible fruit, reducing pollution by waste at fruit packaging stations and creating a niche market for West Indian bananas.

There has been progress in understanding the parasite complex involved in banana anthracnose and how the fruit becomes infected. Three *Colletotricum* species have been described on banana, but only *C. musae* is highly pathogenic. A tool for quantifying fruit contamination is now available. It can be used to obtain early estimates of the risk of post-harvest fruit damage and to conduct epidemiological studies. The banana plant is contaminated when fungal spores invade the floral parts and lower bracts. The spores appear within the first month following emergence of the inflorescence, but soon subside. They do not spread over the fruit peel unless moisture is present. Early bagging of bunches reduces contamination by limiting the spread of moisture-borne spores.

Fungicide treatment of bananas, just before packing.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This technique has been tested in an experimental banana plantation in Guadeloupe. Early preventive measures—eradication of spore sources and bagging of fruit—markedly reduce fruit contamination and the quality of the bananas, which do not subsequently have to be treated with fungicide, meets market standards. These interventions can now be considered ready for adoption by West Indian banana growers.

Observing the plantain sector in Cameroon

The Regional Centre for Research on Bananas and Plantains (CRBP) is conducting an agro-economic assessment of how plantain contributes to development in Cameroon and of the constraints faced by producers and other stakeholders. Special survey methods have been designed for this assessment. All stakeholders are sent a newsletter to keep them informed of the results. An analysis of retail plantain prices revealed highly seasonal trends and a higher peak for this product than for others, reflecting its relative scarcity. This means that urban consumers often do not have market access to plantain.

The scarcity is due primarily to the fact that plantain is produced mainly in extensive low-yielding cropping systems in which yields are low, only 5-10 tonnes per hectare per year compared with a potential of over 30 tonnes. These

© N. Wirt

Local market for bananas and plantains in Cameroon.

low yields reflect numerous constraints, including difficult environments, poor cropping practices and the impact of pests and diseases. Given the complexity of local farming systems and the scarcity of resources, it is probably best to encourage growers to intensify their cropping systems gradually rather than to adopt high-input systems. Various technical innovations developed by scientists are being tested and released to growers, including disease-resistant hybrids, new planting materials and integrated pest and disease management. Information collected by the observatory is essential for guiding research so that it more effectively addresses development needs.

Banana and plantain for local consumption

Development projects to promote banana production for local consumption are under way on smallholdings in three regions where bananas of one kind or another are staple foods: West and Central Africa (Cameroon, at CRBP), the West Indies (Haiti, Cuba, Dominican Republic), and the Indian Ocean (Mayotte, Comoro Islands).

One component of these projects focuses on improving local diversity through the release of high-yielding varieties (natural forms or CIRAD and CRBP hybrids). This operation is conducted in partnership with the International Network for the Improvement of Banana and Plantain. Around 50 varieties have been released as *in vitro* or conventional tissue-cultured plantlets to organizations responsible for evaluating this material and disseminating it to growers. A second component aims to improve cropping practices, covering soil fertility management, plant nutrition and the integrated control of pests and diseases, especially weevils, nematodes and black leaf streak disease.

Development support is provided through participatory research on new crop management practices and methods for producing healthy planting material, with the aim of boosting yields. Regional economic concerns are addressed through studies on market trends in large urban centres. The aim here is to determine not only the constraints but also the opportunities for increasing this sector's competitiveness.

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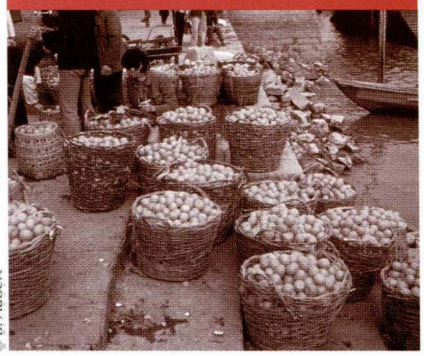
Tissue-cultured banana plantlets being hardened.

Fruit trees



© B. Aubert

Our fruit trees programme conducts research on three major themes. The programme is organized around specialized thrusts and networks and is based on a thorough understanding of the different fruit sectors and markets. The first theme is the acquisition of biological and economic knowledge to promote sustainable citrus production. Research on this theme is pursued at a unit run jointly by CIRAD and the French National Agronomic Research Institute (INRA) at San Guiliano, Corsica. The second theme is the improvement of mango yields and quality, with research on ecophysiology and crop management under way in Réunion. Third, many projects are geared towards promoting fruit diversification. A key source of economic growth in the countries of the South, the main aim of diversification is to find alternatives to banana and sugarcane monocropping in the French overseas departments and territories.

Pest and disease risks for citrus in the West Indies

A workshop organized in collaboration with the Technical Centre for Agricultural and Rural Cooperation (CTA) was held in Guadeloupe to review the pest and disease situation with respect to citrus crops in the West Indies. This workshop was attended by scientists from 13 countries and by representatives from the Inter-American Institute for Agricultural Cooperation (IICA), the leading research and development organization in the Caribbean (CARDI), the Inter-American Citrus Network (IACNET), CIRAD and INRA.

Planting material released to growers must be healthy if pest and disease problems in citrus orchards are to be reduced. The French overseas departments plan to raise the quality of their fruit to minimum international standards.

Four serious diseases currently threaten citrus production in the region. The tristeza virus is spreading quickly via *Toxoptera citricida*, its most efficient insect vector. West Indian citrus orchards currently risk infection by citrus canker *(Xanthomonas a.c.)*, which is present in Florida and Brazil. Pierce's disease, transmitted by *Xylella fastidiosa*, is infesting citrus crops in Brazil and will probably soon reach the Caribbean. *Diaphorina citri*, a vector of huanglongbing disease, is spreading throughout the region.

© F. Leblanc

Diaphorina citri, *the vector of huanglongbing disease.*

The countries represented at the meeting agreed to participate in a Caribbean regional citrus project. A working group within CIRAD's network will investigate the main plant health issues, draw up an inventory of available resources and decide on the tools required for diagnosing diseases, informing citrus growers about efficient control procedures and encouraging their adoption. This project will benefit from CIRAD and INRA's expertise on integrated pest and disease control and on diagnostic tools.

Passifloraceae diversity in the Andes region

CIRAD and IPGRI are collaborating with national genetic resources programmes in Venezuela, Colombia, Ecuador, Peru and Bolivia in a study on the subgenus *Tacsonia* (Passifloraceae), which includes 47 known species, 13 of which bear edible fruit. Two of these latter species, *Passiflora tripartita* var. *mollissima* and *Passiflora tarminiana*, are cropped in the Andes region and were recently classified as new species on the basis of results yielded by this project.

In 2000, thesis research was carried out to assess evolutionary patterns in this species complex. Morphological characters, iso-enzyme profiles and amplified fragment length polymorphism (AFLP) markers were used to assess differences between species and between sections of the *Tacsonia* subgenus, thus clarifying relationships within the subgenus. Data from a geographical information system (GIS) and climate database were used to analyse potential distributions of the main species. This study highlighted some regional differentiation within *P. mollissima* and *Passiflora mixta*. An analysis of iso-enzyme variability in *P. tripartita* var. *mollissima*, *P. tarminiana* and *P. mixta* revealed that cultivated forms have a very narrow genetic base and that gene flow could occur between these species.

© P. Ollitrault

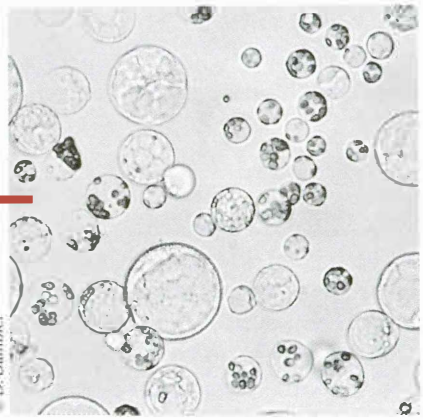
Passiflora tripartita *var.* mollissima, *the sweet calabash of Colombia.*

These results suggest that *in situ* conservation strategies could be of interest in areas where wild and cultivated forms grow together. New collection surveys will also be undertaken in various areas, including Peru and Bolivia, to enhance Passifloraceae species diversity in *ex situ* germplasm collections. The intraspecific geographical differentiation noted for *P. tripartita* var. *mollissima* should be used in Passifloraceae breeding programmes, while interspecific hybridization for *P. tarminiana* should also be implemented.

Tropical fruit flavours and vitamins in concentrated juices

Tropical fruit juice processing is a growth industry and a boon for local development. In Colombia, a juice-making process has just been launched on the basis of pilot testing carried out at the PASSICOL company in collaboration with Del Valle University in Cali, Colombia, at a French college for advanced food industry studies and at CIRAD.

The concentrated juices obtained by this cold-extraction process—passion fruit, mango, naranjilla, mulberry, lemon and pineapple—are highly nutritious and have a good taste. The process does not alter the vitamin potency, flavour or colour of the fruit.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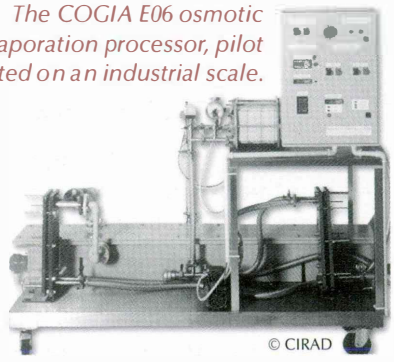
Leaf protoplasts of kumquat (Fortunella japonica) *and embryogenic calluses of common mandarin* (Citrus deliciosa) *before fusion.*

The process consists of three operations. First, a cold enzyme-based treatment is performed to liquify the fruit pulp. A new technology is used to limit the consumption of enzymes in highly acidic juices: the enzymes are fixed in what are known as bioreactors. Next, a membrane process called tangential flow filtration is used to sterilize fruit juice without heating it. Finally, the juice is concentrated up to 65% dry extract by osmotic evaporation, a recently developed membrane process that is performed at ambient temperature.

The process is currently being assessed on an industrial scale at PASSICOL. The juice quality results achieved so far are very promising. Research is under way to improve performance still further. Several European and Latin American partners have shown great interest in the process.

The COGIA E06 osmotic evaporation processor, pilot tested on an industrial scale.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Attractive fragrances from somatic citrus hybrids

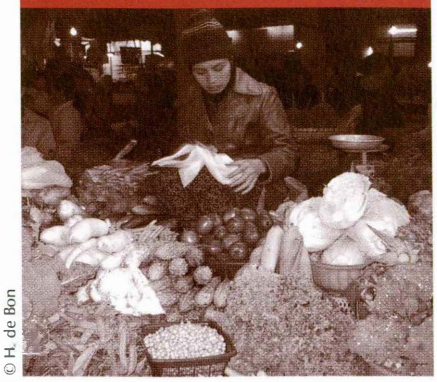
Over the past decade, a somatic hybridization and protoplast fusion procedure has been used to create citrus rootstock containing the resistance traits of the parent plants, and triploid cultivars producing seedless fruit with novel taste and quality properties.

Identification of the compounds responsible for aroma in leaves has enabled scientists to predict the aroma of the fruit with a fair degree of accuracy. This advance also meets the needs of breeders, who are keen for rapid feedback on the outcome of the crosses they make. Four tetraploid somatic hybrids were tested in partnership with the joint INRA-CIRAD Corsican Agricultural Research Station: mandarin crossed with kumquat or lime or lemon, and lime crossed with pomelo.

The aroma compounds present in the hybrids were found to differ from the sum of the aroma compounds present in the parents, even though all the chromosomal DNA from both parents was present in the hybrids. In the three mandarin hybrids, essential oil production was lower than in the parents. Some aroma compounds from the lime and lemon parents—mainly aldehydes—are synthesized only in minute amounts or not at all. The lime x pomelo hybrid, however, produced the same amount of aldehydes (neral, geranial, b-sinensal) as both parents, while overproducing citronellal. This hybrid is of commercial interest to aroma specialists seeking aldehyde-rich plants with a high potential for the production of essential oils.

With support from a Corsican regional fund, a PhD thesis study is underway to determine the biochemical and genetic mechanisms that underlie the expression of the different aroma compounds. Using a somatic hybrid population, the candidate will analyse secondary metabolites in citrus leaves and fruit peel and investigate the expression of enzymes involved in their biosynthesis.

Horticultural crops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Our horticultural crops programme conducts research on three main themes: vegetable consumption, income from horticulture, and the sustainable management of natural resources. The programme's first goal is to ensure that urban markets are supplied with fresh, healthy vegetables. This means evaluating the role of peri-urban market gardening and using our understanding of specific commodity systems to stabilize supplies. Research is also under way to diversify the sources of income from horticultural production and thus to stabilize incomes. This work mainly concerns onion- and tomato-based systems in Africa. Lastly, the programme promotes environmental protection, chiefly in densely populated areas where vegetables are cropped intensively. Many national and international partners participate in these multidisciplinary projects, which aim to develop practical recommendations for growers.

Virology of vanilla in French Polynesia

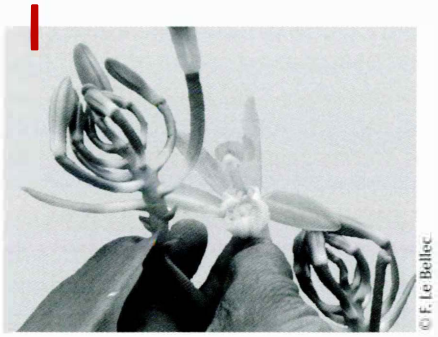
Tahitian vanilla *(Vanilla tahitensis)* is the product of first choice on the natural vanilla market on account of its fine flavour. French Polynesia is the world's only exporter. To develop this subsector, it is crucial to control the spread of untreatable viruses. The rural development service of this French overseas territory has therefore asked CIRAD to conduct research on vanilla virus diseases.

A survey revealed five viruses on *V. tahitensis*, belonging to three different families. Their symptoms vary markedly. For instance, the cymbidium mosaic virus (CymMV) is almost completely asymptomatic, whereas the cucumber mosaic virus (CMV) causes spectacular damage that reduces vanilla yields to zero.

The epidemiology of these virus diseases was then studied under different cropping conditions. Adapted cropping practices were proposed after 2 years of research. They are based on phytosanitary surveillance of vanilla vines at planting and elimination of the plants and vectors that serve as virus reservoirs.

These control strategies are now being applied by growers and a plant health certification scheme for vanilla cuttings is currently being developed. CIRAD research teams in Réunion and the virology laboratory of Auckland University are developing efficient virus detection tools. The knowledge gained in French Polynesia should be of interest to many other vanilla growing regions.

Flowers and young pods of vanilla.



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Flies damaging fruit and vegetable crops

CIRAD, the French Guiana crop protection service and a federation of crop protection groups are jointly involved, along with representatives from Surinam, Brazil and French Guiana, in a regional programme to eradicate carambola fruit flies *(Bactrocera carambolae)*. The method used is to prevent reproduction by attracting and eliminating males with the help of a sexual pheromone, methyleugenol. Another biological control programme under way in partnership with Brazil focuses on acclimatizing carambola fruit fly parasitoids *(Anastrepha* sp.). Several millions of parasitoids were released in French Guiana during 2000.

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Dacus demmerezi, *the cucumber fruit fly of the Indian Ocean.*

In Réunion, tomato fruit flies *(Neoceratitis cyanescens)* and cucumber fruit flies *(Bactrocera cucurbitae, Dacus ciliatus* and *Dacus demmerezi)* cause considerable crop damage and can only be partially controlled with pesticides. Modeled on the biological control strategies used for protecting fruit trees, control techniques involving traps baited with visual or olfactory attractants, sometimes combined with chemical treatments, are being assessed. Several attractants were tested on the melon fruit fly *(B. cucurbitae)* at concentrations ranging from 0.5% to 10%. The trapping rate for male and female flies was found to increase with attractant concentration, with no difference noted between sexes.

Intensive soilless vegetable production in the West Indies

The soil and climate conditions of the West Indies, together with the region's shortage of land, are serious constraints to vegetable production. Growers overcome the constraint of excessive rainfall by sheltering their crops. The use of soilless cropping techniques avoids infection by soil-borne pathogens and allows farmers to control crop water supplies and mineral nutrition closely. Farmers are thus able to intensify production in small areas. Since 1980, soilless cropping practices have been used in French Guiana, Martinique and Guadeloupe, and on English- and Spanish-speaking West Indian islands.

In Martinique, research conducted by CIRAD since 1985 has led to the development of recommendations on types of shelter and soilless cropping techniques for use under humid tropical conditions. These recommendations have been extended to vegetable farms in collaboration with local agricultural councils. Over the past decade, the area cultivated under shelter has risen threefold to its current level of 15 hectares. Seven thousand tonnes of lettuce are produced yearly under these conditions, thereby meeting consumer demand throughout the year.

The same trend can be seen in Guadeloupe, French Guiana and Réunion. In collaboration with the French Embassy, English-speaking West Indian farmers are also now benefiting from CIRAD's technical support in this field. CIRAD scientists were recently involved in a national programme on sheltered crops in Cuba. The aim of this programme is to meet the demand for fresh vegetables from the tourist industry.

The results of this research are presented in the *Guide des cultures sous abri en zone tropicale humide* (a manual for protected cropping in the humid tropics), which was published in French in 2000, with the participation of the French Interministerial Cooperation Fund. This guide will be published in English and Spanish in 2001.

© C. Langlais

Soilless courgette production on a pumice substrate in Martinique.

Flower production in the French West Indies

To meet the high demand from flower growers, CIRAD is distributing hybrid and standard anthurium plants free of *Xanthomonas campestris* pv. *dieffenbachiae* and *Acidovorax anthurii*. Around 100 000 micropropagated plantlets have already been disseminated; a further 10 000 have been ordered by Martinique, Guadeloupe and French Guiana; and 12 000 are currently being micropropagated or hardened. A collaborative project has been launched with INRA to develop *in vitro* propagation and hardening techniques for *Xanthomonas*-resistant anthurium plantlets.

© C. Amar

CIRAD's anthurium collection in Guadeloupe.

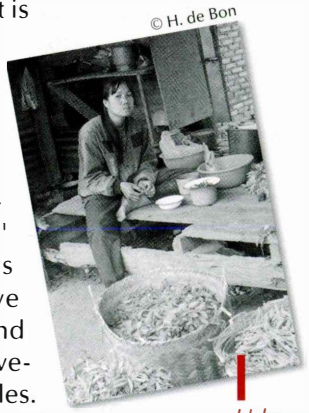
Many collection missions have been undertaken and acquisitions made to enhance the available diversity of ornamental plants, which includes more than 250 species belonging to 10 families. Eighty new species and varieties have now been introduced in Guadeloupe. Micropropagation and hardening techniques were developed to produce plants for release to flower growers throughout the French West Indies. The quarantine and indexing procedures for these flower varieties have been approved by the French Ministry of Agriculture.

CIRAD is also helping establish a national botanical germplasm collection for the West Indies, in partnership with the University of the West Indies and of French Guiana and the Regional Environment Directorate. This collection currently contains 40 wild and horticultural orchids. Micropropagation and hardening techniques have been successfully tested, which means that replanting can now start. Scientists are also providing access to micropropagation tools for other protected species.

Peri-urban agriculture in Southeast Asia

Four large Southeast Asian cities—Hanoi, Ho Chi Minh City, Vientiane and Phnom Penh—are participating in a project headed by CIRAD and the Asian Vegetable Research and Development Center to promote the development of peri-urban agriculture. The overall thrust of this project is to improve vegetable and fish-farming yields and marketing. The first phase (2001 to 2003) aims to strengthen the institutions involved, both governmental and non-governmental. In a workshop held in February 2000, the themes requiring action were jointly identified, including analysis of peri-urban production systems, the expansion of urban commodity markets, technology transfer and institutional innovations.

An initial analysis carried out in Hanoi revealed that vegetable consumption and production during the hot season are important issues for stakeholders. Consumers want to be able to buy clean, healthy vegetables. The government is concerned to reduce health and pollution problems caused by the overuse of pesticides. Farmers' chief priorities are to achieve higher yields and harvest attractive-looking vegetables. A better trade-off between consumers' expectations and farmers' economic interests is thus essential. To iron out these problems, the partners will attend negotiating workshops and training sessions. ■



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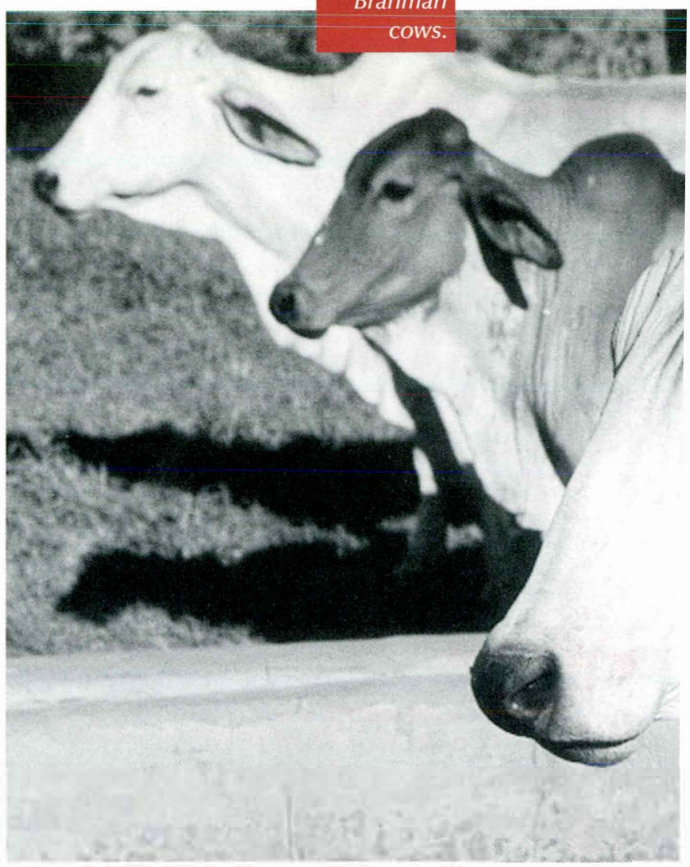
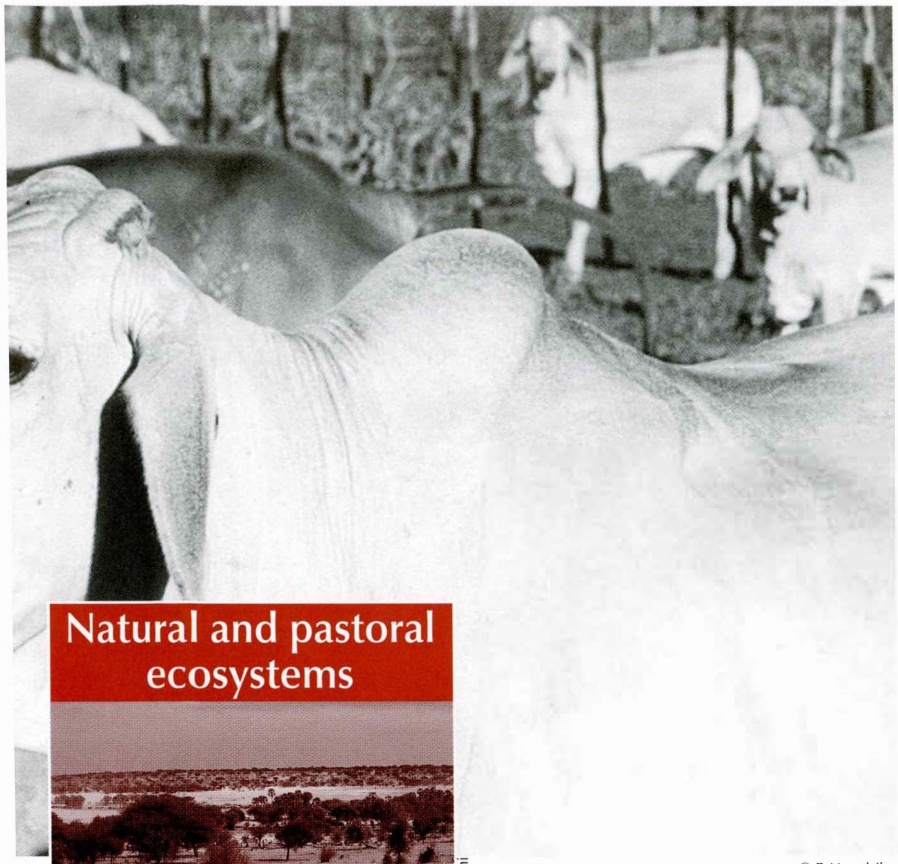
Urban market in Vietnam.

Animal production and veterinary medicine


Brahman cows.

In 2000, several major aspects of the Animal Production and Veterinary Medicine Department's strategy, adopted 2 years ago, were further strengthened. First, its horizontal links: the activities of our epidemiology group (EPITROP) expanded; our dairy production group, which now has a stronger capacity in economics, launched several new projects; our pastoral natural resources group broadened its expertise; and the department's training activities were consolidated and diversified.

The department began several new activities. On the production side, the use of draught animals in cropping systems based on direct seeding into a mulch cover is being studied. On the veterinary side, a new group was formed to study emerging vector-borne viral diseases, which are spreading from the developing to the developed world—a subject that considerably exercised our animal health and environment team. Four European animal health projects coordinated by CIRAD were launched: three are on vaccine development—against peste des petits ruminants, *contagious bovine pleuropneumonia (CBPP) and heartwater—while the fourth is on the control of trypanosomiasis. A regional research thrust on pastoralism in the arid zone was established in Dakar, in which ISRA, Senegal's national agricultural research institute, will play a leading part. The team is to study the conditions under which pastoral societies can be sustained in this zone, in which livestock production is the major activity. The department also plays an active part in a network of observatories monitoring long-term environmental change in sub-Saharan Africa. The major component of the network is the Sahara and Sahel Observatory (OSS). The year 2000 was marked by several important events. CIRAD was given the mandate to co-ordinate the research component of the European biodiversity management programme for a wildlife park on the border between Niger, Benin and Burkina Faso, in West Africa. In addition, the Centre's investment in the international livestock-environment-development initiative gained it a place on the initiative's steering committee. And an international agricultural exhibition held in Paris was the occasion of intensive dialogue on livestock production in the South, including a day specifically devoted to international conferencing.*



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Natural and pastoral ecosystems

© G. Forgiarini

Whether its cause is local or distant, any change in the environment of domestic or wild animals will have an impact on their numbers, distribution and productivity. The resulting imbalances endanger the sustainability of ecosystems shared with human beings and hence the viability of human societies.

In 2000, CIRAD's programme on this theme focused on characterizing and forecasting a number of risks—man-made, ecological or disease-related—that threaten animal resources in tropical environments. This multidisciplinary work culminated in the development of a tentative set of indicators and tools adapted for intervention in local contexts according to local needs.

Mapping of pastoral resources

Kanem is a Sahelian region of transhumant livestock production that extends from central Chad westwards towards the border with Niger. It has a human population of around 300 000. Chad's Ministry of the Environment and Water Resources has implemented a pastoral water resources programme in the region. The aim of the programme is to provide year-round access to water resources, as far as this is possible given the constraints imposed by the climate and the dangers of overuse. This is a crucial element in the drive to secure a viable future for pastoral livestock production systems. Eighty new wells are planned in addition to the rehabilitation of 265 existing wells.

In preparation for these interventions, CIRAD was asked to assess the region's potential for livestock production. An updated map of pasture resources was made, covering an area of 112 000 square kilometres.

The preliminary data for the map were obtained from Landsat 7 satellite imagery for December 1999. In October 2000, the vegetation, topography and soils of 51 plots were surveyed. The data collected on vegetation included the diversity, abundance and dominance of the main species. Thirty-six points were selected as a basis for describing transitional areas, degraded areas and detail that cannot be picked up on satellite imagery. Lastly, existing data were integrated, specifically the map of natural pastures produced by CIRAD in 1975. Eleven main rangeland ecosystems were distinguished and characterized in this way.

The new map of Kanem shows that some areas have considerable potential for grazing while others are degraded, either by natural climatic causes or by grazing. It confirms that the grazing potential of this region has remained relatively stable for decades and that some degraded areas have regenerated since 1975. Water points explain many of the differences observed.

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Water point in Kanem, Chad.

These results, which have been integrated using a geographical information system (GIS), will be useful for monitoring future

trends in the resource base. They will allow researchers to assess the effects on herd/flock numbers and distribution of introducing further water points.

Outbreak of West Nile fever in the Camargue

In autumn 2000, an outbreak of West Nile fever occurred in the Petite Camargue, France. The disease is caused by an arbovirus of the genus *Flavivirus*, which is transmitted by blood-sucking arthropods, notably mosquitoes. The virus is spread mainly among wild birds but occasionally infects horses and man.

Black-headed gull

A working group was formed as early as September. CIRAD was asked to participate because of its expertise in vector-borne diseases in Africa, alongside the French Food Safety Agency, an inter-departmental group on mosquito eradication, the Pasteur Institute, the Institute of Research for Development (IRD), the departmental veterinary laboratory and the National Hunting and Wildlife Board (ONC). The group's first objective was to manage the crisis.

In September and October, 141 possible cases of the disease were identified in horses, of which 78 were confirmed. The vast majority occurred in the Petite Camargue, within a 15-kilometre radius spanning the Gard and Hérault. Three cases occurred in the middle of the Grande Camargue, near Saintes-Maries-de-la-Mer. No human case was found.

To gauge the extent of the outbreak, surveys were conducted on bird hosts and the mosquito vector. CIRAD took part in planning and conducting the preliminary survey on the bird population, which was implemented by the ONC at the request of the Directorate General for Food. Blood samples were taken from 435 individuals belonging to five species of wild bird—herring gull, black-headed gull, house sparrow, magpie and jackdaw—and a species of duck used as a decoy in shooting events. The analyses are under way at the Pasteur Institute.

In 2001, research will focus on preparing for further outbreaks and improving our understanding of the epidemiology of the disease. CIRAD will continue to contribute to the study of bird hosts and to data management and integration.

Epidemiological surveillance of rinderpest in wildlife

Between 1994 and 1997, East Africa was struck by a sudden outbreak of rinderpest, which occurred despite the large-scale vaccination campaigns that were already under way in the region. A CIRAD team with expertise in animal biodiversity was assembled in 1999-2000 to take part in a veterinary project on African wildlife financed by the European Union under the supervision of the Bureau of Animal Production of the Organization of African Unity.

Two regional coordination units were established, one for East Africa and the other for Central and West Africa. A network was set up to monitor the epidemiology of the disease in wildlife. Serosurveillance studies were conducted throughout the area. Substantial resources were mobilized, both human—veterinarians, capture teams and lab assistants—and physical—four-wheel drive vehicles, helicopters and light aircraft. A thousand wild ungulates were captured and tested.

The surveys confirmed the recent spread of the virus in residual areas where rinderpest is considered to be endemic—Kenya in 1999, Tanzania in 1998 and Ethiopia in 1995. Traces of older hot-spots were identified in several countries of Central and West Africa. Contrary to previous assumptions, the virus appears to be still present, even in Central Africa. Observations confirmed that wildlife can play an important role as 'sentinel' species, providing an early warning of the presence of the disease.

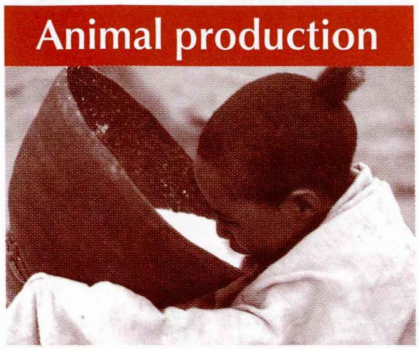
The survey and analysis results were disseminated to the relevant national bodies in each country. Most decision makers in the institutions responsible for livestock production and wildlife conservation are now aware of the need to include wildlife in programmes to control epidemic livestock diseases, which have hitherto focused exclusively on domestic animals.

The presence of strains with low virulence, which are difficult to detect, has yet to be confirmed. To this end, better tools are needed for diagnosing and monitoring the disease. This includes identifying the best sentinel species and monitoring the specificity and

Capturing a buffalo.


© P. Chardonnet

sensitivity of the diagnostic assays available (c-Elisa H and c-Elisa N). Three CIRAD programmes are heavily involved in this research.



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The research conducted by our animal production programme focuses on three major themes: aquaculture, monogastrics and dairy ruminants. The programme's objectives are threefold: to improve our understanding of the mechanisms of heat adaptation in domestic animals, including the genetic basis and changes in feeding behaviour and metabolism; to evaluate and model productivity as a function of feed quantity and quality, health and the use of inputs; and to assess the effectiveness of commodity and production systems for milk, meat and work, with increasing emphasis on quality. Work in all three areas leads to the development of decision support tools.

The Mbarara dairy basin in Uganda

Since 1997, CIRAD has been supporting dairy development in Uganda's Mbarara basin. Before identifying possible interventions, farm types were characterized and constraints were identified.

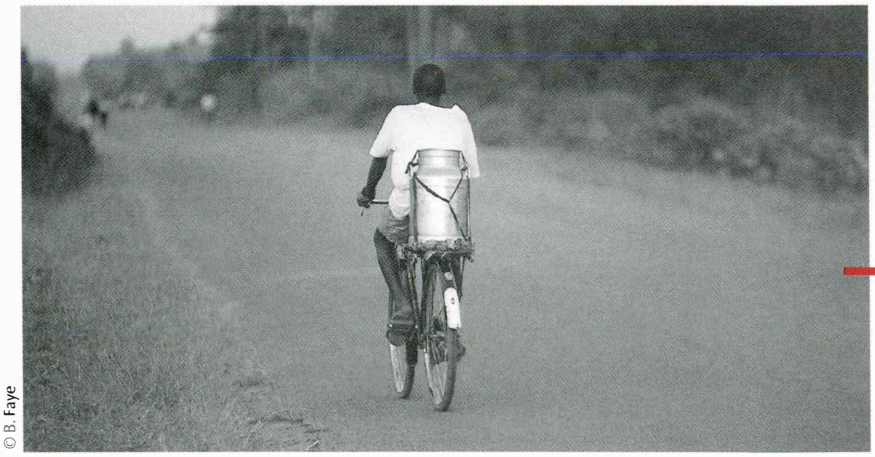
An animal health survey revealed that 70 to 90% of herds, depending on administrative region, were affected by tuberculosis, with an average of 10 to 15% of animals infected. The proportion of the herd affected by brucellosis ranged from under 10% to 75%. As dairies are demanding safer milk for consumers, a food hygiene laboratory has been established at Mbarara University. Studies are ongoing, with a larger sample of dairy farms now included.

Dairy farms have been monitored. A framework for differentiating economic strategies according to farm type has been developed. For small-scale producers, milk represents only 5% of total farm income, whereas for farmers with larger holdings it may account for 25%. For all farmers, veterinary costs are significant—amounting to up to 80% of operating costs for small-scale producers. The Ankole and Friesian breeds kept by farmers differ greatly in their growth characteristics: birth weight is 25 kilogrammes for Ankole calves and 38 kilogrammes for Friesian calves, with a corresponding difference in the rate of weight gain to six months. The growth of Ankole calves varies greatly, however, suggesting a potential for improving the performance of this breed.

Lastly, to overcome feed shortages during the dry season, on-farm feeding trials using *Chloris gayana* and *Dolichos lablab* were conducted. The costs of producing these feeds were calculated on 20 farms. Production of fresh biomass alone cost FF 300 (€ 45.52) per acre per year, an amount equivalent to the sale of 300 litres of fresh milk, while producing hay cost a further FF 100 (€ 15.7). To these costs should be added those of seed production, amounting to FF 350 (€ 53.11) for 20 kilogrammes at the local market price. At present, cows produce around 2 to 5 litres of milk per day. The impact of intensification of the feed component on milk yields will be measured in subsequent trials. Other trials have shown that the local production of mineral feed blocks is economically attractive, as also is the use of agro-industrial residues, such as cottonseed cake, sugarcane byproducts and brewing wastes.

Modeling the productivity of small ruminants

Increasing the productivity of small ruminants is especially important in warm climates. Animal feed and health experts need methods for diagnosing needs



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Taking milk to market, Mbarara, Uganda.


© D. Bastianelli

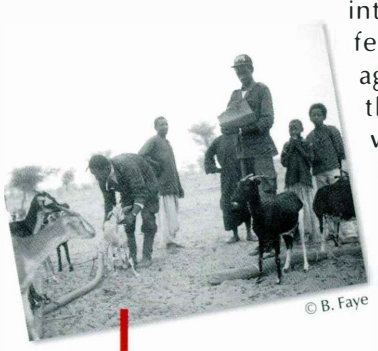
The first reaction to heat stress in poultry is to hold out the wings and accelerate respiration to increase heat loss.

and evaluating the impact of their interventions.

CIRAD has long undertaken research in this area, devoting its early efforts to the development of survey methods and databases as well as to the dissemination of results. Today, the Centre is involved mainly in modeling research. For example, using population growth models, a thesis candidate has just developed a methodology for the comparative analysis of flock productivity.

Conventional methods use Leslie-matrix models with an annual time-step; this is inappropriate for species with a relatively short breeding cycle and in which births are spread throughout the year.

The new methodology, which predicts flock trends at fortnightly intervals for different sex and age classes, takes the animals' whole life-cycle into account in calculating productivity. Between- and within-year variations in the parameters of flock growth—fecundity, mortality, offtake and feed intake—and in weighting factors such as sale price and weight of animals are represented at the same time.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A survey of peste des petits ruminants in Senegal.

The model allows users to determine the overall productivity of a flock and the reasons for differences between flocks. It provides indicators of productivity that are more robust than those obtained using classical approaches.

The method was validated using field data collected on sheep flocks in Senegal, under a joint ISRA-CIRAD programme on small ruminant health and productivity. It can be used directly in the field and, in many settings, it can be applied to species other than small ruminants. Several CIRAD projects intend to use the method, including studies of cattle herds in Senegal and Uganda and the study on CBPP in Ethiopia. Other projects could also benefit, including those on the management of ranch enterprises and wildlife populations.

Poultry production and public health

In Senegal, especially around Dakar, a semi-industrial poultry sector has developed over the past decade. The chicken produced by these modern factory farms is the cheapest meat available to consumers. But the food scares that have hit Europe have also dented the confidence of African consumers.

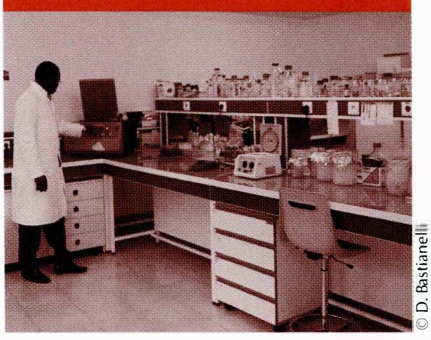
The first step towards restoring consumer confidence and protecting the national poultry sector is to gain a better understanding of the health risks associated with eating locally produced chicken. Research conducted by ISRA's poultry disease laboratory focuses on the potential for contamination by micro-organisms and the detection of drug residues in meat. It aims to identify the risks associated with each stage of the commodity system: hatchery, husbandry, slaughter, point of sale and restaurant. At the same time, the etiology of diarrhoea in human beings is being investigated as a basis for assessing the impact of poultry meat consumption on public health.

Out of 500 chicken carcasses analysed, only 10% were satisfactory according to European standards, while a further 16% were acceptable, but 76% were not. The high levels of contamination found—aerobic flora surviving at ambient temperatures, heat-tolerant *Escherichia coli* and *Staphylococcus* bacteria that were assumed to be pathogenic—were often the result of poor hygiene conditions at the husbandry stage but occurred most frequently during slaughter. However, relatively few microbes that were actually pathogenic were isolated: *Salmonella* in 10% of skin samples and 7% of muscle samples, *Campylobacter* (mostly *C. jejuni* and *C. coli*) in 32% of carcasses. Fifteen different serotypes of salmonella were identified, one of which was new and showed multiple resistance to antibiotics. Improving the hygiene conditions at different stages of production would bring about an immediate reduction in the contamination of carcasses with bacteria.

In restaurants too, improved hygiene procedures need to be put in place. Contrary to what is generally assumed, pathogenic bacteria are not always killed during cooking, especially in dishes where meat is served in a sauce.

We do not yet know whether the pathogenic strains of bacteria found in meat are genetically identical to those found in human diarrhoea. If they are, this will be a decisive moment in the drive to improve the food safety of locally produced meat.

Animal health



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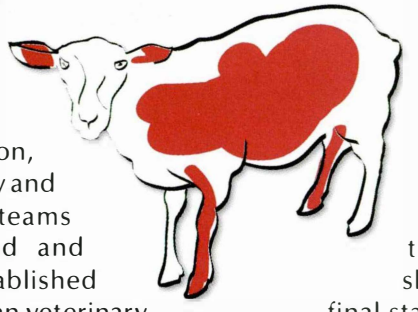
The challenge facing CIRAD's animal health team is to monitor and control the major tropical livestock diseases: rinderpest, *peste des petits ruminants* and African swine fever, contagious bovine and caprine pleuropneumonia, trypanosomiasis and other vector-borne diseases. The research programme focuses on the development of diagnostic tools, molecular studies on epidemiology, the study of immune responses and vaccine development, the identification of genetic markers for resistance or susceptibility to diseases, and epidemiological surveys. In 2000, the programme dealt with emerging diseases in France, in addition to its normal activities in developing countries.

Bluetongue disease in Corsican sheep

In August 2000 an outbreak of bluetongue disease in sheep occurred in Sardinia. The neighbouring island of Corsica was directly threatened. In mid-September, France's Directorate General for Food established a monitoring operation, CIRAD's virology and entomology teams were mobilized and links were established with the Corsican veterinary services.



Bluetongue is a viral disease transmitted by biting insects of the Culicidae family. In temperate areas, where the insect vector does not survive the winter, the first clinical signs of the disease appear towards the end of summer. The disease spreads quickly, affecting most animals, but tails off as winter sets in.

The symptoms of this serious disease are fever, discharges from the nose and mouth, inflamed skin and a swollen tongue, which may turn dark red or blue, blistered and swollen mucous membranes, and lameness.

Entomological surveys, during which 13 000 insects were trapped and analysed, showed that *Culicoides imicola,* which is considered to be the principal vector of the disease in the tropics, had arrived in Corsica. The spread of the insect in the south of the island in early October preceded the first outbreaks of the disease by a few days.

Nearly 14 000 diagnostic tests were carried out on the susceptible ruminant population. The tests showed that the infection, initially confined to the south of the island, had first spread northwards then affected the entire island at altitudes below 900 metres.

By the time the epidemic was subsiding, in mid-December 2000, the laboratory had confirmed the presence of the disease in over six out of ten animals. The cases examined accounted for around 14 807 sheep. Thirty-two per cent of the animals infected either died from the disease or were slaughtered in the final stages as a preventive measure.

Thanks to the resources assembled to tackle the disease, the Directorate General for Food was able to act rapidly to contain it. Restrictions on the movement of animals were applied in October. A vaccination campaign was conducted in the winter of 2000-2001, to prevent the disease from flaring up again in the spring if, as seemed likely, the vector had survived. It is still difficult to guarantee that the measures taken have been entirely successful. CIRAD will remain on the alert in 2001, ready to participate in the control of this emerging disease.

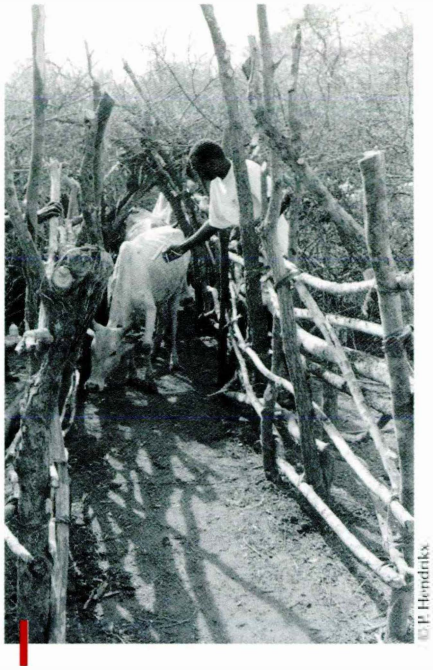
Advances in controlling contagious bovine pleuropneumonia

Improving existing vaccines, developing new ones and identifying genetic markers for resistance or susceptibility to the disease: these are the lines of research pursued at CIRAD to control CBPP, a disease that can have disastrous consequences, especially in Africa.

The vaccines currently available, T1/44 and T1/SR, have been field tested. When challenged with the disease 15 months after administration of the vaccine, 80% of animals were immune when T1/44 was used, but only 30% when T1/SR was used. A booster administered after 1 year improved protection levels: in a test conducted 3 months after the booster, 96% and 80% of animals boosted with T1/44 and T1/SR respectively were immune. Regular revaccination would thus be highly effective. The duration of immunity and the effect of increased doses will be tested in future trials.

CIRAD's scientists are investigating two possible new types of vaccine: a recombinant or subunit vaccine and a deletion mutant vaccine. Their first task was to understand the mechanisms by which animals protect themselves against the disease. Research showed that immune responses to CBPP are cell-mediated and involve cytotoxic T-cells, mostly T-helper cells, which secrete high levels of gamma interferon. The second step is to identify the protective antigens and the components that determine virulence. Various antigens have been selected for their ability to trigger the synthesis of gamma interferon. Four proteins found in the pathogen have been cloned and expressed by one of CIRAD's partners in this work, and these are now being tested. One protein, which stimulates the synthesis of interferon, has been selected for cloning and expressing in a virus vector, the capripox virus. Other proteins will also be screened. The virulence factors are being identified through molecular analysis.

A preliminary study is under way to explore the possible existence of genes that code for susceptibility or resistance to CBPP. The study targets a gene known as *DRB3,* located in the major histocompatibility complex in cattle *(BoLA).* Marker studies using polymerase chain reaction (PCR) and restriction fragment length polymorphism (RFLP) have shown two significant correlations between alleles of the *BoLA-DRB3* gene and resistance or susceptibility to CBPP. These correlations have enabled our scientists to form populations of animals with a known genetic status, so that vaccines will be tested only on animals known to be susceptible.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Vaccination in southern Sudan.

Vaccines against heartwater

Heartwater is a fatal disease of ruminants. Its causal agent, *Cowdria ruminantum,* is transmitted by biting ticks of the genus *Amblyomma.* Endemic in sub-Saharan Africa, Madagascar and parts of the West Indies, this major disease of cattle is difficult to control using conventional approaches such as antibiotics or eradication of the vector. Moreover, the diversity of biotypes found in different geographical areas is a constant threat to efforts to contain the disease. An experimental first-generation vaccine, consisting of inactivated organisms administered with adjuvants, was developed at CIRAD. At the same time, molecular approaches were developed to help diagnose and characterize the different strains of *Cowdria* found in ticks or in the blood cells of ruminants. Once these strains have been isolated *in vitro,* it should prove possible to develop an *'à la carte'* vaccine tailored to specific outbreaks. Trials are now starting with national partners in Senegal, Burkina Faso, Kenya, South Africa and Mozambique, aimed at determining the efficacy of the vaccine in different livestock production systems.

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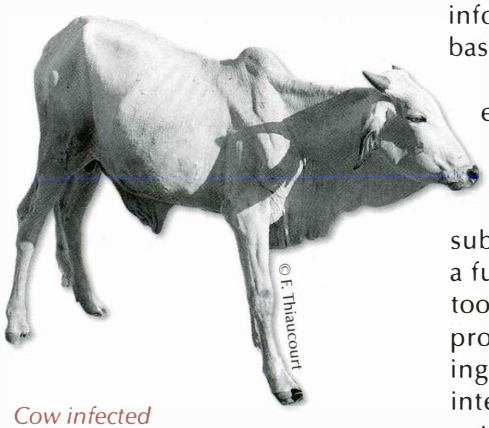
The costs of producing an inactivated or dead vaccine are nevertheless high, so the main emphasis of our research falls on recombinant vaccines, using a multidisciplinary approach. Immunological studies have shown that immune responses against heartwater are produced by a population of T-cells that secrete gamma interferon. These cells, taken from immune animals, enable scientists to screen the

'proteome'—the entire set of proteins expressed by a genome—of *Cowdria*, so as to identify the fraction of proteins that act as antigens. Separation in a two-dimensional gel and micro-sequencing of the isolated proteins will enable the scientists to pinpoint the relevant genes within the entire *Cowdria* genome sequence. At present, we have nearly finished sequencing the genome of two strains of *Cowdria*. Once we have the complete sequence, we plan to study the expression of the key genes, using DNA micro-array techniques. However, an appropriate vector will still be needed to inoculate ruminants with the genes conferring the immune response. An attenuated capripox virus, recombined with a synthetic gene coding for the major *Cowdria* antigen (MAP1), is being used as a model for optimizing the expression of bacterial genes in mammalian cells *in vitro*. Trials on live animals will begin soon. Several genes can be introduced into this vector, making it a choice candidate for a recombinant multivalent vaccine.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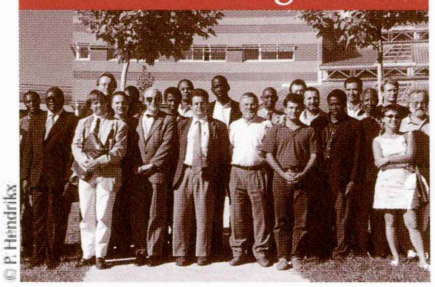
Cow infected with CBPP.

Training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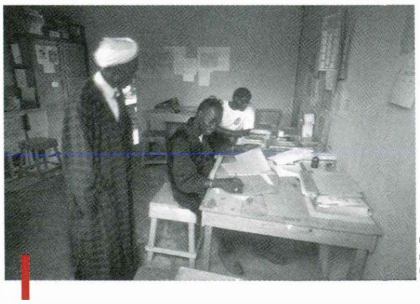
In the year 2000, the department began offering training in two new fields: epidemiological surveillance and wildlife.

Epidemiological surveillance is a core activity in all veterinary services. An effective network for collecting data on animal health should involve partners in both the public and private sectors, who must share a common approach and procedures. The survey techniques must be flexible enough to adapt to changing livestock production systems and the emergence of new diseases, especially those that can be transmitted to man. Sometimes, wildlife populations must also be surveyed. Sizeable amounts of data may be collected and these must be correctly handled to extract reliable information that can serve as the basis for effective intervention.

Planning and organizing an epidemiological survey network is the subject of the first four-week module of our new training course on this subject. A second module, lasting a further three weeks, covers the tools available for managing and processing the data collected during surveys. Both modules are intended to address the needs of national survey teams. The course forms an integral part of two higher national diploma courses available in France: the certificate of advanced veterinary studies on animal diseases in warm climates, offered by the national veterinary school in Toulouse, and the certificate of higher studies in animal epidemiology, offered by the national veterinary school in Maisons-Alfort.

Wildlife and its habitats offer local populations a resource that is important for food and for a range of other purposes: hunting and gathering, husbandry and —more recently—ecotourism. Entrusting the conservation and use of this biodiversity to local communities is the best way of guaranteeing sustainable, controlled development. The integration of wildlife perspectives and objectives into the planning and implementation of development activities is the subject of another new CIRAD course. The course is orientated towards national staff working in livestock or natural resource management departments. It also welcomes students from the veterinary schools in Nantes and Lyons. And it is an option in the course on animal production in warm climates offered by the Montpellier II University and co-organized with CIRAD. ■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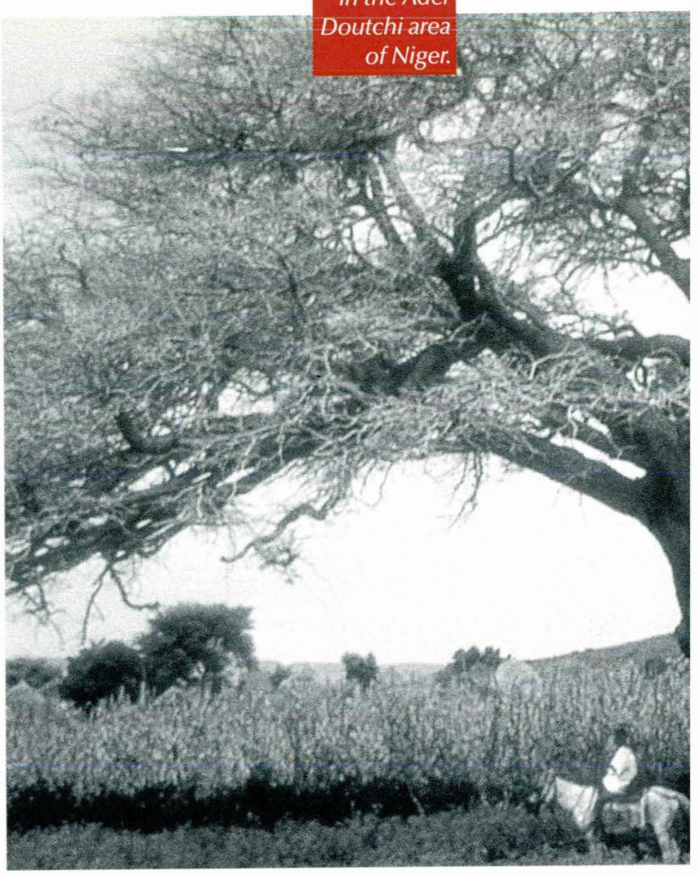
Checking data collection sheets in Ndiagne, Senegal.

Forestry

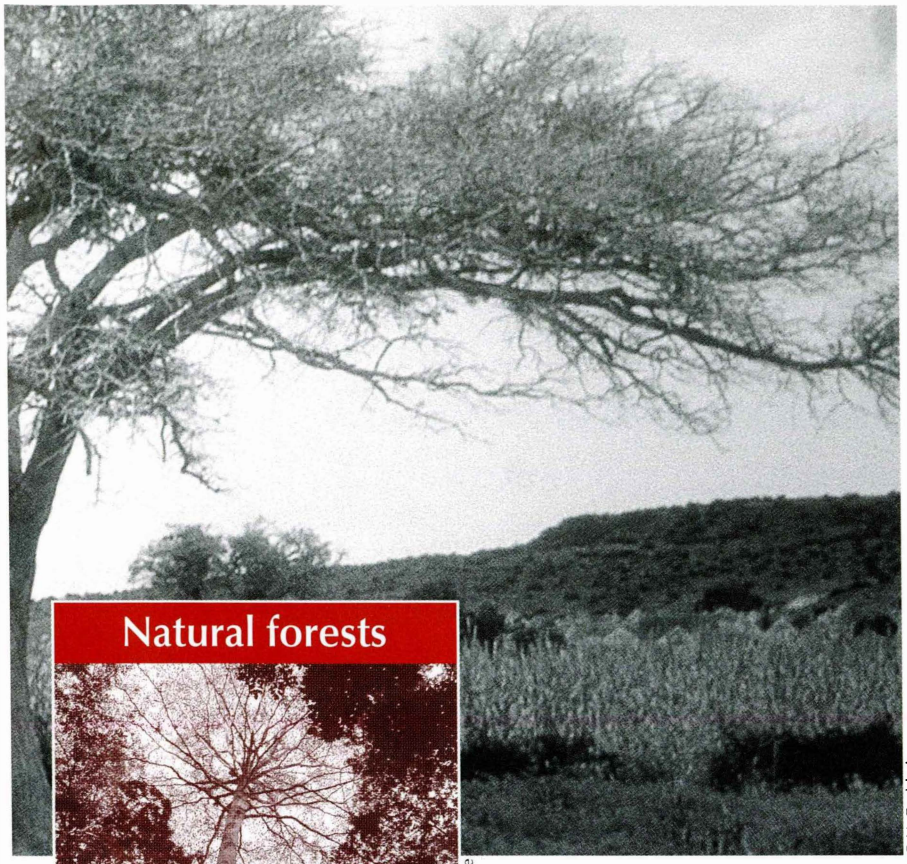


Faidherbia albida, *in the Ader Doutchi area of Niger.*

Foresters are accustomed to working to a long time-horizon. Appropriately, then, it will have taken 3 years of internal discussions and external consultations for CIRAD's Forestry Department to assess the changes taking place in the world around it and to translate these into a coherent strategic plan for the years to come. Over the next few decades, trends in the demand for wood and other forest products will continue to reflect world population growth. Between now and the year 2050, an extra three billion human beings will need access not only to food but also to the energy required to process it and to the materials necessary to build a shelter in which to live and work. The department's strategic choices for the period 2000-2004 take into account the human dimensions of the forest management challenge and emphasize a holistic approach to the themes that will be addressed through development-orientated research. Because of their natural and social functions, forests are often afforded the status of a public good intended for the benefit of all mankind—a status thrown into sharp relief by the recent international conventions on such topics as biodiversity, global warming and desertification. Resolving the contradictions between global imperatives and local needs has become a central theme of our research.

The new constellation of problems facing research was reflected in the recent strategic planning exercise conducted by CIRAD as a whole. As part of this exercise, different research objectives were compared with the human resources available to achieve them. The outcome was that some 15 extra scientists either were recruited during the year 2000 or are about to be recruited, in fields ranging from sociology to functional genomics.

Science in the service of mankind was the subject of much debate at the world congress of the International Union of Forestry Research Organizations (IUFRO), which was held in August in Kuala Lumpur, Malaysia. The department was well represented at the congress and played an active part in the discussions there.



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Natural forests

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There is growing awareness worldwide of the need to preserve the fragile balance of the environment, threatened as it is by deforestation, global climate change and the greenhouse effect. The effective management of forests, which are a renewable natural resource, requires understanding and management of the many interactions between human beings and the complex workings of forest ecosystems. Against this background, our natural forests programme aims to develop the regulatory tools and institutional innovations needed to support effective management and to improve understanding of forest ecosystems. The ultimate objective is sound management of all the areas that are, or could be, used for forestry.

Forestry information systems

Forestry information systems comprise a set of tools designed to integrate and make accessible to users various kinds of forestry-related information, including geographical, socio-economic, environmental and tree measurement databases. CIRAD's priorities in this field are to support the exchange of scientific information, better management of forest areas, and spatial data analysis at different scales.

A means of both disseminating existing research results and generating data on new research themes, forestry information systems are fast becoming a vehicle for dialogue between researchers globally. For example, *Arlequin*, a website run by researchers in French Guiana, will be our partners' gateway to the databases of France's National Agronomic Research Institute (INRA) and Institute of Research for Development (IRD), besides those of CIRAD. More broadly, these systems are part of a global trend towards greater exchange and dissemination of scientific data. The Global Forest Information Service (GFIS) has been established by IUFRO, the Food and Agriculture Organization of the United Nations (FAO) and the European Union (EU) for the benefit of all developing countries. Initially, this service will be directed primarily towards African countries, including Gabon, Ghana, Kenya, Malawi, Senegal and Zimbabwe. CIRAD actively supports this initiative.

For an information system to fulfil its purpose as an aid to decision making and management, the data it contains must be structured according to end use. For example, TANGO, a tool developed by CIRAD for monitoring and managing forest plantations in New Caledonia, offers a custom-made cartographic interface developed for the forestry services of the island's North province. The databases that can be loaded include maps of specific forest resources, a record of management interventions and road building works, details of planned operations, and annual statistical reports. Other countries that have

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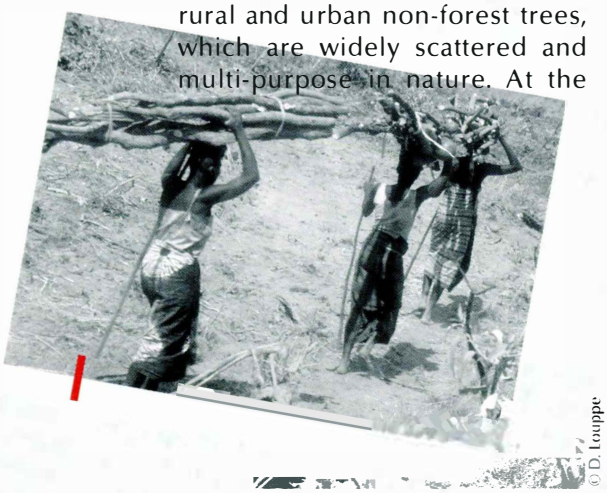
Forest in Gabon.

already expressed an interest in adapting this tool to their needs include French Polynesia, Laos and Vietnam.

The information system as a tool for analysing spatial information—its third function—can be applied at the level of the whole forest or of smaller tree stands. As such it can be used to model tree growth and mortality or forest regeneration after felling. Applied on larger scales, it can be used to study trends in forest landscapes or to identify new sites suitable for tree planting.

Non-forest trees

The quantification of global forest resources and of the timber and non-timber products they contain has improved markedly over the years. The same cannot be said of rural and urban non-forest trees, which are widely scattered and multi-purpose in nature. At the request of the FAO, and specifically of its global Forest Resources Assessment programme (FRA 2000), a multidisciplinary team of CIRAD researchers has conducted an initial analysis and synthesis of available information on this rich but frequently overlooked resource. The aim was to develop a better conceptual framework for dealing with non-forest trees, so as to build awareness among decision makers, planners and donors.



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Women collecting firewood, Burkina Faso.

Rural non-forest trees are integrated into local production systems by farmers and pastoralists. On pioneer fronts, they help to offset forest losses and to recreate a tree cover where deforestation is well advanced. Their social and cultural functions—in landscapes, as ornamentals, or as objects of religious or symbolic value—can be as important as their productive or ecological functions. They contribute greatly to people's livelihoods in both urban and rural areas.

Left out of conventional management plans and uncounted in national statistics, non-forest tree resources distort the forecasts made in national plans, especially as regards the future supply of firewood. Eight case studies conducted by national experts around the world were selected to enrich our deliberations. They illustrate both the wealth of this highly diverse resource and the difficulty of evaluating it accurately.

The study, which covers all the world's regions (both tropical and temperate), will be published in French and English in 2001 and in Spanish in 2002.

Modeling forest growth

In tropical forests as in temperate ones, tree growth varies according to species, soil type, local climatic conditions and population characteristics, which determine competition for space and light. It is the latter set of characteristics that are the subject of forest management. Clarifying and understanding these relationships within models of forest dynamics makes it possible to test the robustness of a number of biological hypotheses and the possible consequences of different silvicultural scenarios. A forest growth modeling platform is under development by CIRAD and INRA. The platform, known as CAPSIS, simulates the growth of trees in stands in response to different silvicultural interventions. It offers a common environment in which the development and application of models of forest dynamics can be shared by different users. Those developing the platform make the results of their work available to the scientific community, whose members meet regularly to redefine needs and share experiences. The users, including institutions such as the French National Forest Inventory (IFN) and National Forests Board (ONF), enjoy easy access in either a PC or a Macintosh environment. CAPSIS is useful not only in forestry research and management but also in training.

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Conducting an annual species inventory in French Guiana.

At present CAPSIS supports around 10 models. In 2001, the SELVA model, which describes tree growth dynamics in a humid tropical forest around Paracou, in French Guiana, will be integrated. It will then be possible to build a model that simulates the spatial dynamics of heterogeneous, variable or mixed populations in different forest contexts, either natural or managed. In addition, links with other software

packages describing wood quality or growth will broaden the scope of applications still further. At the same time, an index of the different models available will be posted on the Internet.

Trees and plantations

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Our trees and plantations programme concentrates on the economic and environmental challenges associated with forest plantations at either village or industrial level and with agroforestry. Projections of global demand for wood show that natural forests alone will be unable to meet the demand.

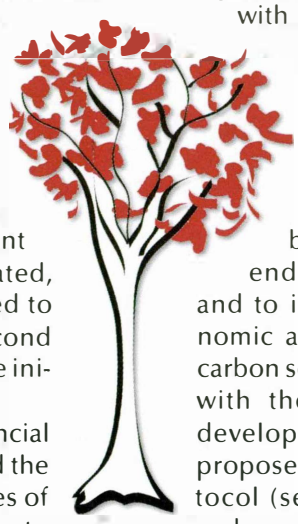
Okoumé in Gabon

At the request of the Government of Gabon, a study was conducted on the costs and benefits of planting *okoumé (Aucoumea klaineana)*. Plantations of this timber species were established on 28 000 hectares between 1953 and 1993. The study required an evaluation of the current state of plantations, which was assessed using previous inventories updated on the basis of field observations, and the development of a growth model. After estimating the future growth of plantations, management scenarios were developed, taking into account the products most likely to be in demand from industry.

The costs of planting and managing a forest were established, together with the costs of preparatory operations for offtake. Depending on the scenario envisaged, the costs of regenerating and managing subsequent plantations were estimated, with the analysis extended to cover the felling of a second rotation, 120 years after the initial planting.

This economic and financial modeling exercise allowed the calculation of internal rates of return according to different scenarios ranging from clear-felling of all trees to the offtake of individuals when trunk diameter reached a minimum level, which could be varied. This had implications for the second rotation, which could consist either of replantings or of natural regeneration, assisted to a greater or lesser degree according to the intensity of offtake during the first rotation.

The management of *okoumé* plantations is a textbook case in which the viability of development, including its environmental constraints, clashes with the profitability required by the private sector. A choice must be made between two approaches to the management of reforested areas: the focus must be either on productivity pure and simple, with the area seen as separate from natural forest, or on reconstituting and optimizing the use of a degraded forest heritage, in which case the area is managed as an integral part of the natural forest. The choice of approach determines the way in which trees are taken off, the duration of the rotation, the viability of privatizing the plantations in the short term and the licensing arrangements associated with privatization.



Okoumé

One of the original features of this work has been our attempt to calculate the carbon balance at the end of each rotation and to include in the economic analysis a value for carbon sequestration, in line with the so-called 'clean development' mechanism proposed by the Kyoto protocol (see below). If these carbon values are correct, they profoundly modify the economic rationale in favour of a more sustainability-orientated management regime.

Measuring and modeling the carbon cycle

The Kyoto protocol adopted in late 1997 proposes so-called flexibility mechanisms for industrialized countries committed to reducing their greenhouse gas emissions. Under the clean development mechanism, the countries of the North can finance the reduction of emissions in countries of the South that are not committed to reductions and credit these savings to their own carbon account. Methods for quantifying both the carbon market and carbon sequestration have thus become necessary.

Near Pointe-Noire, in Congo, CIRAD has established a trial in collaboration with INRA-Bordeaux, a group at France's National Centre for Scientific Research (CNRS) and the University of Franche-Comté to measure water, carbon and energy exchanges between plants and the atmosphere in an

industrial eucalyptus plantation. The method used is the eddy correlation method. The data are integrated over time and compared with measured variations in carbon stock in the original savannas and in other tree populations of various ages, so as to estimate the net carbon balance over a plantation cycle. Other parameters measured include the structure of the tree cover in eucalyptus plantations, the response of trees to environmental factors, the decomposition of tree litter, soil carbon exchanges with the atmosphere, micro-climate variables and soil water content.

Rational forest use allows the forest to regenerate afterwards and so to sequester carbon.

The entire data set forms the basis for developing and validating models of carbon exchanges, energy flows and production which simulate the interactions between soil, plant and atmosphere together with the carbon and water metabolism of plantations in response to vegetation structure, climatic variables and forestry practices.

Biosynthesis of eucalyptus lignins

In Congo, clonal eucalyptus plantations, grown mainly to produce wood for the manufacture of pulp for paper making, cover around 43 000 hectares. Reducing the lignin content of the wood and selecting lignins with the highest syringyl contents—which are the easiest to eliminate during processing—remain major objectives, since the industrial extraction process is expensive and produces wastes that pollute the environment. Recently developed techniques of molecular biology and chemical analysis allow scientists to include traits for lignin and syringyl contents in breeding programmes.


© B. Mallet

Eucalyptus plantation in Congo.

As a result of research conducted by CIRAD in collaboration with INRA, CNRS and the Pine Institute, eight genes coding for the biosynthesis of lignin have been located using a mapping population derived from a cross between *Eucalyptus urophylla* and *E. grandis*. In addition, the regions of the genome controlling the relationship between the monolignols syringyl and guaiacyl have been identified. These regions have been found to be co-located with three genes—*CCR*, *PAL* and *C4H*—thought to be involved in the biosynthesis of lignins. Combining favourable alleles at two loci—*CCR* and *PAL* or *CCR* and *C4H*—increases the ratio of syringyl to guaiacyl by a further 10%.

Marker-assisted selection of trees with a low lignin content should greatly reduce production costs in the paper industry. Once the effects of these genes in breeding populations has been confirmed, this method can be used to select for other traits of interest.

Invasive species in Réunion

In island environments, especially those on shipping routes, invasive plant species can threaten local biodiversity. In Réunion, nearly 500 introduced species have become naturalized, of which around 30 are woody species that grow both in wild habitats and in areas used for crop or livestock production.

Among these species, *Acacia mearnsii* is particularly common, covering over 5500 hectares, and especially abundant between 600 and 1600 metres altitude. Originally from Australia, this tree was highly valued as a fallow species when geranium was widely grown for export at high altitudes on the island. Then came the 1960s recession in the geranium oil sector, which provided the tree with an opportunity to colonize the thousands of hectares left bare by farmers. Its expansion continues today at a rate of around 100 hectares per year, threatening nat-


© M. Baumer

Tamarin forest in the Hauts region of Réunion, with great mullein and Hypericum *sp.*

ural ecosystems. The effects of this invasion have been studied by CIRAD, in partnership with INRA and regional bodies in Réunion.

Natural formations containing *tamarin (Acacia heterophylla)* are locally invaded by this competitor, which has more vigorous early growth. But the most important finding was that *A. mearnsii* spreads in Réunion's best conserved natural environment, the highland moors, which now cover only 60% of their original area. The rapid formation of a thick cover and the production of a sterile litter turn these areas into an inhospitable environment in which bird populations, in particular, are reduced to levels of poverty similar to those in the sugarcane belt of the lowlands.

The aim of this study is to provide managers and planners in rural areas with tools to support decision making and intervention, both of which are at present failing to keep up with changes in the island's landscapes.

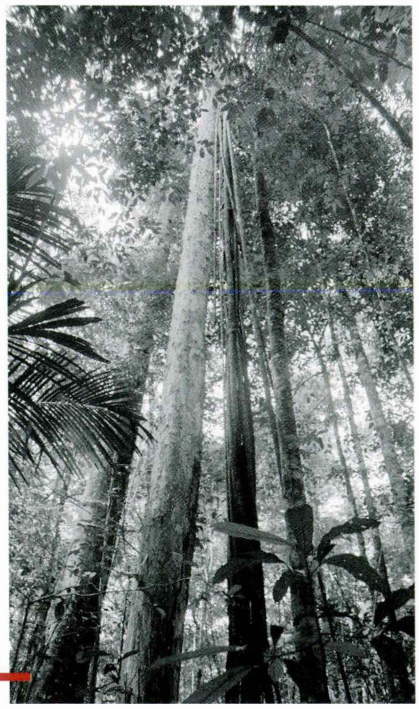
This 15-year rolling programme aims to improve our understanding of this threatened species and to put in place a strategy to safeguard its future. Three thousand trees will be planted on a 10-hectare plot in a State forest managed by ONF near Kourou. The plot will produce seed for reforestation or for increasing local populations in natural habitats.

During 2000, an inventory was made of residual populations, both natural and planted. Seeds and leaves were harvested as a basis for developing seed-based propagation techniques and molecular markers for use in evaluating the genetic diversity of the species. A nursery and a clone bank were also established. These will be used for propagation from cuttings of accessions that do not produce seed.

The next steps, in 2001, will be the harvesting of seed to develop a conservation plot and the development of techniques for propagation from cuttings.

Conserving rosewood in French Guiana

CIRAD and the ONF have joined forces with the well-known perfume manufacturer Chanel in a programme to study and conserve rosewood *(Aniba roseadora)*, which provides an ingredient of Chanel No. 5 perfume. The overutilization of rosewood began in the nineteenth century and reached its zenith in the 1930s in both French Guiana and Brazil. Production began falling in the 1960s, when a synthetic product became available. Nevertheless, the intensive exploitation of this species for over a century has sharply reduced natural populations.



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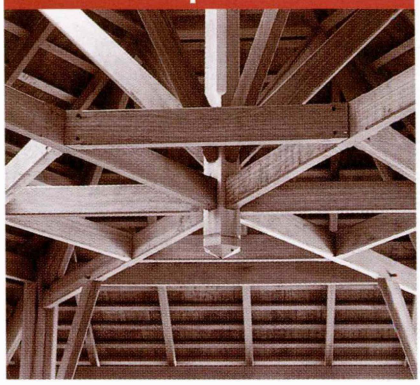
Forest in French Guiana.

Forest products



© M. Vernay

Meeting the ever increasing demand for wood means making a rational choice of raw materials and optimizing yield at the different stages of processing. At present, only 10 to 15% of the woody biomass deliberately felled in natural forests, excluding the wastes associated with the felling operation itself, actually reaches the final marketed timber product.

Mechanical classification of sawn timber

To ensure optimum use of timber species, sawn timber is sorted into lots with similar levels of resistance, classification being done either visually or mechanically. The visual method takes into account the look of the wood, the type of cut, any biological deterioration or abnormal shapes—all of which are external signs that can be related to three classes recognized by French national standards. Each of these classes corresponds with a specific resistance category. Mechanical classification is faster, measures more accurately, gives a true value for mechanical resistance and therefore results in optimal utilization.

Each resistance category obtained mechanically can be

associated with a visual resistance class. However, the knots present in sawn timber may determine a classification that does not necessarily correspond with the effective mechanical resistance as measured using a standard mechanical test. This leads to a low yield of good timber in the best classes.

The non-destructive Bing method developed by CIRAD classifies structural timber by analysing cross-sectional vibrations in timber pieces. An industrial prototype has been developed and used to demonstrate the relevance and quality of this continuous measurement method for timber products. The prototype was tested at the Technical Centre for Wood and Furniture (CTBA) in Bordeaux. Mechanical testing over 2 years has shown that the Bing machine developed by CIRAD and CTBA leads to optimum timber classification, whatever species is tested.

Sawn logs, made from Sipo *(African mahogany).*

The ongoing collaboration between users at CTBA and scientists at CIRAD has helped increase the reliability of both the machine and the information processed, in partnership with CNRS-Marseille. What started as a diagnostic tool in the Bing laboratory has become a practical tool for determining wood quality in industry, whether the material tested consists of roofing timber made from spruce, joinery wood of oak or larch, pallets made from maritime pine (*Pinus pinaster*) or laminated beams made of oak.

Databases and information systems on tropical woods

In the timber sector, it is becoming easier to get access to information and the data available are constantly being expanded and adapted to the needs of users. In the late 1980s, with support from the International Tropical Timber Organization (ITTO), CIRAD and its national partners in developing countries developed a software programme that displays the technical characteristics of tropical woods and allows users to select them using multiple criteria. The most up-to-date version of TROPIX, as the software is called, is more user-friendly than its predecessors and is now used in CIRAD's work to provide technical information and assistance to wood production and processing enterprises. In addition, a special version containing 80 tropical American species will be made available in 2001.

To enlarge the range of useful species included in an international database on tropical woods, the University of Nagoya, in Japan, which is the implementing agency for the ITTO project, has asked CIRAD to conduct a study on underused African tropical woods. The study will examine all the relevant aspects of these woods, from their physical characteristics to their actual or potential uses. Nearly 300 African species have been entered on the ITTO database, which now has around 1000 tropical species in all.

Lastly, in partnership with the private-sector company Ablewood.com, technical information sheets on tropical woods have been developed and disseminated through the Internet under the combined auspices of Ablewood and CIRAD. Access, at www.dicobois.com, is via a multiple-criteria search and selection module.

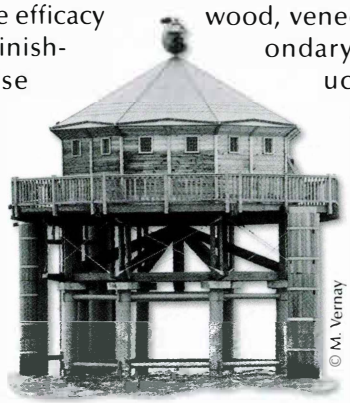
*Montpellier's tram platforms are made of iron wood (*Tabebuia *spp.).*

A centre for timber technology in French Guiana

In French Guiana, where tropical forest covers more than 95% of the land, the government is trying to develop the timber sector and to promote efficient use of local resources. In 1999, with the support of France's Directorate of Agriculture and Forests and various regional authorities, CIRAD established a National Centre for Timber Technology, which will serve as a vital support unit to local enterprises.

To promote the sector, CIRAD participates in stakeholder workshops and organizes training sessions on specific themes. A quarterly information bulletin was developed this year. However, for the most part the new national centre's activities complement, and indeed cannot be separated from, the research work carried out in this overseas department. At the request of construction companies and other users, the centre develops building specifications and provides advice and technical

assistance in fields ranging from design or assembly work to on-site construction or official acceptance of timber deliveries. It also provides expertise in pathology and recommends treatments, especially for termite control. It conducts tests on the efficacy of preservation or finishing products. These activities rely greatly on the characterizations of tropical woods, including 800 species from French Guiana, available in the wood collection at CIRAD, and on the technical database, which contains around 150 species. A research project to prospect the secondary species found in the Amazon and on the Guiana plateau, conducted in partnership with Brazil and Guyana with funding from the Inter-Caribbean Fund, will be completed in 2002. The results of these studies will complement the information available in the Kourou wood collection.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Replica of the 'lighthouse at the end of the world', made of angelique from French Guiana.

Economics of tropical timber

The forests of the tropics account for more than half the global forest area and make a corresponding contribution to meeting the demand for raw wood, timber and derived products. A bilingual reference work, *State of tropical timber economics 2000,* has been published in French and English. It offers an overview of the international market for timbers and its past development. It was compiled using annual statistics and reliable recent information gathered from international sources such as ITTO and FAO, with the purpose of providing a synthesis of what is known at the same time as a useful teaching material. Most of the data are presented as illustrations, especially maps and graphs. Supply, demand and trade in the principal timber products—logs, sawn wood, veneer, plywood and secondary processing products—are presented and then reviewed in a broader context. The rationale for the review section is that, although a great deal of trade will continue to take place in domestic markets, globalization is leading to major shifts in world trade. Published periodically, the reference work will serve as a barometer of trends in timber markets and a practical tool for use in studies of production, consumption and international trade in tropical timbers.

Holm oak as a timber species

An abundant species throughout the Mediterranean Basin and the dominant broad-leaved species of Languedoc-Roussillon, the holm oak *(Quercus ilex)* is still used only for firewood. However, its wood has highly valued mechanical and aesthetic qualities and is suitable for a range of joinery uses, such as parquet floors. Well shaped logs with the required quality characteristics could fetch prices at the top of the range.

A technical and economic feasibility study was conducted by CIRAD and an industrial joinery company with financial support from the General Council of Hérault and the EU, and technical support from the Regional Centre for Forestry Property in Languedoc-Roussillon (CRPF). The study determined the physical and mechanical characteristics of holm oak wood and defined the optimum technological parameters for processing and utilization. Technical solutions were developed for the specific constraints encountered when processing this wood. For example, experiments showed that, for this species, which has a reputation for 'nervous' behaviour, it is best to dry timber pieces in the sizes closest to those of the final product. This practice, which runs counter to the convention for other species, will limit losses during drying. ■


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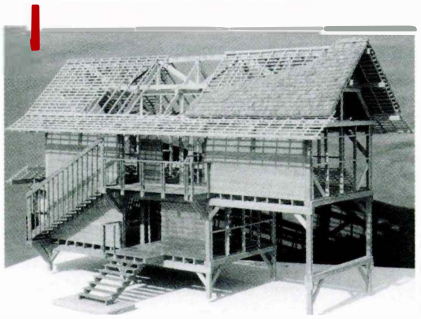
Parquet floor in holm oak, made for the CRPF.

Model of a wooden house.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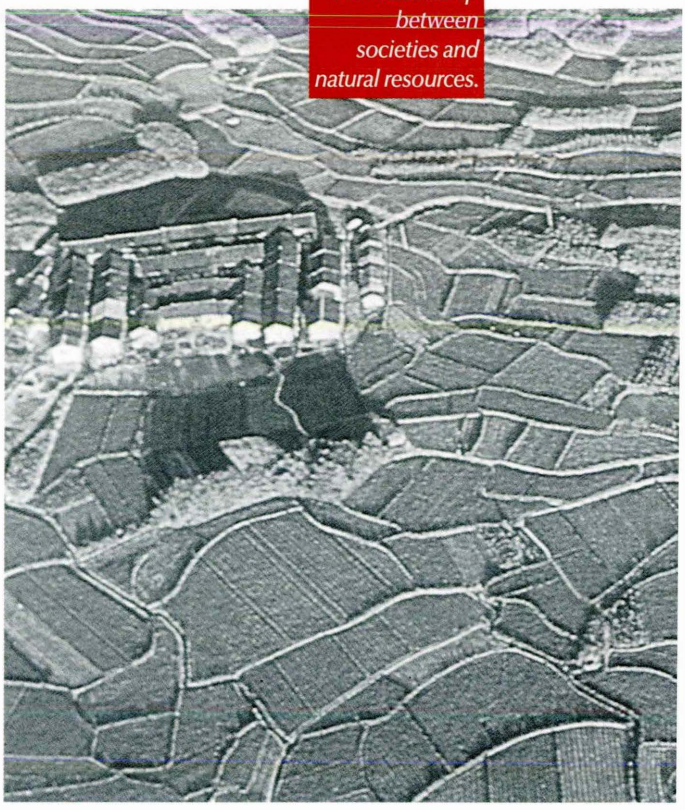
Territories, environment and people



A territory is the expression of the relationship between societies and natural resources.

Economic liberalization has led to the replacement of subsidies and other forms of support with a new and more demanding set of rules for farmers that reflect, above all, the requirement to remain competitive. Similarly, policies of decentralization require a new and broader set of stakeholders—regional or local bodies, farmers' organizations, trade or professional associations and private companies—to be responsible for the services once offered by the State, without necessarily providing the means for discharging this responsibility. Added to this, the rapid changes in agriculture, continuing population growth and rising pressure on the natural resource base are fuelling a debate about the social and environmental values associated with agriculture. As economies open up and agriculture's multiple functions are recognized, questions are being raised about the roles and positions adopted by public-sector bodies—local organizations, States or groups of States. In France's overseas departments and territories, for example, the so-called agricultural orientation law passed recently encourages new contractual arrangements between private- and public-sector bodies.

How should we measure and manage the public goods generated by agriculture? New and complex questions on this issue are being asked of the scientific community. To answer them, new models, reference data and methods are needed, as a basis for analysing change in rural societies, for devising information systems that meet the needs of multiple users, for strengthening training facilities and opportunities and for facilitating the coordination of collective or government action.

CIRAD's Department of Territories, Environment and People analyses the strategies adopted in response to these issues by different organizations and individuals—and the resulting dynamics of land use. It conducts cross-sectoral and comparative studies on the processes of collective decision making and concerted action. It contributes to the development of the tools needed to represent and model territories, infrastructure and commodity systems, so that these can be better managed. Through its action research, the department helps to organize negotiations between different groups and to analyse the conditions under which new practices are learned about and implemented in rural areas.

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Family agriculture

© J. Muchnik

Our family agriculture programme focuses on the individuals and institutions active in rural areas. It analyses the conditions that govern the adaptation of family farms to globalization and the ways and means by which producers and their organizations can be strengthened.

Multifunctional agriculture

The concept of multifunctional agriculture captures the full range of goods and services produced by farmers, which benefit the economy and society as a whole. The origins of the concept lie in two major recent developments in global thinking about agriculture: the challenge to the productivist model and its consequences for the environment and for food security; and the growing consensus that the proper management of natural resources is in the interests of all society. The concept lies at the heart of the vigorous debate now taking place about the liberalization of international trade, which is stripping away the various forms of protection previously enjoyed by the agricultural sector. Some countries invoke multifunctionality as the reason why they would like to see these protective mechanisms retained or restored.

Through its work, CIRAD contributes both to this debate and, more generally, to the definition of public policy and to the development of a consensus for action among rural people. A number of events during the year enabled us to engage in a dialogue on this new theme with organizations in our partner countries. The first of a series of seminars was held in Costa Rica and was attended by representatives from eight Latin American countries. A one-day meeting took place in Montpellier in September between CIRAD researchers and representatives from French, foreign and international institutions, who presented their institution's strategic choices and programmes of work. In November, a seminar was held in Guadeloupe with all our partners in agricultural research and development in the overseas departments, on the development of *contrats territoriaux d'exploitation*. These are land use contracts that reflect multifunctionality. Made between farmers and government, they commit the farmer to certain objectives other than those of production, such as maintaining public footpaths, laying or replanting hedges, and so on. Together with our programme on economics, politics and markets, we began working with the Ministry of Agriculture and Fisheries to identify tools for use in analysing multifunctionality. The debate with our partner countries will continue, with further seminars planned in Cameroon and in Southeast Asia for the purpose of ascertaining the views of African and Asian countries respectively.

© E. Penot

Rice plots help control runoff in Asia.

Farmers' organizations and globalization

In November, an international workshop in Montpellier brought to a close the first phase of an integrated research, action and training project entitled Farmers' Orga-

nizations and the Challenge of Globalization. The workshop brought together country-level project leaders from eight countries: Ecuador, Chile, Peru, Uruguay, Senegal, Cameroon, Benin and China. The project also includes Zimbabwe.

The aim of the project is to provide farmers' organizations with methods and tools that will help them develop strategies for dealing with changes in local and global markets. In 2000, the project's analytical work focused on three issues: the economic and institutional changes that have affected family agriculture over the past 15 years; how these changes are perceived by the leaders of farmers' oganizations; and how the organizations themselves have responded to the new challenges faced by rural people.

The workshop provided an opportunity to synthesize the results achieved by the international and national teams and to define the objectives, research themes, methodologies and modes of operation of the project's second phase. Among the new themes will be the relationships between farmers' organizations and other local organizations in the three major developing regions, the role of farmers' organizations in preventing conflicts in Africa and the strengthening of autonomous economic organizations in China and Africa.

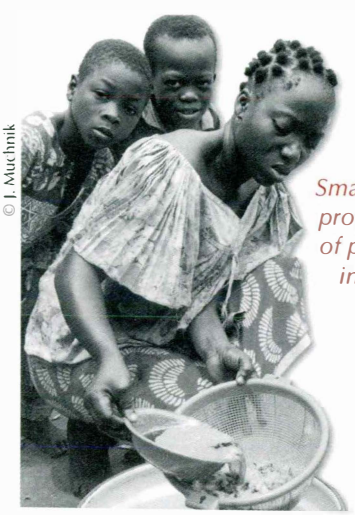
This project benefits from financial support provided by the French Ministry of Foreign Affairs and the Foundation for the Progress of Man.

Local agro-food systems

Given their relationship with the soil and their emotive food-related connotations, agro-food activities create strong links between people, products and land. They contribute greatly to local development. Since 1999, CIRAD has been conducting research on local agro-food systems and the evolving relationships between their different inputs and outputs. Various products are studied, including smallholder oil palm and small-scale cassava processing (into *gari*) in Benin and small-scale rural cheese making in northeastern Brazil and the Cajamarca region of Peru. Research focuses on understanding the links between products and land, on how enterprises can strengthen their identity so as to improve their position in the global market, and on collective action, for example to defend the right to use a certain label or to negotiate better credit terms. A seminar to present the findings will be held in 2002.

In 2000, CIRAD contacted the universities of Versailles Saint-Quentin and Montpellier, the National Agronomic Research Institute (INRA), the National Centre for Agronomic Studies in Warm Regions (CNEARC) and the Agropolis Museum to establish a group of scientists sharing an interest in local agro-food systems. A three-day meeting took place in November on the perception of quality in food products and the links between products and land. The first meeting of the new scientific committee on these matters will take place in March 2001.

In Latin America, a tripartite agreement was concluded with the Inter-American Institute for Cooperation in Agriculture (IICA) and the International Center for Tropical Agriculture (CIAT) on a project to collect and synthesize information on this subject in the region.



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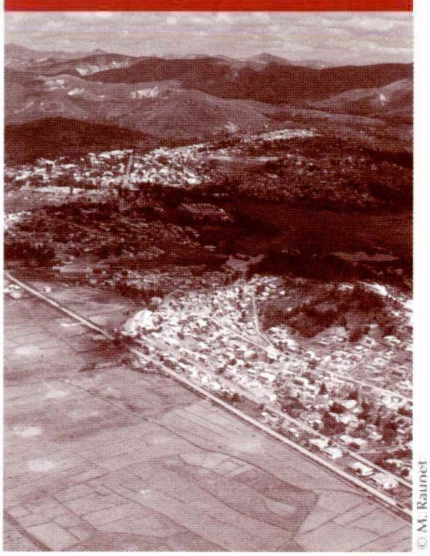
Small-scale processing of palm oil in Benin.

Land and resources



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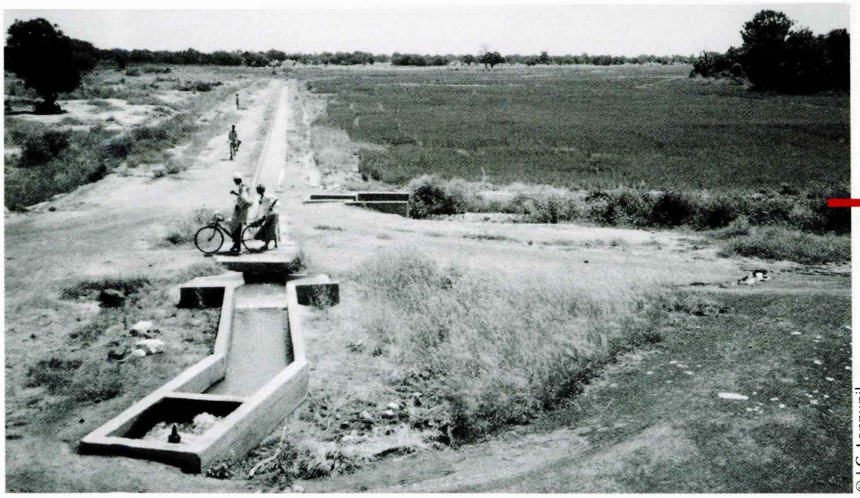
The land and resources programme both produces and processes information. It creates tools and methods for monitoring changes in land use and the natural resource base, and in particular for processing and representing spatial information. Many of the tools are intended to support decision making and the conduct of negotiations by the leaders of rural development.



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All involved in managing irrigation are having to adapt to a changing environment.

Towards better irrigation management

The management of irrigation schemes is being gradually transferred from State-owned bodies to farmers' organizations or to mixed public-private enterprises. These need to acquire expertise in both day-to-day and strategic irrigation management if they are to respond adequately to technical, economic or environmental challenges.

In 1998 CIRAD launched a project whose aim is to understand how the different people at work in an irrigation scheme coordinate their activities and to use this understanding as the basis for developing advice for managers. The project has conducted research in two rice growing areas, the *Office du Niger* scheme in Mali and the Senegal River delta in Senegal, and a fruit and vegetable growing area, around Petrolina and Juazeiro in Brazil. Two simulation tools have been developed to support managers' efforts to allocate water supplies and to help them choose a pricing system that will balance their budgets while still allowing farmers' incomes to rise. On the *Office du Niger* scheme, the project has improved the monitoring of canal maintenance by putting in place a computer-managed database. These tools can be used to simulate different scenarios of the scheme's future, which can then be compared on the basis of quantitative indicators. The resulting information feeds into long-term planning and into discussions with farmers.

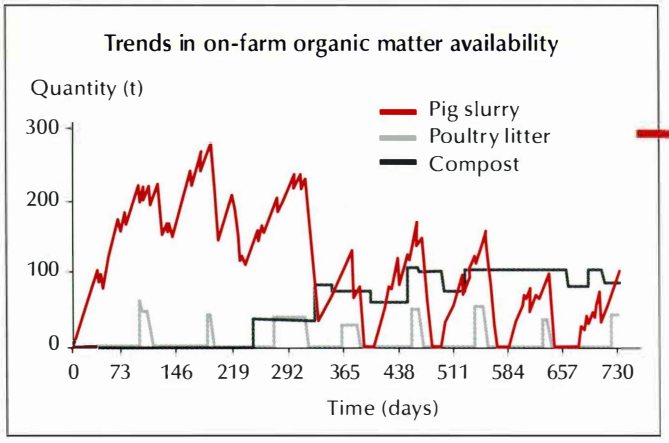
This project is implemented in partnership with other CIRAD departments, the Catholic University of Leuven and regional research and development institutions. Similar projects are in preparation in Brazil, South Africa and Morocco.

Modeling the management of slurry in Réunion

To improve nutrient cycling in Réunion, simulation models have been developed in collaboration with INRA and the University of Réunion. The models are based on farmers' current practices and on the results of researchers' agronomy trials.

Known as MAGMA, the model depicts nutrient flow within the farm. An initial validation using real cases has been carried out and the model appears accurate enough to allow its dissemination to agricultural advisors. To simulate the transfer of organic matter between farms, the model was linked to the multi-agent CORMAS platform. To the same end, another multi-agent system, BIOMAS, has been developed. Two additional models have been designed to simulate the recycling of organic matter managed collectively. Lastly, yet another model simulates the circulation of nitrogen in water, soils, air and plants.

Experimental results have been obtained on the use of sugarcane straw in filtering pig slurry, the release of ammonia to the atmosphere following spreading of pig slurry and the mineralization of organic matter and various waste materials in the soils typical of Réunion. Much work remains to be done to make the management models more widely applicable, as well as to determine biophysical parameters by studying the real relationships between soils, plants, wastes and the envronment.



Organic matter modeled using MAGMA software.

A seminar was held in October in Saint-Denis, to summarize the work done so far and outline activities in the near future.

Tools for collective land management

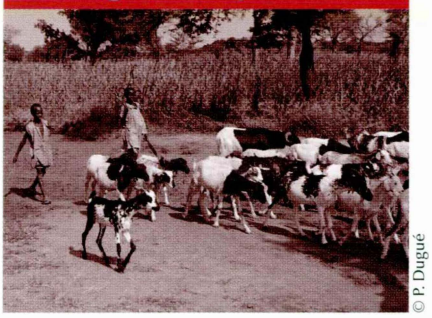
CORMAS is a multi-agent software programme used to support negotiations between different people trying to manage a piece of land jointly. In 2000, the programme was improved. Users can now define spatial units more realistically, as these are constructed using real maps. Direct links to a geographical information system (GIS) have been established, with the two systems able to function simultaneously during the simulation process.


© F. Bousquet

Using multi-agent systems at a workshop in Senegal.

In the Senegal River valley, farmers both grow rice and raise livestock, with the two activities competing for land. To stimulate discussion, explore the different options possible and project trends over 20 or 50 years, workshops were organized in three villages. Role play was used to identify the rules governing the behaviour of local people, which were then introduced into a model using CORMAS. Another workshop was held jointly with INRA, in the Cévennes national park, where the uncontrolled spread of pine trees is leading to the closure of large areas of countryside, requiring concerted action by foresters, livestock producers and park officers. Here too, a multi-agent package and role play were used in combination to support initial discussions. Elsewhere, training courses in the use of the CORMAS software were held in South Africa, at the University of Pretoria, and in the Philippines, at the International Rice Research Institute, as well as at Montpellier.

Savannas and irrigated systems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Our savannas and irrigated systems programme implements a coherent global research effort in collaboration with other programmes of CIRAD and of other institutions. The programme's aims are to improve our understanding of how these complex ecosystems work and to develop decision support tools for those responsible for rural development.

Management advice in Burkina Faso

In Burkina Faso, CIRAD is a partner with the cotton company SOFITEX and the National Union of Cotton Producers in designing and implementing a plan of action to stabilize and then increase cotton production. Leaders of the main groups in the sector—producers, cooperatives, wholesalers and so on—have undertaken to equip themselves with tools for analysing the diversity of producers and to establish a mechanism for advising farmers. They approached CIRAD for support for these initiatives. Seven SOFITEX employees conducted a survey of 180 farms spanning the range of conditions found in the country's western cotton basin. The survey enabled a typology of farms to be developed on the basis of operational characteristics. A prototype structure for conveying management advice to farmers was proposed. In 2000, the tools and the structure were adapted to the specific conditions of the cotton sector in Burkina Faso. Ten advisers were trained and 10 groups of 20 producers each were formed and supported as they tested the interventions.

In Burkina Faso, cotton producers will soon be able to get advice from other stakeholders in the industry.


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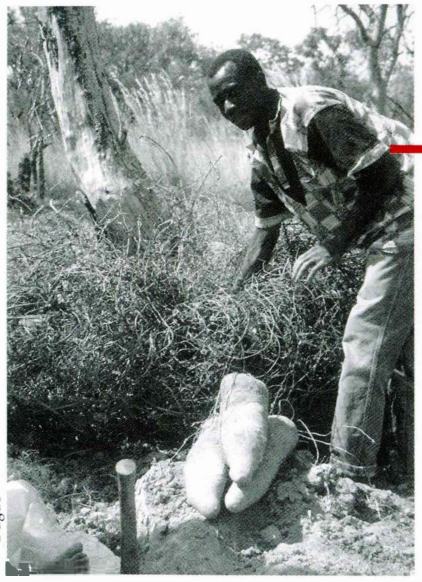
Trends in farming systems in Côte d'Ivoire

In Côte d'Ivoire, the development of a market for yam, a boom in cashew and the continuing advance of a pioneer front associated with cotton production have accelerated the existing trend towards shorter fallow periods, reduced tree cover and, in some areas, declining soil fertility. In collaboration with the Laboratory of Rural Economics and Sociology of the University of Bouaké, CIRAD is studying these trends and supporting a number of development projects. Early work has concentrated on the area around Bouaké, in collaboration with a national project on rural infrastructure and land management. After a diagnostic exercise conducted at



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Yam harvesting in Côte d'Ivoire.

regional level, which resulted in a typology of farming situations, the team focused its efforts on four small areas, where it studied trends in farming systems and the behaviour of rural enterprises against a background in which new local development projects and new decentralization laws were being implemented. The team also takes part in the courses offered by the university. Students of development sociology are doing their dissertations in the project's study areas. On the basis of its experience in the Bouaké area, the team will in 2001 participate in a module on regionalization and local development livelihoods, which forms part of a university degree course.

Savanna development in Central Africa

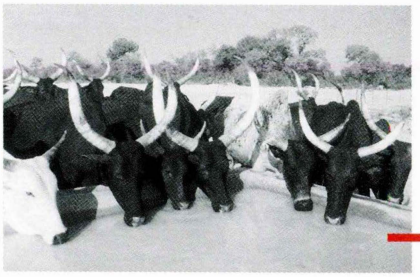
The regional research thrust on the development of the Central African savannas brings together various development-orientated national research groups in Cameroon, the Central African Republic and Chad with advanced research partners in the North, including CIRAD. In 2000, in partnership with other CIRAD departments, the national groups tested various technical innovations with farmers, including animal traction equipment, candidate vaccines against *peste des petits ruminants*, anti-erosion structures and processing and drying procedures. Statistics and maps are available for a number of important commodities in the region. An agricultural atlas of Central Africa was completed and is currently being transferred to interactive CD-ROM. A bibliography, also on CD-ROM, allows easy access to information about research and development activities in the region. A brochure was produced, together with a regional agricultural news bulletin, *Letter from the Savannas*, of which 500 copies are distributed.

Support to producers in Cameroon

In northern Cameroon, CIRAD is involved in a local development programme with the cotton company SODECOTON, as part of a project on small-scale farm development and land management.

CIRAD supports producers' associations involved in the storage of cereals. The support is directed towards the construction of communal granaries and the development of a technical support service for small-scale farmers. In 2000, over 200 groups raised nearly FCFA 95 million for the storage of 1700 tonnes of sorghum. The technical support service is now running and pays its own advisors, whose principal intervention so far has been the development of an innovative management regime for off-season sorghum (*muskuwaari*). Tracks, fords, wells and stores have been built in various communes, depending on local people's ability to contribute to the initial costs and to future maintenance. The investment options chosen by these people have implications for local planning and provide opportunities for them to forge closer links with the organizations responsible for local land use.

Tensions are mounting in the rural areas of southern Benoué, which are filling up with migrants. Methods have been developed for evolving a set of regulations governing land tenure, either through interventions in specific situations or through a more general approach involving village-level agreements and local development plans. The project works closely with the authorities established by Cameroon to oversee its policy of decentralization.



© A. Teyssier

Water trough for cattle in Cameroon.

Management of irrigation schemes in Nigeria

In Nigeria, CIRAD collaborates with the National Agricultural Extension and Research Liaison Service (NAERLS) and the Hjrbda Basin Authority in an effort to improve the management of irrigation schemes in the Hadejia-Jama'are Basin. This partnership has led to the creation of water users' associations, each of which helps to regulate and maintain its own irrigation scheme. In 2000, an information system was developed as an aid to irrigation officers and the associations in managing the schemes. Four of the authority's staff were

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Irrigation scheme, Nigeria.


© J. Wey

Visit to on-farm cover crop trial in Guinea's forest zone.

trained in the system's use. A users' manual was prepared, to facilitate the daily tasks of staff. The training exercise also enabled the tool's developers to adapt it to local needs. A joint inspection of the irrigation and drainage network was conducted by the authority and the associations, and the results were integrated into the information system. This gave rise to a discussion of how responsibilities should be shared and of how a programme to clean the canals and drains could be implemented.

Humid and insular tropics


© E. Pernot

In collaboration with the other programmes of CIRAD and other institutions, our humid and insular tropics programme designs interdisciplinary research projects that will develop technical, policy or institutional innovations to promote sustainable development in environments with a high potential but a fragile ecosystem.

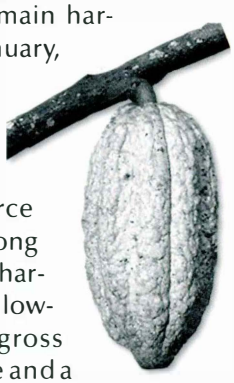
Participatory research in the forest zone of Guinea

A participatory research project was launched in 1996 in the forested N'Zérékoré region of Guinea, in partnership with Guinea's Institute of Agronomic Research (IRAG), the regional chamber of agriculture and various development bodies. The project focuses on the improvement of cropping systems based on perennial crops, including coffee, cocoa, oil palm and raffia, or on annual crops, including rice, cassava, groundnut and banana.

Various technical and policy innovations have been developed at the Kbaya research station, where farmers interact with scientists and development workers. A network of 50 farmer-researchers is now testing these innovations. As part of a broader effort to maintain soil fertility, one of these innovations consists of substituting the traditional slash-and-burn system for clearing land with the cultivation of a cover crop, the legume *Pueraria phaseoloides*, which will increase the soil's organic matter content and protect slopes from erosion. This technique is already familiar in intensive cropping systems, where it is often mechanized, but in this case it has been adapted for use in a system that remains entirely manual. It has been tested in the farmers' network since 1999 and has begun spreading beyond it. Besides its effects on soil fertility, the feature of the technique that interests the farmers is its reduced drudgery compared to slash-and-burn. Between 10 and 15 hectares of *Pueraria* are now being cultivated. Several other innovations have been introduced at the request of farmers: rainfed rice varieties with a 120-day cycle, cassava varieties resistant to mosaic disease, use of the cover plant *Arachis pintoi* to reduce the weeding requirement in coffee plantations, and improved oil palm varieties.

Liberalization of cocoa production in Côte d'Ivoire

In partnership with Côte d'Ivoire's Centre for Economic and Social Research, CIRAD is monitoring around 300 cocoa farms to analyse their strategies and investment decisions and to assess the impact of liberalization on them. A study was conducted on the prices paid to producers between 1998 and 2000. In the years immediately before and after liberalization, which took place in 1999, prices varied according to the season. At the end of the main harvest, towards January, producer prices rise to the level of the world price, indicating fierce competition among buyers. When harvests are at their lowest, traders' gross margins increase and a gap opens up between the world price and producer prices. The explanation is that the cost of marketing is higher while the volume and quality of the product are reduced. In addition, competition among buyers is low during this period, because the cooperatives have ceased to operate. This within-year cycle shows that the apparent rise in producer prices from FCFA 200 to FCFA 300 per kilogramme that occurred in December 1999 in fact owed little to liberalization, which was officially announced in October. Indeed, anticipation of the effects of liberalization on the part of



international buyers, against a background of overproduction, probably contributed to the collapse of prices that occurred in late 1998. In 2001, our analysis of price trends continues, amidst growing economic and political difficulties in Côte d'Ivoire.

Agriculture in Guadeloupe's banana zone

The landscape in the southern part of the island of Basse-Terre, near Guadeloupe, is dominated by banana plants. Around 5000 hectares are devoted to the crop; farmers' incomes, investments, labour, employment and support systems are all to a great extent linked to banana production, which accounts for half the island's exports. But banana cropping practices are thought to have a harmful effect on the environment. The capital locked up in the crop's production complicates negotiations when land is to change hands, either by sale or by inheritance, and banana monoculture is a production system prone to instability through such factors as market fluctuations or attack by pests and diseases.

The recognition afforded to the multifunctional nature of agriculture by France's new agricultural orientation law has encouraged CIRAD to study the sustainability of production systems in the banana zone. The studies are being undertaken in partnership with France's INRA, the regional Directorate for the Environment and the Directorate for Agriculture and Forestry. The project combines biophysical, agronomic and economic approaches on various scales.

The first studies, conducted at watershed level, enabled scientists to characterize the diversity of farm types and their operations, identify the various functions fulfilled by agriculture and draw up proposals that would provide farms with incentives to enter a *contrat territorial d'exploitation*. They also revealed the risk avoidance strategies associated with banana production. The sizeable financial risk involved in starting a plantation, together with the equipment required for production and the general indebtedness of farmers, are offset by the low economic risk: participation in contract farming, guaranteed prices and outlets, insurance against natural disasters—all things that other, less risky crops cannot offer and which therefore mitigate against diversification.

Food crops intercropped with banana in Guadeloupe.

© C. Fovet-Rabot

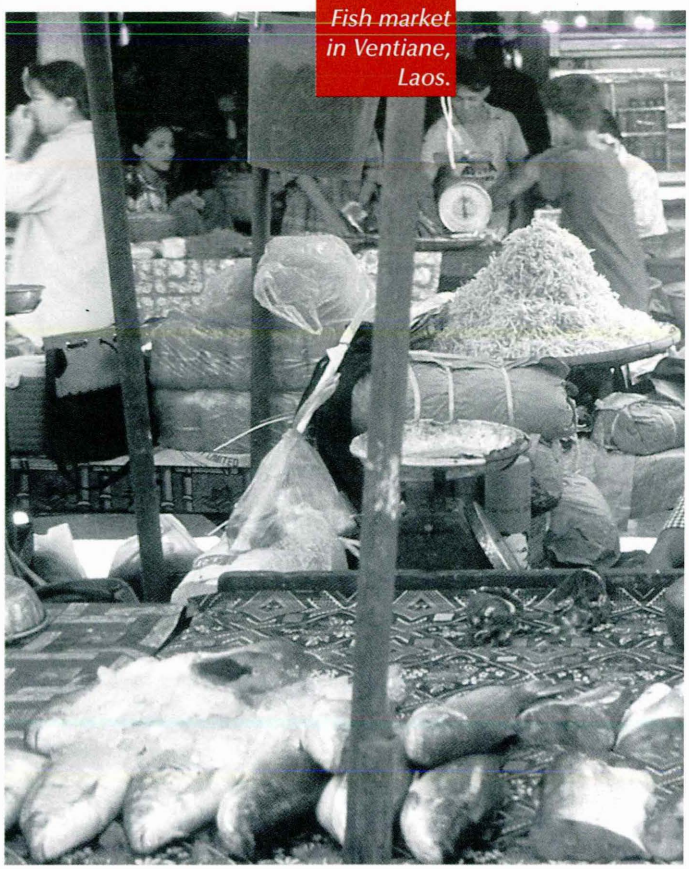
Sustainable agriculture research in Réunion

The research thrust on sustainable agriculture, environment and forestry, based in Réunion, brings together researchers from several CIRAD departments. Under this thrust, support was provided to the Directorate of Agriculture and Forests for the development of *contrats territoriaux d'exploitation*. A matrix for analysis and intervention was designed for those implementing the project, and some indicators of sustainability were defined at the farm and village levels. In addition, studies were conducted on diversification into fruit and vegetables. The studies examined the ability of local produce to compete with imports and applied to fruits the model of price fluctuations tested on vegetables in 1999. In collaboration with France's Institute of Statistics and Economic Studies (INSEE), the economic impact of various commodity production systems and the incentives for farmers to diversify into fruit and vegetables were analysed and compared. Research and training programmes were launched on these themes in collaboration with the University of Réunion. The programmes will contribute to the development of an information system for use in diagnosis, forward planning and decision support by relevant government bodies. ■

© F. Normand

Strawberry guava.

Advanced **methods** for innovation in science



Fish market in Ventiane, Laos.

In 2000, CIRAD's Department of Advanced Methods for Innovation in Science continued to host scientists from other institutions in its teams based at Montpellier, in Réunion and in other countries, for training in the use of the tools, software, models and methods it has developed. Our links with higher education were strengthened, with researchers from CIRAD participating in seminars or training modules in several university departments and colleges. Several projects submitted jointly with other CIRAD departments were approved by the European Union.

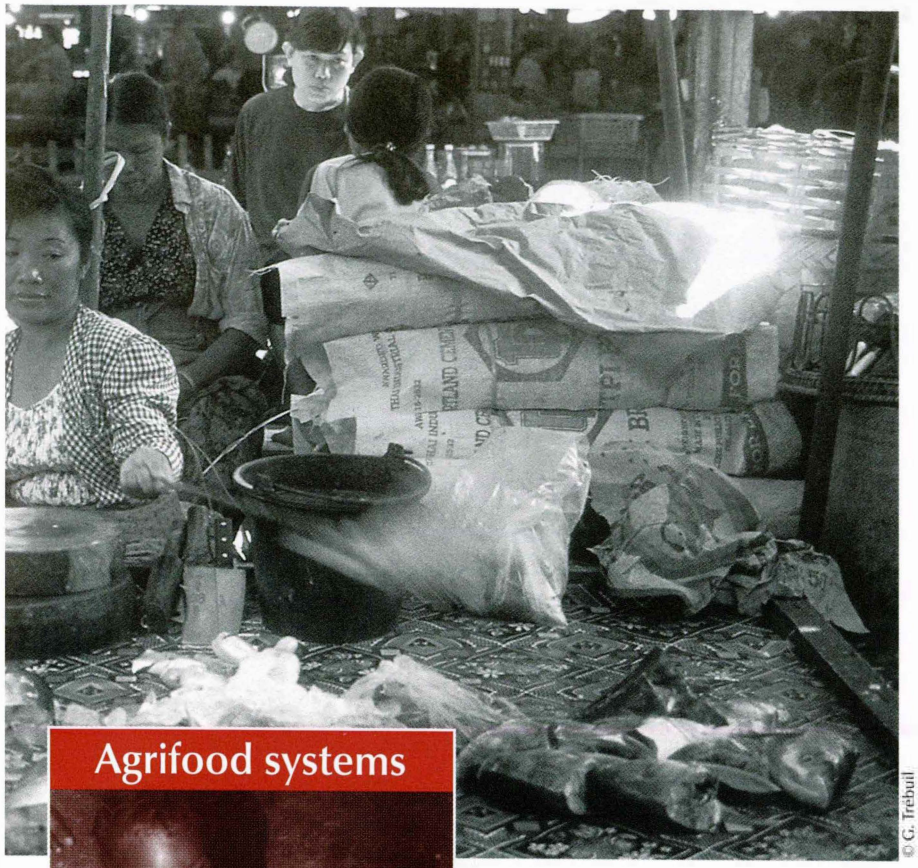
The joint research unit on the botanics and bio-informatics of plant architecture, shared by our plant modeling programme and the Institute of Evolutionary Sciences at Montpellier II University, became operational.

The first phase of the department's initiative on quality standards in commodity production came to fruition with the ISO 9002 certification of the agronomy programme's analytical laboratory. Now being applied by our agrifood programme and extended in 2000 to include Réunion, this initiative covers all aspects of quality in analytical work.

The Montpellier Génopole *—a cluster of local institutions conducting genomics research— and the associated* Génoplante *initiative became fully operational. This was marked by the establishment of a robotics laboratory within our biotechnology and plant genetic resources programme. Work on rice as a model plant, covering the full spectrum of research from the gene to the cultivated crop, also made considerable progress.*

The models developed by our economists gained increased recognition. These models, which take into account the institutional determinants of economic performance, are firmly anchored in real situations and form a marked contrast with classical general equilibrium models, which are little suited to the needs of developing countries.

Lastly, in response to the global emergence and spread of new plant diseases, CIRAD can now offer its partners in developing countries a comprehensive package of expertise with which to build understanding of the underlying mechanisms and develop a range of locally adapted control strategies.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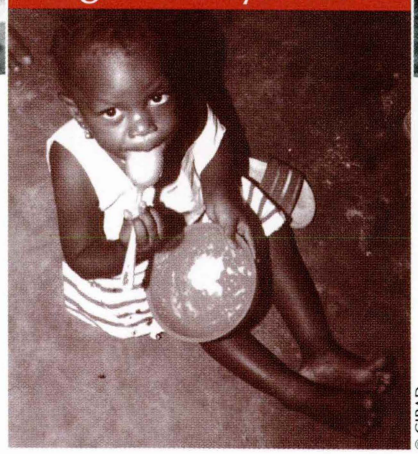
Agrifood systems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Global demand for food is rising rapidly, primarily as a result of population growth and urbanization in developing countries. The challenge is to increase the competitiveness of tropical produce on local and international markets by lowering costs and improving food safety and quality. Our research aims to contribute to the sustainable development of processing and marketing activities at small-scale or industrial level, so as to add value to agricultural produce. To complement commodity-based or ecoregional approaches, CIRAD's agrifood programme develops tools and methods in four fields: food technology, focusing specifically on improved procedures, processing equipment and food quality; the socio-economics of food, with special reference to trends in demand; support to enterprises for technological innovation and the development of quality assurance systems; and the planning of development-orientated research with local institutions.

Partnerships and projects

The programme's overseas activities were strengthened through the establishment of a regional research thrust based in Réunion. Collaborative arrangements with local institutions and enterprises participating in the PROSPER project, which seeks to develop links between public-sector research and private enterprise, were strengthened in Brazil and other Latin American countries. A researcher is now based in Africa, in Cameroon, and a post in the socio-economics of food is planned in Vietnam.

Food quality and safety: the ISO 9000 standard

The food quality and safety initiative, which at first focused on management procedures and the food safety aspects of processing equipment, was extended to cover all the programme's activities, with the 2000 version of the ISO 9000 standard serving as a common point of reference. The first outcome is usually a stronger grasp of technical management, including computerized inventorying and management of equipment and various interventions with regard to safety. Next, processing becomes more reliable and follows clearly defined procedures, such as good laboratory practices and the hosting of trainees. In addition, procedures for bringing about a continuous improvement in performance are established and followed, using accident report sheets and corrective and preventive measures.


© B. Barêa

Knowing how to handle dangerous products safely is part of quality assurance.

Adding value to animal products

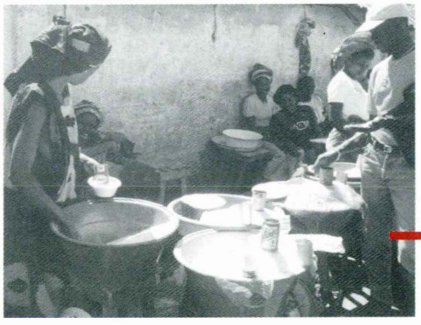
In Réunion, traditional processing of *boucané*, a form of salted, dried and smoked pork, was described in order to assess the effects of processing methods on product colour, flavour and stability. This study led to the development of a new food safety-orientated processing technique using a concentrated aqueous solution to salt, dry and flavour meat pieces in a single step.

To preserve fish, new immersion techniques such as concentrate solutions or liquid ice were tested as possible replacements for traditional refrigeration techniques. This work involved scientists from France's Centre for Food Preservation Technology (CTCPA) and Centre for Studies on Agricultural Machinery and Rural Civil Engineering (CEMAGREF), in addition to professionals from the industry. The thermal efficiency of the two techniques was evaluated on board fishing boats using a range of approaches on two types of fish, sardine and coal-fish. In 2001, the prototype equipment will be installed on board trawlers so that more detailed studies can be conducted with fishermen on how the technology works in real life and its impact on quality.

Fish fitted with sensors for thermal efficiency studies.

A watching brief on food and nutrition

In Tunisia and Vietnam, special teams with a watching brief in the field of food and nutrition were established, as part of a collaborative effort between CIRAD, the Institute of Research for Development (IRD), the Institute of Mediterranean Agronomy (IAM) and various local partners, including the National Institute of Nutrition and Food Technology in Tunisia and the National Institute of Nutrition in Vietnam. The teams will mainly serve the needs of agrifood enterprises, government services and donor agencies for scientific and technical information as a basis for orientating and evaluating their interventions in food-related areas. They will help assess the effectiveness of a new initiative on nutrition that has come in response to a critical assessment of global experiences in this field over the past 30 years. The teams will develop models of cause and effect in food-related situations, identify stakeholders' information needs, develop and use databases and conduct surveys.



Selling cassava meal, Guinea.

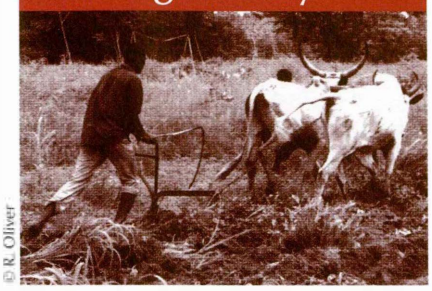
Grain mill, Guinea.

Increased collaboration in Guinea

Guinea's capacity in agrifood science and technology has been strengthened through CIRAD's participation in research planning and training activities at the Guinean Institute of Agronomic Research (IRAG).

Specifically, a number of new research projects have begun, for example on the preservation of cassava chips and the small-scale extraction of palm oil. New products have also been launched, including fruit juice, biscuits and a flour made of cassava and groundnut. For the team of young Guinean scientists, these initiatives provided opportunities to take market trends into account and to forge partnerships with small-scale enterprises.

Agronomy



© R. Oliver

Our agronomy programme builds teams to conduct agronomic research in tropical environments and underpins the development of agronomic decision support tools by improving research and diagnostic methods.

Plot-level cultivation models

The PASTIS model, developed by the National Agronomic Research Institute (INRA) at Avignon, has been enriched so that it can now describe more accurately the mechanisms by which soil properties are improved and the net transfers of water and nutrients occurring under different cultivation systems in tropical environments. These subroutines, which sometimes integrate two crops, cover plants and the *in situ* use of crop residues to form a mulch, are laborious to develop and difficult to use in the field. Nevertheless, they are useful for analysing the complex mechanisms that come into play and as a test-bed pending the development of simpler tools that are practical for field use, can be widely applied in different geographical contexts and—the ultimate aim—can be used as decision support tools.

In 2000, work on trends in soils under irrigation on Mali's *Office du Niger* schemes led to the characterization of soil alkalinity and soda accumulation processes and their kinetics. Modeling can now be based on a better understanding of the mechanisms at work. Questions relating to the management of water in flooded rice plots are being addressed in order to reconcile the conflicting objectives of achieving high yields in the short term while preserving soil fertility in the longer term. In Mexico, in systems based on direct sowing into a residue mulch, the model has been applied to quantify the effects of different amounts of residues on infiltration, evaporation and runoff and, more generally, to assess the availability of water and nitrogen to crops.

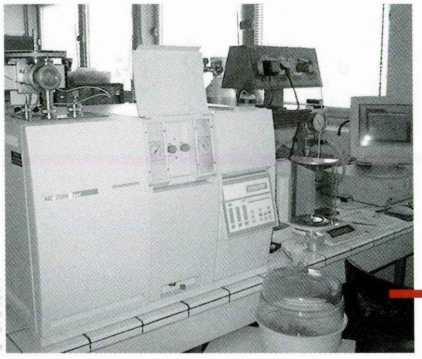
The model can be adapted to other situations in which transfers of water and nutrients are the main determinants of crop yields. This is the case in the live cover crop-based systems of Brazil, where nutrient flows, especially those of nitrogen, are critical. Water is still essential, of course, but does not appear limiting under these bioclimatic conditions.

Partnership with CERAAS

Our partnership with the Senegal-based Regional Centre for Studies on Drought Adaptation (CERAAS) was consolidated in the year 2000. It is the first step towards the development of a regional research thrust that will focus on modeling water and nutrient constraints and identifying biochemical and molecular markers for drought tolerance.

ISO 9002 certification of the analytical laboratory

Each year the agronomy programme's analytical laboratory processes around 20 000 samples of soils, fertilizers, water and plants, sent mainly by CIRAD researchers or their partners in developing countries. In February 2000, the laboratory was certified as meeting the ISO 9002 standard. This success crowns a voluntary initiative started five years ago, in which there has been strong participation by all staff and especially



© C. Bastid

Carbon and nitrogen analysis equipment (Thermoquest

© A. Findeling

Direct sowing of maize into maize stubble, using animal traction, Mexico.

technicians. Certified for the analysis of soils and plants, the laboratory can now offer its services with the full assurance for clients of high-quality work. The initiative, now extended to Réunion, aims to integrate a concern for quality throughout the research programmes of CIRAD and its partners.

SYSTEM, a new joint research unit

SYSTEM, a new joint research unit established to investigate component interactions and their management in Mediterranean and tropical cropping systems, brings together around 20 scientists at the Agro-Montpellier college of higher education, INRA and CIRAD. The combined team will work on modeling and diagnosing existing systems and designing new ones. The MOST laboratory, which will conduct research on organic matter in tropical soils, is being established at CIRAD and will be run jointly by CIRAD and IRD. It will support the activities of IRD's research unit on carbon sequestration, as well as CIRAD's work on the management of soil organic matter and its effects on fertility, carbon storage, nitrogen availability and soil biology in general.

© R. Oliver

Instruments for measuring soil water movement and composition, Brazil.

Plant biotechnologies and genetic resources

© J.C. Glaszmann

The support to plant breeding provided by our plant biotechnologies and genetic resources programme is reflected in the programme's three objectives: improving the management of genetic resources to ensure continuing access to useful genes; facilitating the development and identification of improved genotypes with high quality and tolerance to biotic and abiotic stresses; and contributing to the rapid dissemination of improved varieties. While seeking to improve its support to CIRAD's other programmes, the team conducts specific projects to develop new biological resources relevant to strategic objectives.

Specialized laboratories for structured activities

A series of specialized laboratories have been established, some focusing on a specific technical area such as histocytology or DNA extraction, while others cross disciplinary boundaries to tackle problems such as food hygiene and safety. Those in charge of each laboratory are responsible for its effective performance.

A highly automated laboratory was installed to produce and manage DNA libraries and to extract and amplify DNA sequences. This laboratory was financed by the Montpellier *Génopole* and a regional Languedoc-Roussillon fund. Its services are essential for meeting the needs of CIRAD's genomics projects and are also in demand from other regional teams.

DNA libraries enriched with microsatellites

CIRAD and its partners, in association with France's national sequencing centre, *Génoscope*, near Paris, have made available a series of DNA libraries enriched with microsatellites. The libraries cover a large number of plants and their pathogens, including banana (with *Mycosphaerella eumusae*, *M. fijiensis* and *M. musicola*), cacao (with *Phytophthora megakarya* and *P. palmivora*), coconut, coffee (with *Colletotrichum kawae*), cotton, date palm, mandarin, palm oil (with *Fusarium oxysporum* ssp. *elaeidis*), papaya, pineappple, rubber (with *Microcyclus ulei*), sapele, sugarcane (with *Puccinia melanocephala* and *Ustilago scitaminea*), taro, teak and yam. The work also included a grain crop, namely sorghum, and an associated pest insect, *Eurystylus oldi*, a sorghum head bug.

© M. Bartoli

Researchers are using robots to compile DNA libraries.

© M. Bartoli

Rice plants with DNA inserts under observation in a containment facility.

More than 12 000 clones containing a microsatellite have been extracted from these libraries. The clones were sent to *Génoscope* for sequencing and initial processing of the sequencing data. Microsatellite markers are highly polymorphic and easy to use, which will facilitate their adoption by laboratories in the tropics.

Preparing a gel for genetic fingerprinting of a variety.

© M. Bartoli

Rice as a model plant in the *Génoplante* programme

Our work on rice as the model plant for monocotyledons is conducted under four European projects and the French *Génoplante* project. The year 2000 saw the *Génoplante* project become fully operational. Under the project, more than 5000 mutant insertion lines were supplied, the aim being to reach 50 000 lines by 2003. Procedures for sequencing the flanking regions of DNA inserts, which are vital for evaluating these materials in the future, were established and the first sequences were determined. The project benefited by a number of important improvements in our facilities, notably an expansion of 85 square metres in the usable area of the laboratory.

Training and partnerships

In 2000, our laboratories in Montpellier hosted scientists and technicians from Algeria, Australia, Benin, Brazil, Côte d'Ivoire, Morocco, Quatar, Senegal, Tanzania, Thailand, Trinidad and Tobago and Venezuela.

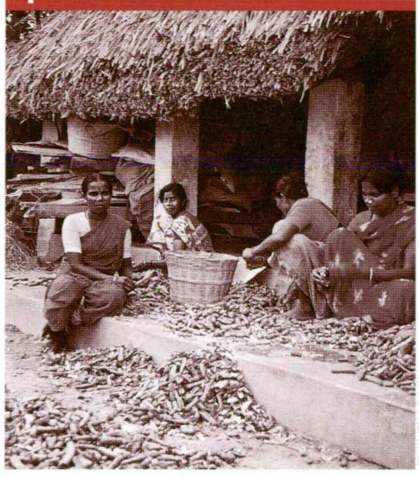
The relationship between CIRAD and CERAAS, in Senegal, integrated, when the two institutions became involved in a workshop on the role of biochemistry and molecular biology in the development of drought-resistant crop varieties. Funded by the West and Central African Council for Agricultural Research and Development (CORAF), the workshop was organized by CERAAS, the Senegalese Agricultural Research Institute (ISRA) and the Cheikh Anta Diop University of Dakar. Afterwards, a visiting technician from CERAAS received training in Montpellier for a period of four months.

The team was also involved in preparing two training courses. The first, on the use of molecular markers in rice improvement, was intended for West African rice breeders. This course was funded by an international agency that promotes university collaboration in francophone countries and by CORAF, in association with ISRA in Senegal and with the University of Abidjan and the National Agronomic Research Centre (CNRA) in Côte d'Ivoire. The second course, on the use of molecular markers in the improvement of plantain, is intended for researchers from Cameroon and the Central African Republic and will be held with support from the French Ministry of Research.

© Keita Abdoul-Karim

Course participants receive attendance certificates in a training seminar on the use of biotechnology in plant breeding, Côte d'Ivoire.

Economics, politics and markets



© N. Druesne

Given the different comparative advantages and natural resource endowments of different countries, market liberalization is creating a range of socio-economic problems associated with economic adjustment and policy making. In some cases, adjustment requires intervention by government or by local bodies to improve the social equity and efficiency of production and trade and hence of economic development as a whole.

This programme's first objective is to help identify these situations, as a basis for developing an economic scenario that reflects stakeholders' needs and aspirations. Its second objective is to outline relevant policy instruments or market interventions for developing countries. Market failures are identified using various diagnostic tools. Tools and methods have been designed to aid our understanding of specific situations, represent them objectively and analyse the consequences of changing them, using different policy scenarios.

The MATA model in Asia and Africa

On the basis of a description of how producers and consumers behave, the MATA model predicts the effects of different agricultural policy scenarios. It can be used for simulating, evaluating and monitoring the results of different interventions. The situations represented are chosen for their relevance to, and representativeness of, conditions in the field, on the basis of requests by developing countries.

Three situations are being modeled in Southeast Asia and sub-Saharan Africa: the diversification of agriculture in Central Luzon, the Philippines; the effects of irrigation facilities introduced in the Niger inland delta, in Mali; and the impact of different policy options on food security in Benin. In the first two cases, progress has been made in developing a typology of farms and the basic structure of the model. In the third, a modeling exercise has shown that the 1994 devaluation of the CFA franc has had a marked and prolonged effect on cotton production. Cotton producers have benefited, especially those using animal traction, but the production of local cereal crops has declined. The exercise was based on real data and a coherent representation of economic factors. It shows that cereal prices have risen relative to those of other commodities and that food consumption by urban populations has fallen, reflecting reduced purchasing power.

Maize intercropped with Robusta coffee, the Philippines.

© D. Snoeck

Market uncertainties: hypotheses and predictions

The signing of the agricultural agreement of the World Trade Organization (WTO), at Marrakesh in 1994, gave rise to new hopes that market risks and uncertainties would diminish, since the trade policies that were the source of the most serious instability would be phased out, to be replaced by multilateral rules of good conduct.

© J.M. Noël

Palm oil factory and estate, Indonesia.

A simple model of the market for palm oil—the world's most widely traded plant oil—over the past two centuries has shown that globalization and market liberalization have probably not reduced the risks of price fluctuations. Developed to elucidate the factors determining the volatility of major agricultural commodity markets, the model has enabled users to test the hypothesis that the volatility of international prices for tropical

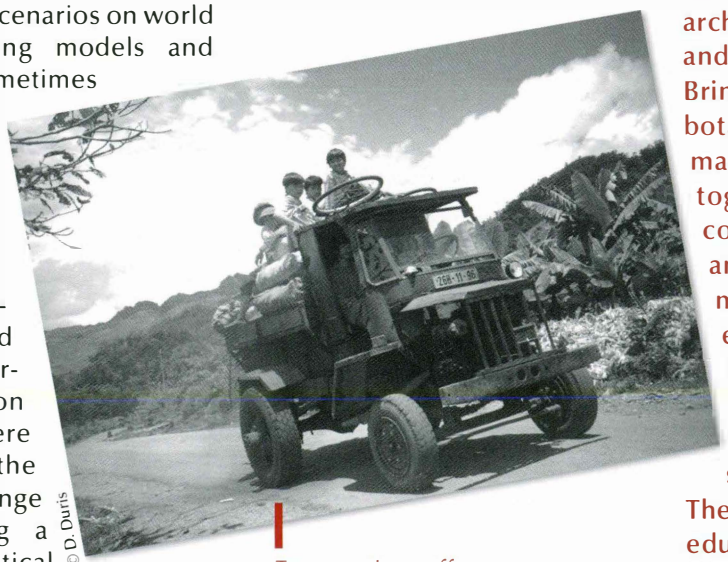
commodities can largely be explained by the co-existence of different distances across which goods are traded. Specifically, it was shown that the emergence of a local trade over short distances increases instability and the risks run by market participants. In some developing countries, new patterns of South-South trade are being superimposed on those of the traditional long-distance North-South trade. This hypothesis, which resembles those describing trends in financial markets, contradicts the arguments put forward during negotiations for the agricultural agreement.

Helping developing countries present their case

A model was developed to quantify the effects of different agricultural policy scenarios on world markets. Existing models and hypotheses, sometimes restricted in their scope, such as instantaneous equilibrium between supply and demand, the absence of risk and uncertainty, perfect competition and so on, were analysed. To the scientific challenge of formulating a new mathematical model of the economy that complements those used in international negotiations was added a development challenge—that of enabling developing countries to present a case that more accurately reflects their situation.

A prototype that integrates new options, such as price fluctuations and the absence of markets that cover risk, was developed. Markets were represented as operating according to a general equilibrium model in which all sectors of activity were taken into account. The model explicitly integrates the time-gap effect caused by the delay between the decision to produce, based on expected prices, and the arrival of produce on the market, which determines the actual prices paid.

According to initial simulations, false expectations are a major cause of variability in the international prices of agricultural commodities. In addition, it was confirmed that a completely liberalized market, as distinct from a partially liberalized one, does not always benefit producers and consumers more than a market with guaranteed prices.



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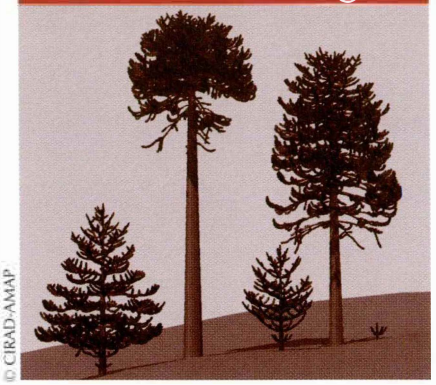
Transporting coffee, Vietnam.

Plant modeling



© CIRAD-AMAP

AMAP, the research unit on plant modeling shared by CIRAD and the French National Institute for Research on Information Technology and Automation (INRIA), is building the knowledge base on how plants develop—annuals and perennials, tropical and temperate. To this end, AMAP designs, develops and evaluates generic methods for measuring, analysing and modeling plant and stand architecture, growth, physiology and productivity.

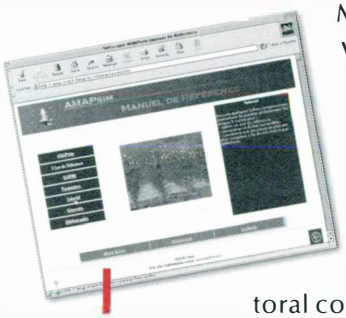
Bringing different disciplines—botany, ecology, applied mathematics, computer science—together, as this unit does, constitutes a major scientific and technical achievement for modern agriculture and forestry. The results, which take the form of knowledge, methods and tools, are made available to the scientists and students hosted by the unit. They are also transferred to higher education and, in some cases, lead to the development of industrial and commercial software.

Training

In 2000, efforts to disseminate the methods and tools developed by the unit were intensified.

Over 50 researchers from CIRAD, INRA and other institutions took part in training. Two courses of five days each were devoted to the measurement and analysis of plant architecture, while a further three-day course covered the simulation of plant growth.

Three modules were developed in colleges of higher education in Montpellier: one on integrated modeling of plant architecture and physiology, with Agro-Montpellier; another on stochastic modeling of biological phenomena, at the biostatistics doctoral college of Montpellier University; and the third on plant structure, scale, shape and algorithms for the computer course, also at a local doctoral college. Around 30 students took part in these modules, each of which lasts about 20 hours.



AMAP's tool for modeling plant growth.

Students from Argentina, Morocco and China were hosted at Montpellier. Lastly, a ten-hour tutorial covering all aspects of the mathematics and computer science of plant modeling was held in Madagascar during the Fifth African Conference on Computer Science.

Franco-Chinese cooperation now in full swing

Cooperation between France and China, which began in 1998 within LIAMA, a Franco-Chinese laboratory for information science, automation and applied mathematics, continued and was strengthened.

At the institutional level, the agreement between China's Academy of Sciences and France's INRIA has been extended to include the National Centre for Scientific Research (CNRS) and CIRAD, and a CIRAD scientist has been appointed a codirector of LIAMA. Links with the Chinese University of Agriculture have been strengthened and contacts established with specialized botany and forestry laboratories. Three Chinese doctoral candidates and two scientists came on short visits to France; CIRAD and INRA scientists went on seven missions to provide scientific and technical support.

© F. Blaise

Monitoring the growth of maize: an experiment under way at Beijing's University of Agriculture, China.

In terms of research, a new theory of plant morphogenesis was put forward, based on automation processes. It can be used to explain a plant's growth pattern and to introduce the effects of environmental variables. The growth models derived through use of the theory have interesting properties: they can be simplified in a rational way; their mathematical performance can be analysed; their parameters can be estimated from observations of plant architecture; and they can be used to optimize technical interventions. The theory is being used by a number of doctoral degree candidates to develop a new generation of software for simulating plant behaviour.

Modeling plant stands and landscapes

In collaboration with CIRAD's Forestry Department, version 4.0 of the software platform CAPSIS was developed. CAPSIS is used to model the growth of tree stands and the effects of different management regimes. The new version enables users to acquire a wide range of models for predicting yield in forest stands.

To advance the design of environmental and land-based information systems, technical partnerships were formed with institutions that generate spatial data, such as France's National Geographical Institute and the National Forestry Inventory. These partnerships build on the advances made by a European project on innovation, known as Imago-Metropolis. Geographical information systems (GIS) were successfully combined for the first time with software in the AMAP range. The partnerships also promote the commercial distribution of plant or landscape modeling software, responsibility for the management of which has been transferred to the company JMG Graphics, which was renamed Bionatics in early 2001. In return for royalties, CIRAD has undertaken to update the database on the plants modeled by these packages on a regular basis.

Modeling trends in land use.

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Botany and bioinformatics of plant architecture

During discussions of the four-year plan of Montpellier II University, the plant modeling unit's researchers expressed a desire to establish a new unit consisting of researchers from other CIRAD programmes, CNRS, Montpellier II University, the School of Practical Higher Studies and the Institute of Research for Development (IRD).

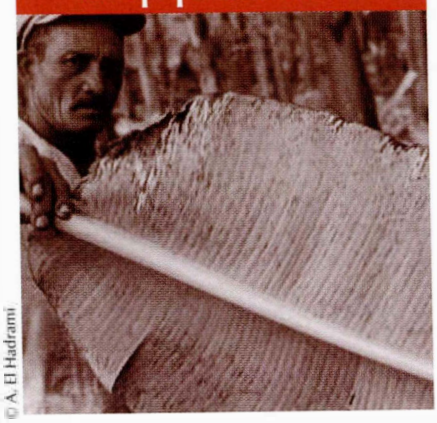
The new unit would be organized to conduct research on three main themes—taxonomy and phylogeny of plants and flowers, plant architecture and development and, lastly, the structure and dynamics of plant stands and landscapes—and to develop methods in three cross-cutting areas—database management, modeling and software engineering.

The directors of CIRAD and INRA, as well as the National Committee for Scientific Research, viewed this project favourably when it was submitted in June 2000. The departments of Life Sciences and Information and Communications at CNRS have proposed that it be officially launched on 1 January 2001.

© R. Lecoustre

Begonia carolineifolia.

Crop protection



© A. El Hadrami

The challenge facing our crop protection programme is to develop integrated control strategies for the major insect pests and diseases of tropical and subtropical crops. Specifically, the strategies integrate the use of genetically resistant plants, appropriate cultural practices, biological control and the rational use of pesticides. Knowledge in this field is being acquired through new alliances. For example the regional research thrust on crop protection, based in Réunion, brings together CIRAD, the University of Réunion, local government departments concerned with agriculture, forestry and crop protection, and an umbrella association of farmers' groups formed to control crop pests and diseases. A joint research unit on the biology and genetics of host-pest interactions in support of integrated crop protection brings together researchers from CIRAD, INRA and Agro-Montpellier. The unit will provide the human resources needed for both research and training in its field of competence.

Nematodes affecting coffee plants in Latin America

Three research projects on nematodes affecting coffee plants are being implemented by our PHYTOTROP laboratory in collaboration with CIRAD's Department of Perennial Crops.

Pratylenchus coffeae, a lesion nematode, is the species traditionally cited as mainly responsible for crop losses in South America and the Caribbean. Thesis work shows that in fact a complex of species is involved—species that are difficult to identify using the classical taxonomy, which is based mainly on morphological data. Thematic research will clarify the taxonomic status and pathogenicity of these populations.

© J.L. Sarah

Dying coffee plants infested with nematodes, Guatemala.

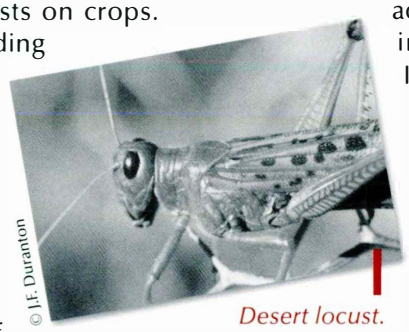
Elsewhere, root-knot nematodes of the genus *Meloidogyne* are dominant and cause serious economic losses. Previous work has revealed the considerable diversity of Central American populations in terms of both the number of species and their pathogenicity. A European project implemented with IRD will examine in detail the genetic and biological diversity within this genus,

in Central America and Brazil. At the same time, molecular probes based on satellite DNA will be developed under a joint CIRAD-INRA project.

Insecticidal plants in Sudan

Following the mass spraying of chemical insecticides to control the most recent plague of desert locusts in 1997 and 1998, it has become vital to develop solutions that are less damaging to the environment.

In Sudan, some plants are traditionally harvested by local farmers or pastoralists to kill cattle ticks or control insect pests on crops. Besides being a breeding ground for desert locusts, Sudan also suffers from chronic infestations of grasshoppers. There is thus good reason for assessing the insecticidal properties of local plants, including *Adenium* sp., *Mucuna* sp., *Azadirachta indica* and *Calotropis procera*.


© J.F. Duranton

Desert locust.

A thesis study undertaken with the University of Kordofan and the Faculty of Pharmacy at the University of Montpellier received financial support from the French embassy in Sudan and technical support from CIRAD researchers. Under study are the mechanisms that make these plants effective against locusts and grasshoppers and the risks of poisoning non-target organisms. This will open up opportunities for developing treatments based on simple formulations that are easy to prepare and apply, for use by national crop protection services and farmers. In 2000, extraction techniques were developed and the first tests were conducted on insects.

Towards the management of black leaf streak disease of banana

Black leaf streak disease is a serious foliar disease of banana, found in almost all banana growing areas. It is caused by *Mycosphaerella fijiensis*. Genetic improvement programmes aim to develop new varieties resistant to this fungus. The sources of resistance used need to be the widely effective and durable.

Research is being conducted in the laboratory and in the field, under a project between CIRAD and the European Union with additional funding from the International Network for the Improvement of Banana and Plantain. The work is conducted in partnership with the Regional Research Centre for Bananas and Plantains (CRBP) in Cameroon and with the Tropical Agronomy Research and Training Centre (CATIE) in Costa Rica.

Because of the diversity of this pathogen, the preferred approach is to look for partial resistance that will slow down the development of the parasite and hence the progress of epidemics. It is thought that partial resistance will prove more durable than total resistance.

To identify this kind of resistance, the different mechanisms at work at each stage of the life-cycle of the fungus are identified under controlled conditions in the PHYTOTROP laboratory in Montpellier. The role of these mechanisms in controlling the disease is then evaluated in the field, mainly by the CRBP in Cameroon. This characterization, which has been partly completed, will allow the most effective source of partial resistance to be selected for future use.

Studies on the structure and evolution of pathogen populations, conducted using molecular markers, and a test for pathogenicity, aim to evaluate the durability of resistance. These analyses are conducted in space, so as to describe the distribution of genetic diversity in pathogen populations and assess their potential for adaptation. The knowledge gained in this way will enable scientists to design control strategies that take into account the pathogen's possible future evolution. Results at continental scale have already been obtained in Africa and Latin America. Studies at country level are now under way.

Since the year 2000, our partners have had access to the methods CIRAD has developed and can therefore conduct analyses directly in the areas of production affected. Nevertheless, samples from different regions can only be compared in non-production areas, so this is done in Montpellier. Lastly, an epidemiological modeling tool is being developed so as to improve the planning of experiments and the interpretation of results as a function of the parameters tested. ■


© E. Foure

Banana severely affected by black leaf streak diseas Gabon.

CIRAD at a glance

Organizational chart

Departments

Committees

Research coordination

Regional representatives

CIRAD worldwide

Budget and staff

Training

Addresses

List of acronyms

Organizational

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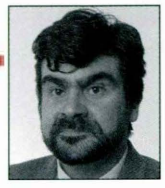
Chairman, Scientific Advisory Committee
Guy Riba

Director General
Bernard Bachelier



Head, Scientific and Technical Information
Jean-François Giovannetti

Head, Information and Communications Technology
Joël Sor

Secretary General
Vincent Dollé

Departmental Directors

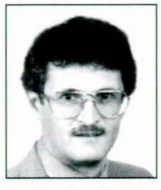
CIRAD-CA
Alain Capillon

CIRAD-CP
Denis Despréaux

Director, Research
Michel Griffon

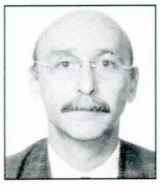
CIRAD-FLHOR
Jean-Pierre Gaillard

CIRAD-EMVT
Joseph Domenech



CIRAD-Forêt
Jacques Valeix

Director, External Relations
Alain Derevier



CIRAD-TERA
Rolland Guis

CIRAD-AMIS
Anne-Yvonne Le Dain

Director, Montpellier Research Centre
Maurice Izard

Chart of CIRAD in 2001

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Marc Gélis, Manager

Human Resources
François Fort, Manager

Installations and Maintenance
Didier Servat, Manager

Management Support
Christian Altairac, Head of Service

French Overseas Departments and Territories
François Pointereau, Head

Representatives
(see page 105)

Scientific and Technical Information

Information and documentation
Lucile Grasset

Publications and multimedia
Martine Séguier-Guis

Research Administration
Deputy Director
Jacques Meunier

Research Coordination
Crop, environment and natural resource management
Eric Malézieux

Plant improvement
Philippe Feldmann

Crop protection
To be appointed

Animal production
Philippe Lhoste

Technology
Guy Linden

Economics and sociology
Benoit Daviron

Applied mathematics and informatics
Marc Jaeger

International Research Training Networks
Michel Benoit-Cattin

Forward and Strategic Studies
Marie de Lattre-Gasquet

External Relations

Africa, Indian Ocean
To be appointed

Latin America, Caribbean
André de Courville

Asia, South Pacific
Patrick Durand

International organizations, Middle East
Pierre-Luc Puglièse

Overseas representatives
(see page 105)

Partnerships, private sector
Christian Brunin

Partnerships, donor and development organizations
Alain Guyot

External communications
Anne Hébert

CIRAD departments in 2001

Annual crops (CIRAD-CA)

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Jean-Luc Khalfaoui, Deputy Director, Research Coordination
Officer, Management Support Service
To be appointed
Philippe Ourcival, Consultancy and Operations Bureau

Robert Domaingue, Head, Sugarcane Programme
Jean-Philippe Deguine, Head, Cotton Programme
Pierre Fabre, Head, Food Crops Programme
Francis Forest, Head, Agrosystems Programme

Tree crops (CIRAD-CP)

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Thierry Corbineau, Assistant Director, Officer, Management Support Service
Christian Picasso, Consultancy and Operations Bureau

Philippe Petithuguenin, Head, Cocoa Programme
Dominique Berry, Head, Coffee Programme
André Rouzière, Head, Coconut Programme
Jérôme Sainte-Beuve, Head, Rubber Programme
Alain Rival, Head, Oil Palm Programme

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Jacky Ganry, Deputy Director, Research Coordination
Pierre-Jean Ballard, Officer, Management Support Service
Jean-Paul Meyer, Consultancy and Operations Bureau

Thierry Goguey, Head, Fruit Trees Programme
Jacky Ganry, Head, Banana, Plantain and Pineapple Programme
Head, Horticultural Products Programme (appointment pending)

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Guilhem Lacombe, Officer, Management Support Service
Jérôme Thonnat, Officer, Formal Education and Training
Jean-François Renard, Consultancy and Operations Bureau

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Bernard Faye, Head, Animal Production Programme
Emmanuel Camus, Head, Animal Health Programme

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Gilles Mille, Consultancy and Operations Bureau

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Bernard Mallet, Head, Trees and Plantations Programme
Christian Sales, Head, Forest Products Programme

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Officer, Management Support Service
To be appointed
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Emmanuel Torquebiau, Head, Land and Resources Programme
Guy Faure, Head, Savannas and Irrigated Systems Programme
Alain Ducreux, Head, Humid and Insular Tropics Programme

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Dany Griffon, Quality Monitoring

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Florent Maraux, Head, Agronomy Programme
Jean Christophe Glaszmann, Head, Plant Biotechnologies and Genetic Resources Programme
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François Houllier, Head, Plant Modeling Programme
Xavier Mourichon, Head, Crop Protection Programme

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Gilles Thevenet, ITCF
Jacques Wéry, Agro-Montpellier

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Adviser
Hélène Joly

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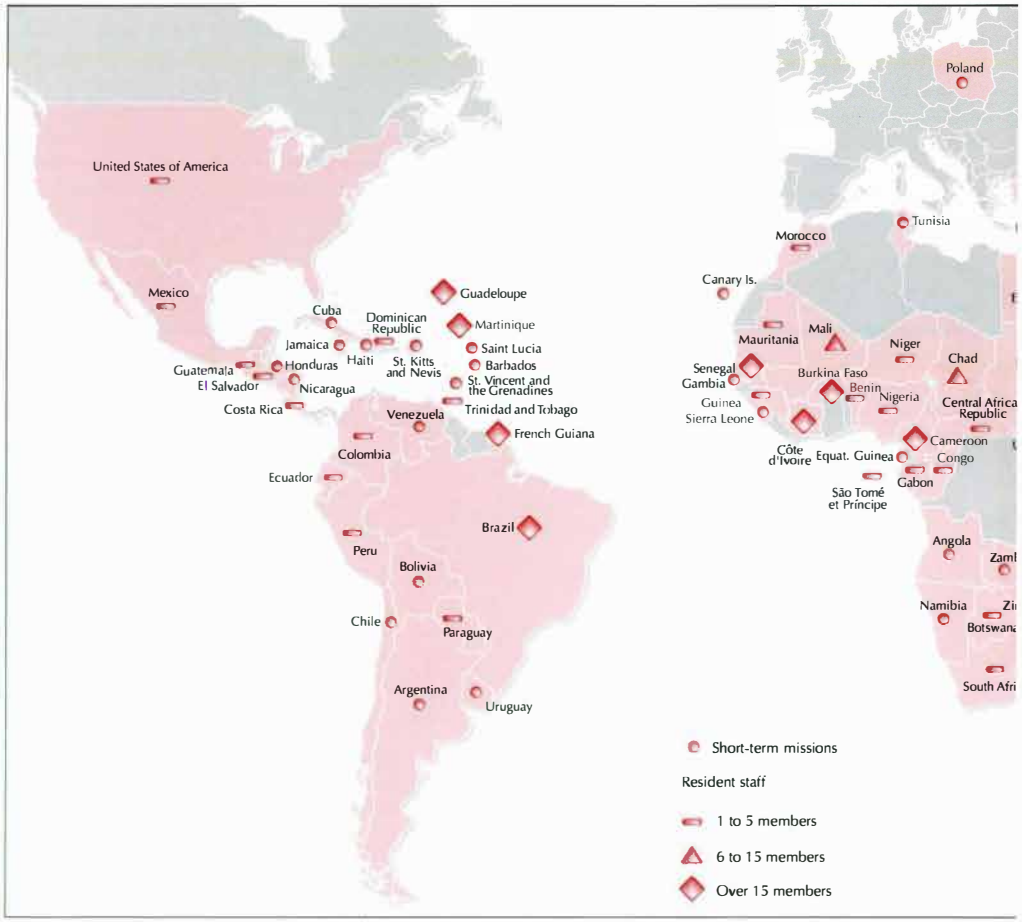
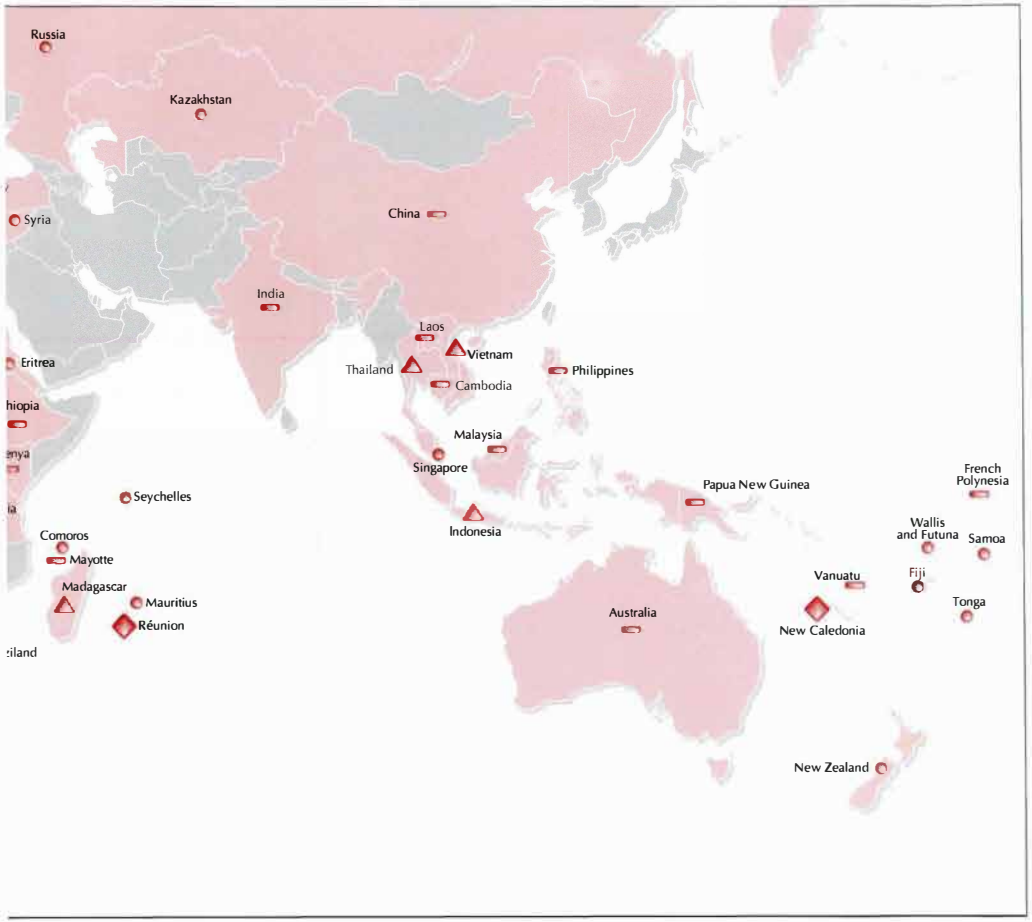
Vietnam, **Gilles Mandret**
Zimbabwe, **Dominique Dulieu**

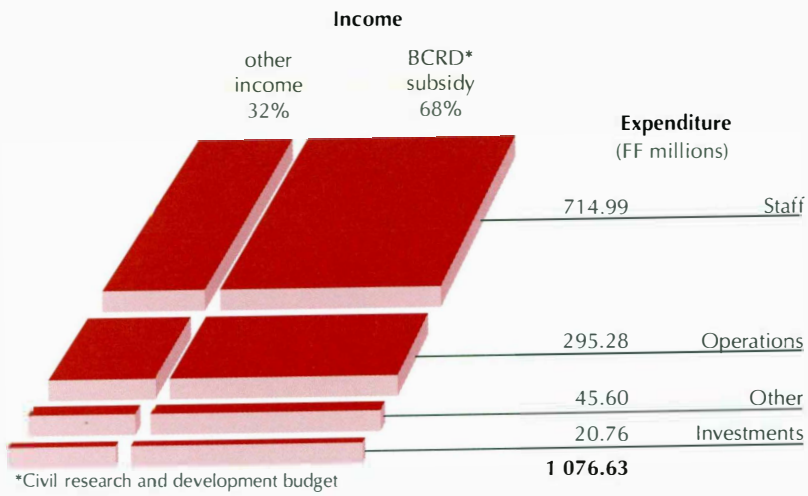
CIRAD worldwide



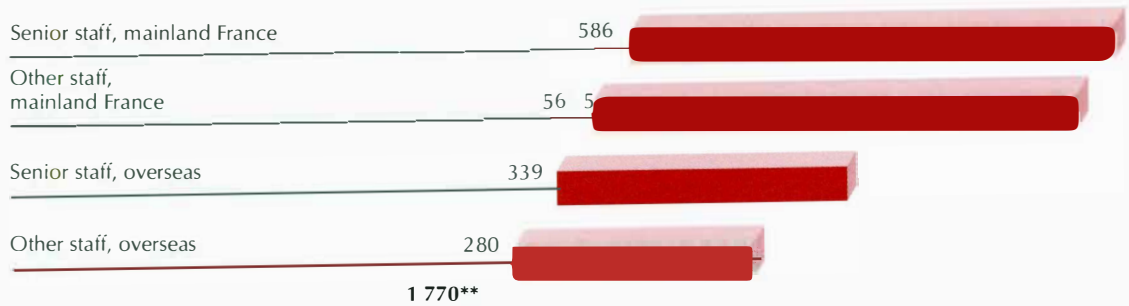


Budget and staff in 2000

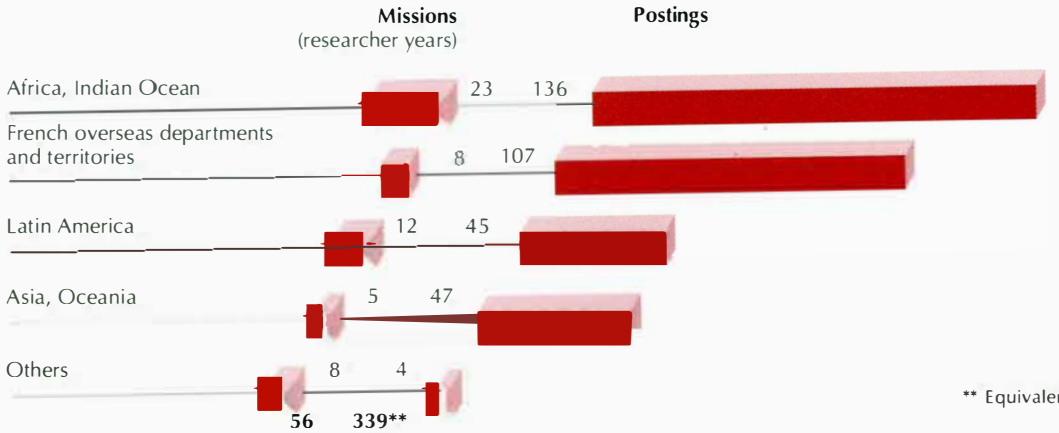
Income and expenditure



Distribution of staff by category and location



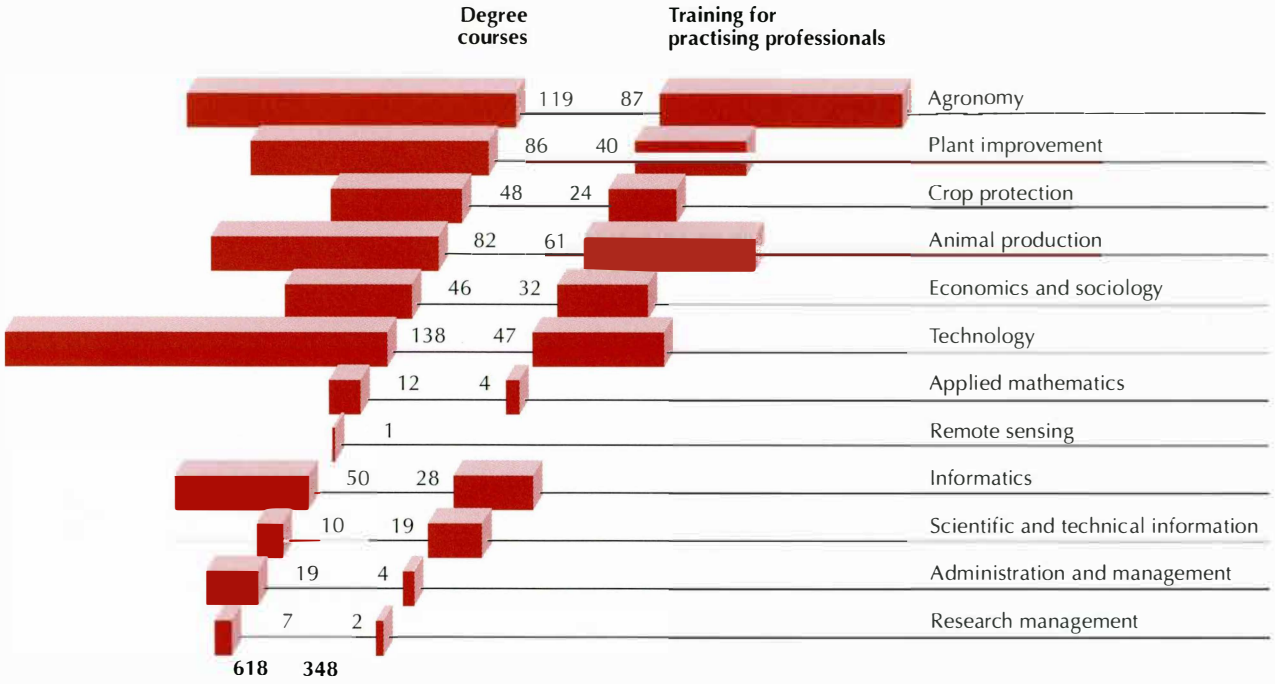
Geographical distribution of senior staff overseas



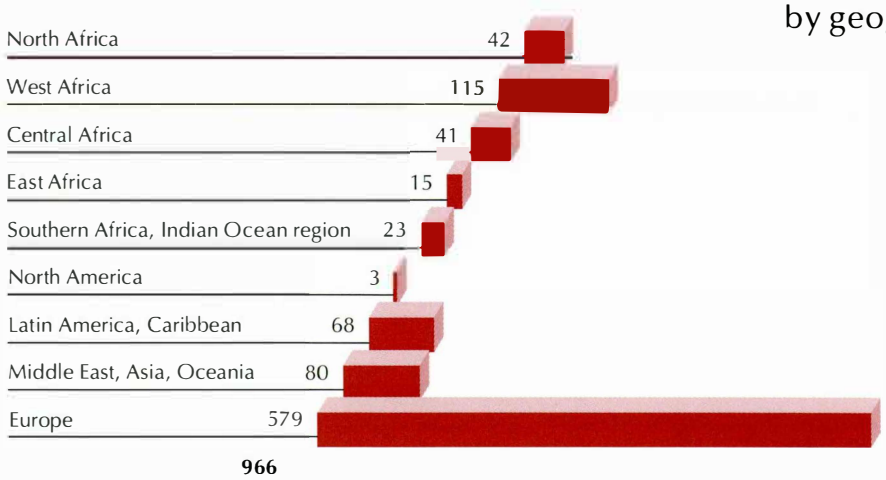
** Equivalent in full-time posts

Training in 2000

Distribution by discipline and type of training



Distribution of trainees by geographical origin



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List of acronyms

AFD, Agence française de développement, France

AFLP, Amplified Fragment Length Polymorphism

AFSSA, Agence française de sécurité sanitaire des aliments, France

Agro-Montpellier or ENSAM, Ecole nationale supérieure agronomique de Montpellier, France

ANACAFE, Asociación Nacional del Café, Guatemala

APROSTOC, Association de producteurs stockeurs de céréales, Cameroon

AUF, Agence universitaire de la francophonie, Canada

AVRDC, Asian Vegetable Research and Development Center, Taiwan

BUROTROP, Bureau for the Development of Research on Tropical Perennial Oil Crops, France

CAOBISCO, Association des industries de la chocolaterie, de la biscuiterie et de la confiserie, Belgium

CAP, Cleaved Amplified Polymorphism

CARDI, Caribbean Agricultural Research and Development Institute, Trinidad and Tobago

CATIE, Centro Agronómico Tropical de Investigación y Enseñanza, Costa Rica

CCRI, Cocoa and Coconut Research Institute, Papua New Guinea

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

CERAAS, Centre d'étude régional pour l'amélioration de l'adaptation à la sécheresse, Senegal

CERF, Canne à sucre création variétale et technologie sucrière, Réunion, France

CGIAR, Consultative Group on International Agricultural Research, USA

CIAT, Centro Internacional de Agricultura Tropical, Colombia

CIMMYT, Centro Internacional de Mejoriamento de Maíz y Trigo, Mexico

CIRES, Centre ivoirien de recherche économique et social, Côte d'Ivoire

CNEARC, Centre national d'études agronomiques des régions chaudes, France

CNRA, Centre national de recherche agronomique, Côte d'Ivoire

CNRF, Centre national de la recherche forestière, Morocco

CNRS, Centre national de la recherche scientifique, France

CNS, Centre national de séquençage, France

COGENT, Coconut Genetic Resources Network, Singapore

COODETEC, Cooperativa Central Agropecuária de Desenvolvimento Technológico e Econômico, Brazil

CORAF Conseil ouest et centre africain pour la recherche et le développement agricoles

CRBP, Centre de recherches régionales sur bananiers et plantains, Cameroon

CRPF, Centre régional de la propriété forestière du Languedoc-Roussillon, France

CRU, Cocoa Research Unit, Trinidad and Tobago

CTA, Technical Centre for Agricultural and Rural Cooperation

CTBA, Centre technique du bois et de l'ameublement, France

CTCPA, Centre technique des conserves de produits alimentaires, France

CTU, Can Tho University

ENSIA, Ecole nationale supérieure des industries alimentaires, France

EU, European Union

FAO, Food and Agriculture Organization of the United Nations, Italy

FAPESP, Fundacão de Amparo à Pesquisa do Estado de São Paulo, Brazil

FDGEC, Fédération des groupements de défense contre les ennemis des cultures, France

FOFIFA, Foibe Fikarohana Ampiharina amin-ny Fampandrosoana ny Ambanivohitra, Madagascar

GAPKINDO, Indonesian Rubber Association

HJRBDA, Hadejia Jama'are River Basin and Rural Development Authority, Nigeria

IAC, Institut agronomique calédonien, New Caledonia

IAC Net, Interamerican Citrus Network

IAM, Institut agronomique méditerranéen, France

ICAFE, Instituto de Café de Costa Rica, Costa Rica

ICARDA, International Centre for Agricultural Research for the Dry Areas, Syria

ICGI, International Cotton Genome Initiative

ICRA, Institut centrafricain de recherche agronomique, Central African Republic

ICRAF, International Centre for Research in Agroforestry, Kenya

ICRISAT, International Crops Research Institute for the Semi-Arid Tropics, India

ICSB, International Consortium for Sugarcane Biotechnologies

IER, Institut d'économie rurale, Mali

IFC, Institut français du caoutchouc, France

IFN, Inventaire forestier national, France

IGN, Institut géographique national, France

IHCAFE, Instituto Hondureño del Café, Honduras

IICA, Instituto Interamericano de Cooperación para la Agricultura, Costa Rica

IITA, International Institute of Tropical Agriculture, Nigeria

INA-PG, Institut national agronomique Paris-Grignon, France

INERA, Institut de l'environnement et des recherches agricoles, Burkina Faso

INIBAP, International Network for the Improvement of Banana and Plantain, France

INRA, Institut national de la recherche agronomique, France

INRAB, Institut national de recherches agricoles, Benin

INRIA, Institut national de la recherche en informatique et automatique, France

INRO, International Natural Rubber Organization

INSEE, Institut national de la statistique et des études économiques, France

IOPRI, International Oil Palm Research Institute, Indonesia

IPGRI, International Plant Genetic Resources Institute, Italy

IRAD, Institut de recherche agricole pour le développement, Cameroon

IRAG, Institut de recherche agronomique de Guinée, Guinea

IRCV, Institut de recherches sur le caoutchouc du Vietnam, Vietnam

IRD, Institut de recherche pour le développement, France

IRRI, International Rice Research Institute, Philippines

IRSG, International Rubber Study Group, UK

ISRA, Institut sénégalais de recherches agricoles, Senegal

ISSCT, International Society of Sugar Cane Technologists, USA

ITRD, Institut tchadien de recherche agronomique pour le développement, Chad

ITTO, International Tropical Timber Organization, Japan

IUFRO, International Union of Forest Research Organizations, Austria

LEAD, Livestock, Environment And Development

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

MSIRI, Mauritius Sugar Industry Research Institute, Mauritius

NAERLS, National Agricultural Extension and Research Liaison Service, Nigeria

OAU, Organization of African Unity

ONC, Office national de la chasse et de la faune sauvage, France

ONF, Office national des forêts, France

OSS, Observatoire du Sahara et du Sahel

PCR, Polymerase Chain Reaction

PORIM, Palm Oil Research Institute of Malaysia, Malaysia

PPZS, Pôle pastoral en zones sèches, Senegal

PRASAC, Pôle régional de recherche appliqué au développement des savanes d'Afrique centrale, Chad

PROCAFE, Fundación Salvadoreña para Investigaciones del Café, El Salvador

PROCITROPICOS, Programa Cooperativo de Investigación y Transferencia de Technologiá para los Trópicos Suramericanos, Brazil

PT SMART, PT Sinar Mas Agro Resources and Technology Corporation, Indonesia

QTL, Quantitative Trait Locus

RAPD, Random Amplified Polymorphic DNA

RFLP, Restriction Fragment Length Polymorphism

SOCFINDO, Socfin Indonesia, Indonesia

SODECOTON, Société de développement du coton, Cameroon

UNICAFE, Union Nicaraguense de Cafetaleros, Nicaragua

UNOCACE, Union de las organizaciones campesinas cacaoteras de Ecuador, Ecuador

UPOV, Union des protections des obtentions végétales, France

WARDA, West Africa Rice Development Association, Côte d'Ivoire

WCASRN, West and Central African Sorghum Research Network

WECARD, West and Central African Council for Agricultural Research and Development, Senegal

WICSCBS, West Indies Central Sugar Cane Breeding Station, Barbados

WTO, World Trade Organization, Switzerland

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