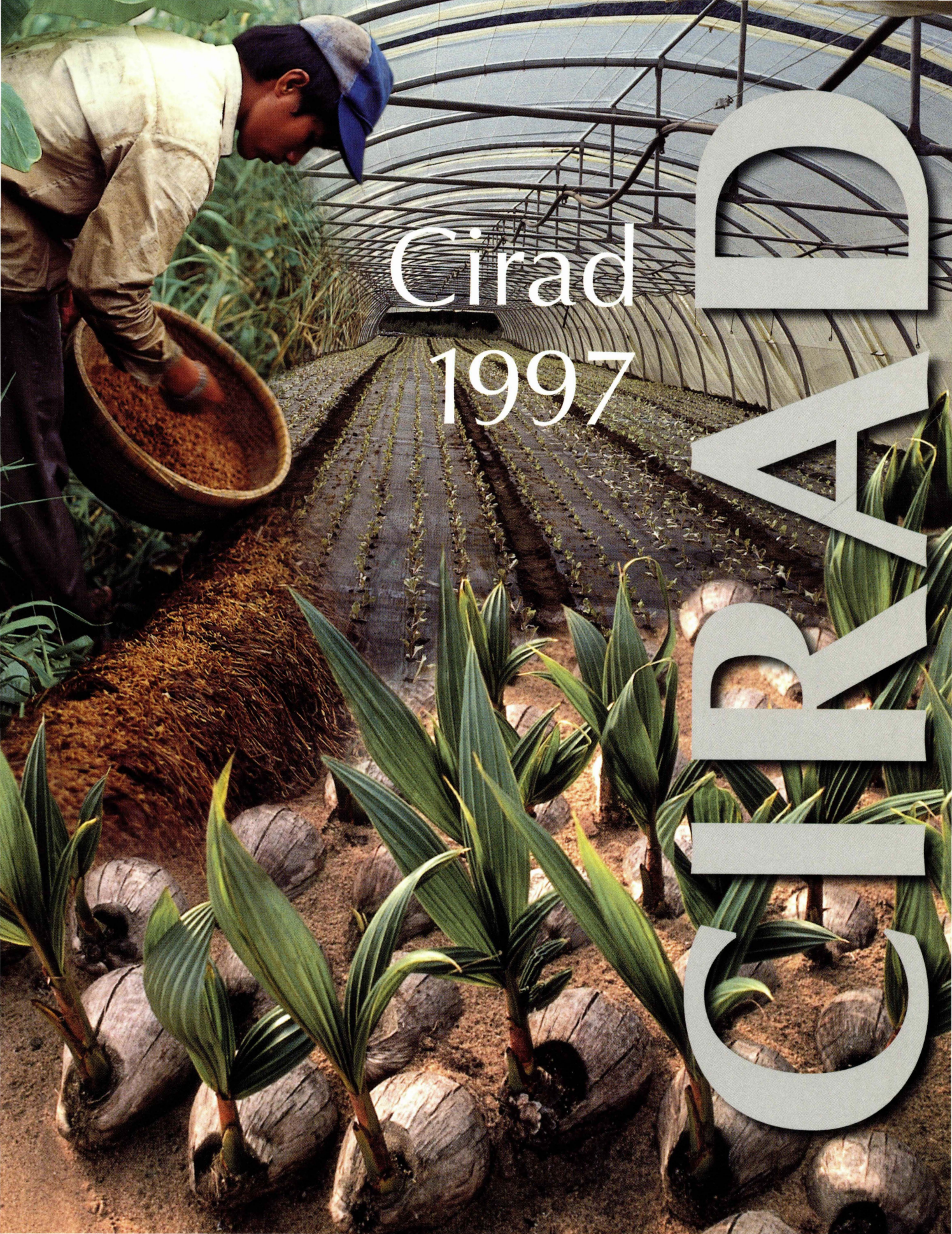
Cirad
1997
CIRAD

Cirad 1997

The Centre de coopération internationale en recherche agronomique pour le développement (CIRAD) is a French scientific organization specializing in development-oriented agricultural research for the tropics and subtropics. It is a state-owned body and it 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 1 billion French francs, more than half of which is derived from public funds.

CIRAD is made up of 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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The President's Message

For CIRAD, 1997 was a year for building up relations of trust with all of its partners and for developing its capacity to anticipate the pattern of events and to foresee their evolution.

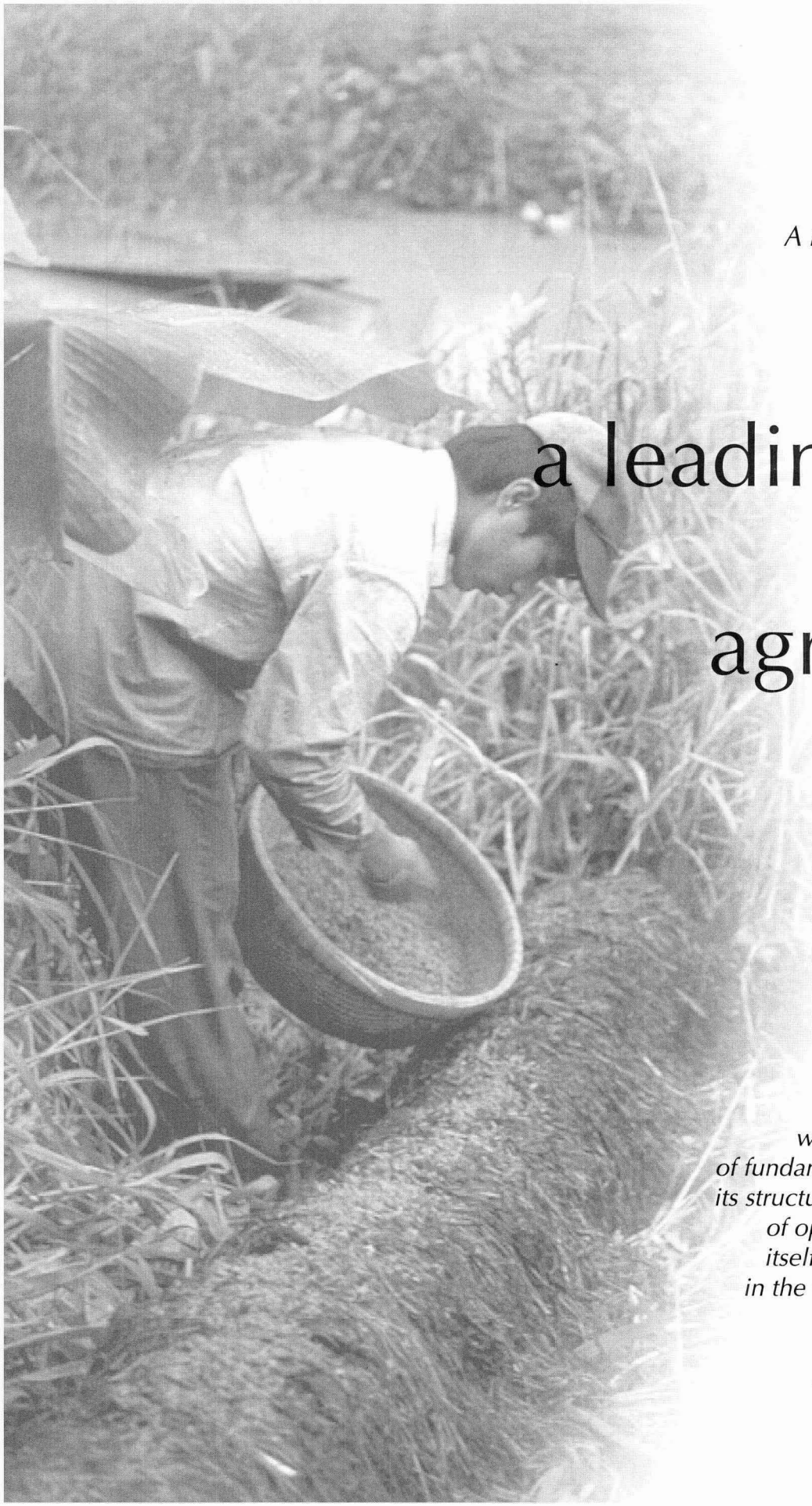
In a rapidly changing world, we must establish a clearer focus for our strategy while broadening the scope of our action. CIRAD is thus continuing its work with research centres in Southern countries and developing active partnerships with regional organizations. It is providing support to both public institutions and private businesses, performing valuable research and making optimal use of the results obtained.

To improve the quality of its work and thereby, contribute more effectively to rural development in tropical regions, it is teaming up with new partners, including producer organizations and NGOs, among others. I am also very pleased to see that the number of laboratories run jointly by CIRAD, INRA, ORSTOM and the French universities is on the increase. They are the cornerstone for the construction of a French system of development-oriented agricultural research and offer optimal facilities and working conditions for visiting scientists from other Northern and Southern countries.

Jacques Poly, the first President of our Board of Trustees, passed away in 1997. I would like to pay tribute to this enlightened and warm-hearted man who, with considerable foresight, began the task of preparing CIRAD for the 21st century. He had a profound understanding of CIRAD's mission. He encouraged CIRAD to create alliances with a wide range of stakeholders and to develop modern scientific tools, biotechnologies in particular. Today, we are reaping the benefits of his initiatives and forging ahead with the projects that he brought into being.

The financial and structural crisis in Asia and the economic and political developments in Africa have shown us once again that the future is never a simple continuation of the past. For this reason, CIRAD must develop a pro-active approach, daring to move out of comfortable, long-held positions to confront the challenges of the future. The structural and organizational reforms adopted in 1997 have given CIRAD greater flexibility and mobility, enabling it to respond more rapidly to new ideas and situations. Its structure is simpler and more clearly focused, thus facilitating dialogue with our partners, in the business sector especially. To promote creative alliances with our colleagues in the South and North, we must strive for exacting scientific standards and show a strong will for achievement and innovation.

Guy Paillotin
President



A new structure, a new strategy

CIRAD, a leading player in world agricultural research

For CIRAD, the year 1997 will be remembered as a period of fundamental reform. By streamlining its structure, its management and mode of operation, CIRAD has equipped itself to occupy a strategic position in the world system of development-oriented agricultural research and to prepare for the future in a rapidly changing research environment.

Following a period of reform launched at the end of 1996, involving 12 months of reflection, consultation and discussion within the organization and with its various partners, a new and radically different CIRAD came into being on 1 January 1998.

Approved by the Board of Trustees on 11 December 1997, the reform affects CIRAD's structure, its management and its mode of operation. Its simplified structure gives greater clarity to research priorities. Its new mode of operation, based on the principle of unity within the organization, cuts down bureaucracy and offers optimum conditions for the creation of common tools to serve every department.

Initially divided among more than 60 different entities, i.e. research units and programmes, CIRAD's scientific potential is now channelled into 28 programmes, based around three major themes: commodity subsectors, regional development and scientific disciplines.

The activities of five departments are devoted to agricultural subsectors: annual crops, tree crops, fruit and horticultural crops, animal production and veterinary medicine, and forestry. By reducing the number of production subsectors from more than 20 down to 14, CIRAD is concentrating its forces in its recognized areas of excellence, capitalizing upon the specific experience it has acquired and enriched during many years of research in Southern countries. It also wishes to play a complementary role with respect to other scientific institutions, such as the international agricultural research centres for example.

At the meeting point between production and the environment

By creating a department devoted to regional development, CIRAD aims to respond more effectively to the needs of decision-makers, governments, local communities and producer organizations responsible for land development and sustainable resource management. The department includes teams working on ecoregional projects, such as the Pôle sur les systèmes irrigués (PRASAC, a regional research centre for Sudano-Sahelian irrigation systems), which provide outstanding opportunities for new types of partnerships with Southern national agricultural research systems, Northern institutions and international centres. At the meeting point between production and the environment, the integrated study of technical, economic and human factors governing development dynamics at the plot, community and regional levels, is enriched by the rational association of methodological know-how and research in the field. This approach offers major potential for scientific advance and CIRAD fully intends to grasp the opportunities provided.

Lastly, the scientific support programmes, grouped together in a new department and based essentially in Montpellier and in the French overseas departments and territories, provide methodological support to the other CIRAD programmes and to its partners. They are also responsible for managing the Centre's large-scale scientific facilities. The size of the new research teams and the range of expertise that they represent have been optimized to ensure that the key research themes for development in Southern countries can be tackled more effectively. This is the case for two programmes in particular, one dedicated to biotechnologies and molecular biology for the development and dissemination of more productive and environmentally friendly tropical varieties, the other focusing on food processing techniques to satisfy consumer demand and to meet the economic imperatives of the commodity subsectors concerned.

After establishing CIRAD's new framework for scientific research, the reform entered its second phase, namely the reorganization of the technical support and management services. Certain sectors such as information and documentation, publishing, computer technology, administration and accounting, were previously attached to each different department. They have now been brought together as specialized services operating under a harmo-

The twenty-eight CIRAD programmes

Annual crops	The annual crops studied by CIRAD are grown mainly by small farmers. They are a key factor of income security in rural areas and constitute a framework in which national processing and marketing enterprises are able to emerge and develop. Their future prospects will depend upon the development of producer organizations which represent the sole means to offset the progressive withdrawal of government support.	• **Sugarcane** • **Cotton** • **Food crops** • **Agrosystems**
Tree crops	Focusing on the major export crops of the humid tropical regions, CIRAD know-how in the field of tree crops is unique and widely recognized. At a time when smallholders are playing an ever increasing role in production, the challenge is to reconcile international market competitiveness, governed by the quality of product processing, with the need to develop sustainable agricultural methods.	• **Cocoa** • **Coffee** • **Coconut** • **Rubber** • **Oil palm**
Fruit and horticultural crops	The production of fruit, vegetables and flowers is a central component of the diversification strategies adopted by farmers in tropical regions. With growing urban demand for fresh produce, this sector is destined to play a crucial role in the agricultural modernization of developing countries.	• **Fruit trees** • **Banana and plantain** • **Horticultural production**
Animal production and veterinary medicine	From the development of treatments and vaccines for animal health, to product processing techniques for the supply of proteins to urban markets, the animal production and marketing subsectors lie at the very heart of economic development in Southern countries. Their development takes account of the need to share land and resources among herders and farmers while implementing rational and sustainable management practices.	• **Rangeland and wildlife management** • **Animal production** • **Animal health**
Forestry	The tropical forest, one of the planet's most abundant reserves of plant and animal biodiversity, is an ecosystem whose highly complex organization is still very poorly understood. Its conservation calls for the definition of rational and cost-effective harvesting methods to safeguard the sustainable reproduction of forest resources. It also calls for the development of silviculture and plantations to satisfy rapidly growing world demand.	• **Trees and plantations** • **Forest products** • **Natural forests**
Territories, environment and people	Changes in society and in land use are the consequence of numerous interacting factors: individual and collective strategies, rules governing property ownership and economic activity, modes of resource utilization, etc. A clear understanding of these interactions, on both local and regional scales is a prerequisite for rational rural development.	• **Smallholder farming** • **Land and resources** • **Savannah and irrigated systems** • **Humid tropics**
Advanced methods for innovation in science	By focusing skills and resources, previously dispersed throughout the organization, on a number of specific scientific themes, CIRAD has strengthened its research potential. New links are being created with French and European research organizations. This pooling of equipment and scientific methods aims to facilitate the work of other research programmes. Likewise, it will be of service to the Southern scientists invited by CIRAD to work and study in its laboratories.	• **Agrifood systems** • **Agronomy** • **Plant biotechnologies and genetic resources** • **Economy, policies and markets** • **Plant modelling** • **Crop protection**

nized set of rules. Common to all CIRAD departments, these services will provide senior staff with a full range of tools for effective management of their activities.

The creation of a human resources office responsible for managing the careers of CIRAD personnel and for bringing new skills and expertise into the organization, was one of the key components of this second reform phase. Set up on 1 January 1998, the role of this office will be to provide the qualified staff required to meet CIRAD's present and future needs.

But what is the purpose of this reform? CIRAD's future will depend upon its capacity to occupy a strategic international position in the field of development-oriented research and to maintain its reputation as a highly respected scientific partner. By highlighting its areas of exceptional expertise and offering the potential to optimize its performance, the new structure will enable CIRAD to satisfy these ambitions.

Among CIRAD's priorities

Following an in-depth analysis of the scope and content of research programmes in 1997, it was decided to devote more extensive resources to a certain number of research themes.

Henceforth, emphasis will be placed on agronomic research through an inter-disciplinary and multi-scale approach, the aim being to understand and to simulate the effects of agricultural activity on the environment, to model the behaviour of plant populations and then to integrate this knowledge at the plant, plot, farm and region level. The objective of this approach is to develop cropping and farming systems which safeguard the economic viability of rural societies, respect their mode of organization and preserve their natural resources.

Similarly, research in the social sciences will be stepped up. The first essential step in defining effective agricultural policies is to make a detailed economic analysis of the commodity subsectors concerned and of the players involved at every link in the chain, i.e. the farmer, the processor, the trader and the consumer. The social dynamics of these interactions and the effects on the natural environment are a core issue of sustainable development.

Biotechnologies also count among CIRAD's priorities. The problem of raising productivity without harm to the environment will call for a radically new technological approach. In certain cases, biotechnologies provide a promising avenue of research. In the field of plant improvement, an understanding of biodiversity and its conservation in plant collections, the analysis of tropical plant genomes, the creation and dissemination of new genetically modified varieties and *in vitro* culture techniques are areas that CIRAD wishes to develop. In animal health, efforts will focus on the development of new multivalent, thermostable, marked vaccines which will make it possible to distinguish between vaccinated and infected animals.

In the sector of agricultural product processing, the Southern countries confront two of their greatest challenges: to feed the population and to sell competitively priced products on the local and international markets. In this field, CIRAD will give priority to processing techniques and quality control on the one hand, and to commercialization, markets and business enterprise on the other.

In crop protection, CIRAD will focus its research on the study of pest and pathogen populations, the analysis of resistance and pathogenesis mechanisms and the development of bacterial and viral disease diagnosis tools, the aim being to define new rational crop protection methods combining an assessment of acceptable risk levels, chemical and biological control and appropriate agricultural practices.

Last but not least, computer modelling techniques will be developed. They are already widely used by CIRAD to describe a range of complex variables such as crop yields, the architecture of plant

growth, collective management of natural resources or the impact of agricultural policies. The models built will serve as a support for the organization of information, for the development of new hypotheses, for informed decision-making, and for long-term forecasting of future trends. They will also make it possible to reduce the extent and duration of certain field trials.

A Europe-wide network of scientific cooperation

At national, European and international levels, CIRAD is working in a rapidly changing research environment. A world system of development-oriented agricultural research is under construction. CIRAD is directly concerned in this process and intends to make an active contribution. The Global Forum, set up in 1996, now has an executive secretariat working in the premises of the World Bank in Washington. In parallel, the regional and national components of the world system are gradually taking shape. In 1997, European countries formed a committee of advanced research institutions heralding the future creation of the European Forum. This Europe-wide network of scientific cooperation is breaking down the old barriers between research institutions and universities, between agriculture and biology, between tropical and non-tropical sciences and, to a certain extent, between public and private research. In France, a national system of development-oriented agricultural research is now emerging. CIRAD is active in this movement and is grasping the opportunities it has created to forge stronger links with its traditional partners, above all the French Institut national de la recherche agronomique (INRA), but also the Institut français de recherche scientifique pour le développement en coopération (ORSTOM) and the universities. CIRAD's dynamic role in the construction of the world system received full recognition when it was appointed to represent France on the European committee during the national consultation between participants in the French system.

The three regional organizations in Africa, i.e. the Conférence des responsables agronomiques en Afrique de l'Ouest et du Centre (CORAF), the Association for Strengthening Agricultural Research in Eastern and Central Africa (ASARECA) and the Southern African Centre for Cooperation in Agricultural Research (SACCAR), have come together in the Forum for Agricultural Research in Africa, whose chairman represents Africa at the Global Forum. Their role in the promotion of regional cooperation between national research systems, international centres of the Consultative Group in International Agricultural Research (CGIAR) and advanced research institutions is now well established. They must now create the necessary means to develop their capacities in this area. At the national level, fully-fledged national agricultural research systems are now operational. They bring together research and higher education institutions along with the users of research —businesses, professional associations, and NGOs—who, for CIRAD, represent a whole range of potential new partners for bilateral cooperation.

The committee of national agricultural research systems, with representatives from Asia, sub-Saharan Africa, Latin America and the Mediterranean basin, is proposing to set up an executive secretariat to be based in Rome at the FAO headquarters.

Piece, by piece, the puzzle is being completed. Each of its parts, in every region of the world and on every geographical scale, from nation to continent, is working to define a common framework for the development of research and cooperation activities. In this rapidly evolving context, CIRAD is adapting its modes of cooperation, building an ever richer network of relations with tropical research centres in France and Europe and with the actors of rural development in Africa. Already strongly committed to regional programmes, in western and central Africa especially, CIRAD is now taking part in the creation of world programmes such as Pro*Musa* for banana research and ProCacao for cocoa.

A CONSISTENT POLICY FOR THE FRENCH OVERSEAS DEPARTMENTS AND TERRITORIES

The overseas departments and territories occupy a special place in this new framework. Though they form an integral part of the French agricultural research system, they also belong to different regional systems: the Caribbean for Martinique and Guadeloupe, Amazonia for French Guiana, the Indian Ocean for Réunion and Mayotte, and the southern Pacific for New Caledonia and French Polynesia. Moreover, the French overseas departments are ultra-peripheral regions of the European Union and as such, they are turned very much towards Europe. For example, the research unit set up to study the natural forests of French Guiana has recently been recognized as a major European facility. CIRAD makes every effort to ensure that its work in the French overseas departments and territories is respectful of this triple identity.

In addition to support for agricultural subsectors, e.g. sugarcane in Réunion and Guadeloupe, banana in the Caribbean, rice and wood in Guiana, which is greatly appreciated by professionals, CIRAD has set up a permanent research facility including some of the world's richest variety collections, experimental stations, laboratories and equipment for observation of natural ecosystems. Its ambition is to bring this facility into line with international standards of quality. To achieve this ambition, CIRAD will need to establish closer ties with the other centres of research and higher education in its overseas departments: INRA, the French Centre national du machinisme agricole, du génie rural, des eaux et des forêts (CEMAGREF), ORSTOM, the French Ecole nationale des eaux et des forêts (ENGREF) and the universities. In 1997, a prospective study was launched with INRA, the Antilles-Guyane university and the Chamber of Agriculture in Guadeloupe. It will bring the research teams together around a shared vision of sustainable island agriculture.

With the development of closer ties between these institutions and the coordination of their activities in these regions of the world, French research capacities have now reached an impressive scale. It is in this context that CIRAD has decided to regionalize its activities. In the Caribbean, it has expressed its desire to take part in the Procicaribe regional plan, destined to form the focal point of the Forum for Agricultural Research in the Caribbean. Two regional programmes covering animal production and fruit are now being prepared. In Amazonia, a group of French scientific institutions, including CIRAD, is now being formed to strengthen ties between French Guiana and Brazil. It has adopted three priorities: natural forest conservation, stabilization of agriculture in newly-cleared areas and processing techniques for forest products and fruit. In the Indian Ocean, CIRAD has developed exchange links with the Comoros, Madagascar, Mauritius and the Seychelles. It is hoping to step up its involvement in the regional research activities of southern Africa, in association with SACCAR. In the southern Pacific, CIRAD aims to stimulate regional cooperation via its local bases in New Caledonia and Vanuatu.

The development of these agricultural research structures in the French overseas departments and territories is helping them achieve European standards. CIRAD is ready to open these facilities to outside research teams and to enable the European scientific community to take advantage of the resources and collections available on these sites, thereby bringing agricultural research in the French overseas departments and territories into the dynamics of the world system.

Annual Crops

The mandate of the Annual Crops Department encompasses a very wide range of crops and farming conditions, with scientists involved in many countries through activities carried out in collaboration with development-oriented stakeholders. Projects and operations coordinated by CIRAD-CA scientists are therefore planned within the framework of multiple partnerships.

Partnerships with national research systems, especially in Africa, bring together CIRAD scientists and others from the host countries for multidisciplinary research projects—which are often stewarded by regional institutions such as the Conférence des responsables de recherche agronomique en Afrique de l'Ouest et du Centre (CORAF).

Cooperative links are also being established within the international agricultural research system. In 1997, ties were renewed and enhanced with research centres such as the Centro Internacional de Agricultura Tropical (CIAT) in Colombia, for breeding disease-resistant rice, and with the International Crops Research Institute for the Semi-Arid Tropics (ICRISAT), for setting up a project to promote groundnut germplasm in West Africa. In Southeast Asia, CIRAD research scientists are now posted in Vietnam and Laos to investigate cropping systems in close collaboration with the International Rice Research Institute (IRRI), which is coordinating an ecoregional programme.

A broad range of development-oriented operations are under way: in Brazil, a direct seeding strategy has been adopted on 3 million ha of land, thus highlighting the quality and economic sustainability of techniques developed by CIRAD scientists; in Madagascar, the Department was assigned the responsibility of overseeing projects on seed production and dissemination of cold-resistant rice varieties.

The Department's expertise is also being tapped for new projects in rapidly expanding fields, e.g. integrated pest management and multimedia information systems. Some subsector components are also being privatized, especially in the cotton and sugarcane industries, with some major concomitant modifications in production systems. CIRAD is analysing such changes under many different conditions and is instrumental in modernizing these subsectors.

In 1998, the Department will be structured around four programmes. The main thrust of the three subsector-based programmes, i.e. annual food crops, cotton and sugarcane, will be to tailor products to actual market needs while ensuring cost-effective production. The goal of the Agrosystems Programme will be to integrate crop management sequences developed for each species, within sustainable cropping systems adapted to farmers' constraints and objectives. ■

Transmission of maize viruses

Insect-vector resistance factors

Viruses transmitted by homopterous auchenorrhyncha insect vectors are responsible for economically detrimental diseases prevalent in tropical maize-growing regions. In Africa, maize streak virus (MSV) is transmitted by *Cicadulina* sp., whereas *Peregrinus maidis* is the vector for maize stripe virus (MStV) and maize mosaic virus (MMV) in island zones such as the West Indies and the Mascarenes. These diseases are now generally controlled by breeding for varietal resistance. In addition to virus resistance factors in plants, insect resistance factors should be better utilized, as they can affect the efficiency of virus transmission. In-depth studies on the feeding behaviour of the insect vectors are required to address this need.

Drought-resistant rice

Indirect selection targeting the genotype rather than the phenotype can be achieved through molecular marking techniques, with the overall goal of creating drought-resistant rice varieties.

Genes controlling root depth and thickness were mapped in collaboration with IRRI for a population of doubled haploid lines from the IR 64 x Azucena cross. Identified chromosome segments each account for 20% at most of the phenotypic variation in these quantitative traits at most. Five segments were chosen from amongst all of the fragments common to both populations. These segments were then incorporated into the IR 64 gene pool by introgression via marker-aided backcrossing, with the aim of creating isogenic lines that differ solely with respect to these genes.

Two marker-aided breeding cycles have already been completed and the resulting isogenic lines could soon be assessed.

An electronic penetration graph is used to measure variations in the electrical resistance and electromotive force generated by an insect and its host plant integrated within an electrical system. This is the best indirect method for studying the feeding behaviour of sucking insects when their mouthparts have penetrated the plant tissues.

In an initial study, classes of signals specific to these insect vectors were determined, and correlated with the locations of the insects' stylets within plant tissues. For *P. maidis,* three separate signal classes correspond to localizations of salivary sheaths in parenchyma, xylem and phloem of maize. The resistance mechanism against *P. maidis* that upsets MMV and MStV transmission, which was previously identified in some maize lines from the Mascarenes and the West Indies, was determined: the insect feeds on the phloem without sustained ingestion, then extends its probing time, increases its trial punctures and stalls access to the phloem. Progeny of segregating maize crosses of susceptible and resistant lines should now be analysed using an electronic penetration graph in order to map the genes involved in this resistance mechanism.

This technique, however, is not yet quick and reliable enough to be used for routine screening of maize plants. Investigations have thus been undertaken, in collaboration with the University of Réunion, to identify parameters that are more discriminating and reproducible than temporal visual signal analyses. Digital signals were thus analysed in terms of time, spectrum and frequency for the MSV leafhopper vector *Cicadulina mbila*. These signals were grouped into five classes, with each class linked to a stylet location in plant tissue cells as determined by electron microscopic observations of serial sections following stylet amputation. The biological origins of the emitted electrical signals were determined on the basis of these results, indicating marked similarities between homopteran groups. As discriminating amplitude and frequency parameters were identified, an experimental software program was developed for automatic signal classification, which should facilitate genetic research applications of this technique. The program is being further developed by the University of Réunion and CIRAD in conjunction with two European teams, i.e. the University of Wageningen (Netherlands) and a joint laboratory of the the French Institut national de la recherche agronomique (INRA) and Institut national des sciences appliquées (INSA) in Lyon.

Molecular markers

Unravelling the sugarcane genome

Sugarcane varieties are highly polyploid, aneuploid and derived from crosses between *Saccharum officinarum,* a sugar-producing species, and *S. spontaneum,* a wild species. Molecular biology techniques are useful for resolving this complex genetic structure and will ultimately

help sugarcane breeders develop more efficient crop improvement programmes.

S. officinarum and *S. spontaneum* chromosomes have been differentiated through *in situ* genomic hybridization, highlighting chromosome recombinations within these two species. The input of *S. spontaneum* genes in different sugarcane varieties can also be quantified by this technique. Moreover, chromosome base numbers were determined for these species by physical mapping of ribosomal RNA genes.

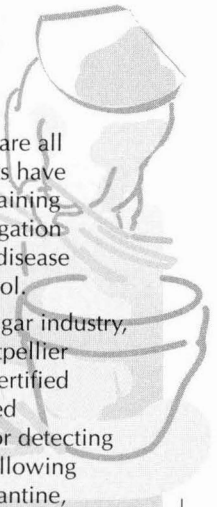
A genetic map was established for an elite sugarcane variety (R570) using clones obtained by selfing this variety along with RFLP probes. Four hundred markers were thus placed on about 100 cosegregation groups representing whole chromosomes or parts of them, which were then pooled into about 10 basic linkage groups. Contribution of the marker in the different cosegregation groups showed that *S. spontaneum* had the best map coverage and confirmed the presence of recombinations between two basic genomes. The chromosomes pair randomly, but with preferential pairing between *S. spontaneum* chromosomes. AFLP markers have been added to this genetic map, which now includes more than 1 000 markers.

Comparison of the genetic maps of sugarcane and sorghum indicates high homology. Conserved linkage groups usually show high collinearity. Current studies are aimed at saturating the sugarcane genetic map using the more complete sorghum map. Comparisons with current maize genetic maps revealed that most sorghum and sugarcane linkage groups correspond to at least two chromosome segments in the maize genome, confirming its duplicate structure.

Genetic mapping is a stepping stone for investigating the use of molecular markers in selection plans. The subsequent step involves identifying genes controlling variations in important traits and localizing them on the genetic map. Progeny of R570 were thus assessed in the field on the basis of several selection criteria. A major rust resistance gene was detected and is currently being accurately mapped. Synteny with sorghum, maize and rice gene patterns is an efficient way to detect new markers in the vicinity of the rust resistance gene.

For more complex traits that control yield, genome regions involved in the expression of quantitative characters, i.e. quantitative trait loci (QTLs), have to be identified. These QTLs that have a weaker relative effect are in a complex genetic environment encompassing multiallelic and even epistatic combinations. Detailed repeated agronomic tests are thus required. In a preliminary study carried out in collaboration with the Centre d'essai, de recherche et de formation (CERF) in Réunion, QTLs were identified for most of the sugarcane yield components analysed. These results indicated that it is possible to identify QTLs in sugarcane clones despite the fact that they are highly polyploid. Larger scale trials are under way to confirm these results.

Support for African sugar industry operators



In western and central Africa, CIRAD has close ties with sugarcane producers who are all agro-industrial operators. CIRAD scientists have thus been involved in consultation and training in western Africa aimed at optimizing irrigation management and analysing the pest and disease situation, along with weed and pest control.

As a service to African operators in the sugar industry, CIRAD's plant quarantine service in Montpellier (France)—which provides growers with certified healthy plant material—has now enhanced its routine screening analyses with tests for detecting sugarcane yellow leaf syndrome virus. Following passage through CIRAD's sugarcane quarantine, FR8069, a variety created by CIRAD's breeding programme in Guadeloupe, was imported into Côte d'Ivoire where it is currently in the pre-industrial assessment stage.

Cotton and textile production worldwide

Economic mechanisms and government involvement

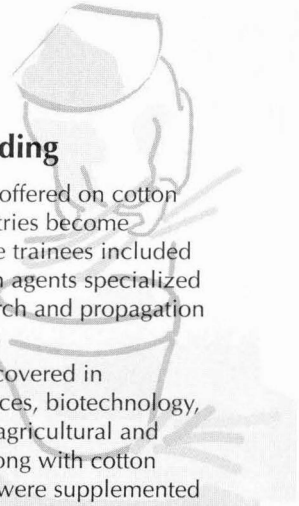
An analysis of production and trade patterns for cotton and derivative semi-finished commodities (yarns and fabrics) in the main cotton-producing countries indicated that the dynamics of this sector are closely tied with economic development, involving two successive and relatively complete phases.

Interactions are positive in the first phase: cotton and textile industries are the driving forces of economic development—estimated in terms of gross per-capita income. This was the situation that prevailed in the UK during the 18th century, in USA at the outset of the 19th century, and more recently in countries such as China, India and Turkey. In the second phase, activities begin slowing down in this sector as economic development reaches a specific level, which can vary according to country and timing. All countries investigated to date have undergone a rising phase, but they have not all experienced slumps in the textile industry.

This pattern of rising and declining phases is in line with the standard trade and development theory put forward to explain economic structural changes in developing countries. Cotton-producing countries initially produced and exported cotton fibre, and many attempted to boost their income by processing this product. The cotton textile industry has therefore often had a key role in countries promoting economic development.

The development of cotton production and industries that process this crop into semi-finished commodities is not solely dependent on economic mechanisms, i.e. there is no record of real development in these fields without government involvement. In the 18th century, the industrial revolution thus gave the cotton textile industry an enormous boost. The advent of the saw gin in 1794 overcame a major impediment for cotton fibre production. Government backing was, nevertheless, essential as inventions and entrepreneurship within the industry would not have been sufficient to actually develop cotton production and processing. The cotton operations that have been under way in Africa since WWII, and the highly voluntarist cotton policies adopted in Turkey since the 1920s, and in India and Pakistan since independence, highlight the same phenomenon.

Government involvement was well founded in all of the situations studied, with positive impacts on development. This involvement is also warranted as constraints associated with commodity and capital market fluctuations have to be reduced when cotton or semi-finished commodity production activities begin. In addition, the government remains much involved beyond the promotion phase. No governments have



Training on cotton breeding

A training session has just been offered on cotton breeding to help Southern countries become self-sufficient in this activity. The trainees included research scientists and extension agents specialized in breeding, experimental research and propagation of new cotton varieties.

All cotton breeding fields were covered in this programme—genetic resources, biotechnology, breeding techniques, biometry, agricultural and entomological implications—along with cotton technology. The theory courses were supplemented with laboratory visits.

Twelve trainees from western and central Africa and Madagascar attended the two training sessions held in 1997. Further sessions are planned, with possible extension into other disciplines.

remained inactive when this sector began declining, because of the potentially devastating social impact.

In the last few years, cotton production has been reorganized on the basis of market forces in many Southern countries, and governments' roles are being challenged. This analysis highlighted that reorganization has to be carried out efficiently and fairly as cotton production can have a decisive role in economic development. Moreover, the results showed that government involvement addresses market imperfections, suggesting that governments should not necessarily withdraw from this sector.

Sticky cotton

An industrial-scale stickiness detector

A high-speed stickiness detector, known as H2SD, was recently developed to assess the stickiness potential of each cotton bale produced. This defect has to be detected at the production stage in order to increase the value of unpolluted cottons. It is also very useful for spinners to have access to such information so that they can make suitable adjustments, e.g. mixing cottons with different stickiness levels and lowering relative humidity levels in spinning mills could help overcome the adverse effects of polluted cotton.

The H2SD detector is fully automatic and belongs to a line of regularly improved detection equipment such as the thermodetector, which is recognized worldwide for its excellent performance. This device is the result of 10 years of research carried out in partnership with two mechanical and electrical engineering companies in Montpellier (France). Two international patents have been filed for this detector, which has also been awarded an innovation grant from the French Agence nationale de valorisation de la recherche (ANVAR). CIRAD has handed over the manufacturing license to a company based in the UK, which is now marketing the instrument. H2SD is a high-speed detector that can analyse four separate samples at once. The samples are continuously fed on aluminum foil through four workstations: automatic opening, hot pressure, ambient-temperature pressure and image analysis. The detector analyses each sample in terms of sticky point counts and size distribution, which are displayed on a screen along with an image of sticky points on the plate.

Analyses can be conducted every 30 seconds with the H2SD device, as compared to every 4 min with the thermodetector, with an excellent correlation. This stickiness analysis speed is thus consistent with standard rates for HVI classification, which assesses various fibre characteristics for each marketed cotton bale.

Groundnut growth and development

Analysing yield components

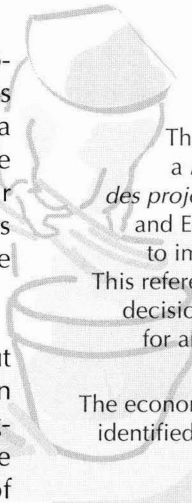
In West Africa, very low and variable groundnut yields are still being obtained by smallholders despite improvements in their cropping practices. An analysis of yield components was undertaken to determine the factors responsible for this situation. This study was carried out with a Spanish-type groundnut variety (CN 94C) on farmers' plots in Burkina in collaboration with the Institut de l'environnement et des recherches agricoles (INERA).

As groundnuts have an indeterminate growth pattern, there is overlap in the different phases

that lead to the determination of yield components, i.e. number of pods, number of kernels and kernel weight. The results highlighted a crucial period that occurs at the beginning of the rapid growth phase, from 50 to 55 days after sowing, after which the number of pods remains constant. The results were comparable with those obtained with pea and soybean.

This analysis of yield components was carried out over a 3-year period as part of a multi-location study. The impact of climatic, soil and cropping-practice constraints on yield components were determined on the basis of the wide range of different situations analysed.

The yield build-up pattern obtained—based on the chronological order of biomass development and distribution—provides a new tool that will be useful for identifying constraints and knowing when they will occur.



Financial and economic analysis of projects

The European Union asked CIRAD to draw up a *Manuel d'analyse financière et économique des projets de développement* (Manual for Financial and Economic Analysis of Development Projects) to improve project decision-making and quality. This reference manual will be useful for development decision-makers by providing them with a method for analysing and assessing projects, and making funding decisions.

The economic forces operating in each project are first identified, and then a financial analysis is carried out to determine a projects' funding needs, cost-effectiveness and sustainability for each stakeholder. The economic analysis assesses the extent to which projects fulfil economic objectives, the level of competitiveness in global economic terms, and the cost-effectiveness for the community.

This educational manual, published by the EU Official Publications Office, was designed for the use of EU agents, authorities from ACP countries, consultants, teachers and students

Maintaining soil fertility in southern Mali

Simple management strategies adopted by farmers

An increase in the overall area under crops and the beginning of farming intensification have led to serious signs of erosion in southern Mali. As part of a study on soil fertility maintenance, CIRAD, in collaboration with the Malian Institut d'économie rurale (IER), have come up with practical ways to reduce erosion in farmers' fields. As of 1997, this programme has been funded by the Compagnie malienne pour le développement des textiles (CMDT).

A group of CIRAD and IER scientists have developed a simple field-scale management plan to help control erosion and conserve rainwater resources. An initial assessment of the field situation, including runoff and erosion, was undertaken. Outlets for water drainage were then selected and the contours staked out. Ox-drawn ploughs were used to till perennial back furrows along these lines, which were subsequently turfed. The enclosed fields were then cultivated in ridges following the contours and ditches were dug to drain excess water.

This technique had a marked effect on crop yields, but this impact was difficult to quantify since farmers use more intensive cropping methods in these managed fields. Water conservation is the main factor responsible for boosting yields, as rainwater percolates through the soil rather than draining off. It is thus possible to conserve up to 300 mm of the total 800 mm of rainwater that falls on these fields during the rainy season, as confirmed by results obtained at Konobougou in the Fana region. This has in-

creased water supplies for crops, and also for intercropped trees (e.g. shea butter trees) as the deep water reserves are replenished.

Farmers who had volunteered to help carry out the experiments and their neighbours, i.e. around 50 farmers, have adopted these management strategies and are even ready to invest financially. The method used is partially responsible for the success of the project. All project participants are involved in the research, including: scientists specialized in farming systems, CMDT staff and extension agents, regional directorates and field agents, associations that stake out the contours for a budget price, and especially the farmers, who are the focal point of these activities.

Farmers are involved in the analysis and discussions on the proposed management plan. Rainwater control was found to be one of their main concerns, i.e. conserving rainwater or using it optimally, and managing excess water or runoff.

The development plans are tailored to the farmers' socioeconomic conditions and their cropping practices, and they comply with traditional land entitlement. Head farmers on each farm decide whether or not to develop their fields, regardless of their neighbours' strategies. The goal of improving soil fertility is fully in line with their priorities. The method, which involves testing and refining, is similar to that used by farmers in the initial experiments. Only light construction is involved, which is inexpensive and can be progressively improved and readily repaired, depending on the cropping schedule and available funds.

Another factor could explain the success of this strategy. Farmers and their neighbours first monitor the development projects until they are convinced that the effects are positive. It can take 2 years from the first demonstration to the time when a new request is put forward to local extension agents.

Senegal and Niger River valleys

Results of the regional research pole on irrigated systems

Significant advances have been achieved in several areas, through projects conducted in collaboration with local implementing agencies, since the launching of the Pôle régional de recherche sur les systèmes irrigués soudano-sahéliens (PSI) in 1995 under the aegis of CORAF.

After publishing bibliographical summaries, the research team focusing on the control of soil degradation under irrigation conditions analysed spatial variability of degradation indicators. The results of this analysis revealed the causes of soil salinization and alcalinization phenomena. These data will be used as a basis for setting up a soil

A geographical information system

The overall mission of the Pôle régional de recherches appliquées au développement des savanes d'Afrique centrale (PRASAC) is to understand the dynamics of land use by rural communities. Relevant and reliable geographical information is required to fulfil this task.

A geographical information system has thus been developed by CIRAD, in collaboration with the Institut de recherche agricole pour le développement (IRAD, Cameroon), the Institut centrafricain de recherche agronomique (ICRA, Central African Republic), the Institut tchadien de recherche agronomique pour le développement (ITRAD, Chad), the Institut français de recherche scientifique pour le développement en coopération (ORSTOM), and the University of Leiden in the Netherlands. This system extracts data from several sources (remote sensing, thematic mapping, aerial photography and field surveys) and combines digital processing and computer-aided photo interpretation.

PRASAC aims to provide stakeholders (ministries, rural communities) with access to this database, which they can then use as a decision-support tool, especially for land-use management.

degradation observatory. The overall objectives, resources required and results expected from this observatory were set out during a workshop held in Ségou (Mali) in July 1997. Simultaneous studies on salt and water balances were carried out, with various types of water flow defined at different observation sites. Assessments of soils under irrigation were enhanced with *in situ* measurements and computerized simulations of biochemical processes. Finally, two techniques for controlling soil degradation were tested, i.e. fertilization and adapting irrigation management strategies to local conditions.

A project on chemical weed control in rice fields was quite successful in intensifying irrigated rice cropping systems. A multilocation test confirmed the positive results obtained with bensulfuron-methyl under specific treatment conditions. Successful results were also obtained when this compound was applied through a dripping bottle. A technical data sheet will be drawn up to present this method to extension services and farmers.

The main focus was on assessing operations in selected irrigation schemes in terms of technical, social, land-use and water management. A series of surveys has been developed to collect relevant data for evaluating management operations. Mapping data can be converted to digital form and then used to provide relevant information for the management and use of irrigated schemes.

Information on farming systems is now available for the diversification of irrigated cropping systems. However, the complexity of the analysis varies according to the country and region. The commodity-chain analysis method that was developed is now being used by all partners. Studies aimed at improving cropping techniques focused on the assessment of plant material (sorghum, maize, cowpea, groundnut and wheat). For vegetable crops, results of variety trials are available for tomato, shallot, sweet potato and onion—they could be useful for guiding farmers in their technical choices.

These results will be published and disseminated in countries where this research pole is involved, and also throughout the international scientific community. CIRAD and ORSTOM will be promoting this innovative programme by jointly collaborating in a workshop to be held in 1999.

Treatment of wastewater from fish factories

Fish factories produce liquid and solid wastes containing fats and organic matter. These wastes stink and therefore have to be pretreated at the factory before final treatment or transfer to waste treatment stations. Seven industrial companies from Douarnenez asked CIRAD to test the efficiency of the Transpaille process for treating their effluents—this assessment was carried out with the support of the French Agence de l'environnement et de maîtrise de l'énergie (ADEME).

Testing was conducted at an experimental site in the Finistère region of France. The results confirmed the efficiency of the Transpaille process for wastewater deodorization and adsorption on straw mulch. In addition, it was found that compost could be completely sanitized by continuing the thermophilic treatment in controlled windrows.

Using this technology, 125 t/year of waste fats from fish factories can be processed into 25–30 t of nitrogen-rich organic fertilizer. Studies are currently under way, in partnership with manufacturers and ADEME (Bretagne, France), to determine whether the straw mulch (which the manufacturers are obliged to purchase) could be replaced by woody fibres from wooden crates that fish factories try to recycle.

The impact of El Niño

The agroclimatic situation in Indonesia

A pilot project was set up by the Indonesian Agency for Agricultural Research and Development (AARD) and CIRAD to improve water management in the Javanese basin of Kali

Recent agricultural changes in Vietnam

Cahiers Agricultures, published by John Libbey and the Agence francophone pour l'enseignement supérieur et la recherche - Université de réseaux d'expression française (AUPELF-UREF), and *Agriculture et développement,* a CIRAD journal, jointly published a special issue on Vietnam for the *VII^e Sommet des chefs d'Etats francophones* (7th Summit of heads of state of francophone countries), which was held in Hanoi in November 1997.

Changes in Vietnamese agriculture and its prospects are reviewed on the basis of recent findings from several cooperation projects. This publication, which covers ecoregional approaches to biotechnological research and contains contributions from 45 Vietnamese scientists, is based on a comparison of north to south regional experiences concerning agriculture in delta, hilly and low mountain regions. In the last 10 years, Vietnam has progressed from a situation of chronic rice shortages to becoming a major rice exporter. Important political and economic reforms are under way in this country, along with rapid major rural changes. Comprehensive knowledge of the technical changes that have taken place on farms and concomitant economic restructuring is necessary to understand farmers' strategies, evaluate ecological imbalances and develop rational rural planning programmes.

Garang, which supplies water to the provincial capital, Semarang. This region, despite high urban development, is a major Indonesian farming zone, with more than 35 000 ha of irrigated land. Three to four crop cycles can be achieved yearly with rice, maize, groundnut and vegetable crops.

Cropping calendars and domestic food supplies are upset by the serious climatic constraints that prevail under this humid tropical climate, i.e. abundant monsoon flooding from October to April, and water deficits during the dry season. From 1973 to 1989, mean annual rainfall levels were around 2 410 mm, with a high of 473 mm in January and a low of 54 mm in July. The climatic conditions have changed in recent years because of El Niño. In 1997, there was a slight decrease in rainfall relative to mean annual levels, with a striking irregularity in annual rainfall distribution. This led to a marked water deficit from June to October. Drought in this area was as serious as in the Sahel, with the worst level in the last 30 years recorded. The prospects are not very encouraging, as indicated by simulations obtained with joint sea-atmospheric models.

The cropping season was delayed to various extents depending on the geographical zone. For rainfed crops, fields could not be seeded before December. As there was a serious water shortage the following month, this late seeding will have a negative impact on rainfed rice, maize and groundnut yields. The traditional cropping schedule for irrigated crops—first rice crop in November, second rice crop in March and diversified crop in July—could only be maintained if water supplies are still available after 3 months of steady drought. In November, many farmers decided to plant a diversified crop (mainly forage maize). In January 1998, most farmers opted to sow irrigated rice to meet family staple food needs. A second diversified crop was planted in many fields as groundwater and river levels remained low. Sowing was very late in some seriously affected areas, matching the situation in rainfed crop zones.

A survey of land around villages indicated a decrease in the rice-growing area associated with sowing delays and changes in the type of crops grown. Losses were estimated at around 70% for the first cycle and 20–30% for the second cycle, representing a rice-production loss of about 70 000 t for the studied region. The forage maize crop grown for livestock feed will only partially offset the financial losses. In the short term, farmers' incomes will likely decrease even further considering the small area that has actually been sown and the current crisis in the livestock production sector—forage prices have already dropped by 20%. In April 1998, a series of governmental measures will be applied, e.g. increasing local transportation prices and eliminating farming subsidies, which will prompt an increase in retail prices, making it difficult for farmers to purchase inputs or pest and disease control products for the third cropping cycle.

Tree Crops

Since 1996, the main challenge for the Tree Crops Department has been to foster rural development in the humid tropics by encouraging the use of tree crops for export.

Almost all tree crops are grown on smallholdings, which are thus at the heart of the Department's new programmes.

Against an international background of market segmentation and privatization, it is important to analyse any strategy changes in the different commodity channels concerned.

The Department's aim is to conduct research taking account of such changes and to transfer technical innovations suited to the socioeconomic conditions in producing regions. These innovations primarily concern the exploitation of biodiversity, pest control—a prerequisite for successful replanting operations, developing flexible crop management sequences that can be adapted to international market fluctuations and understanding how to ensure quality.

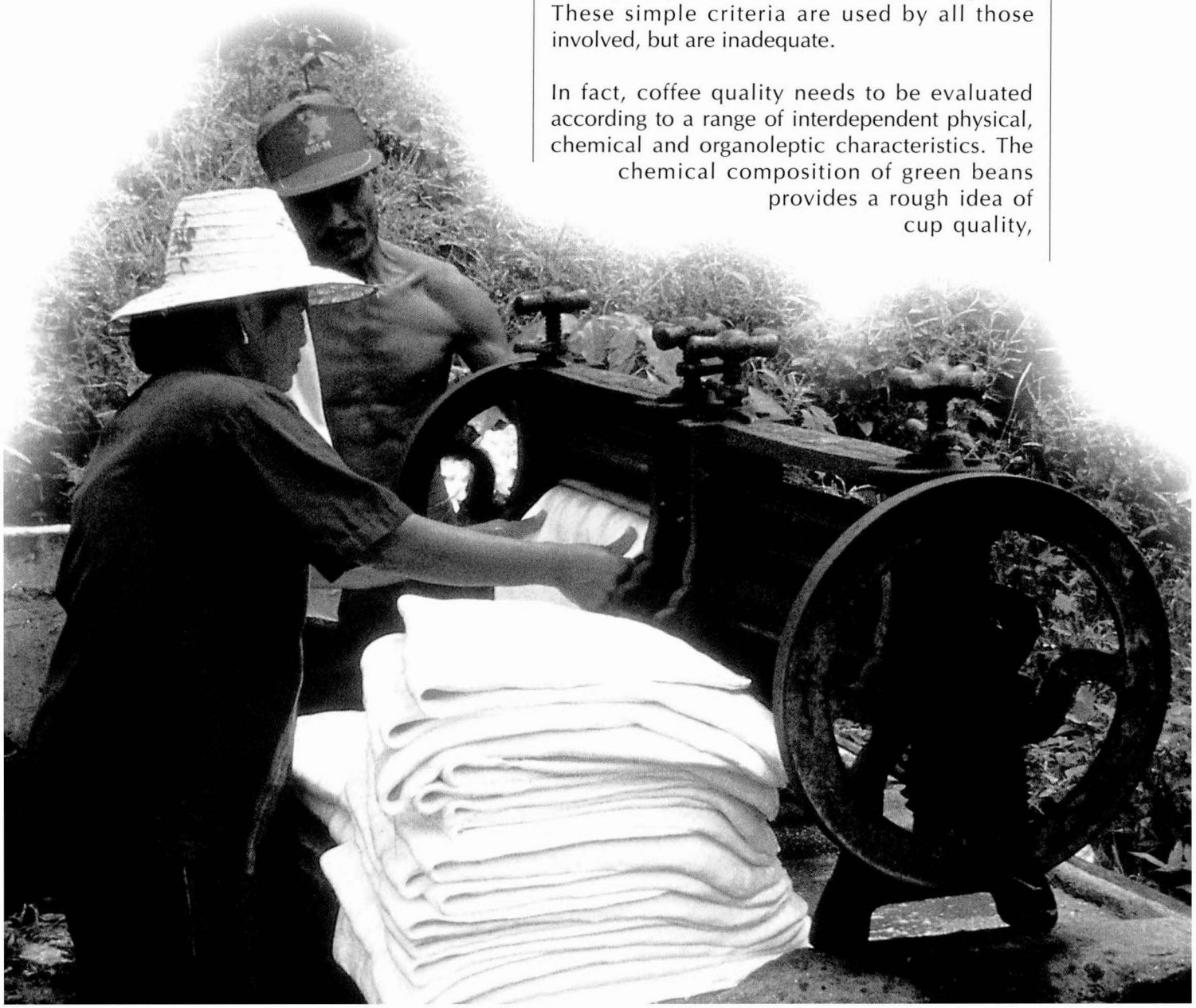
In response to these issues, the Department has five commodity-oriented programmes: cocoa, coffee, coconut, rubber and oil palm. This structure allows for the economic and social realities of the commodity channels, from production structures and policies to international strategies. The research undertaken is based on analysing the interactions between all the elements in the channel linking products, processes and stakeholders. To this end, the Department also calls upon other CIRAD teams with experience of farms, smallholder organizations, product processing and local development.

The Department's overseas installations and its involvement in international networks are proof of its commitment to international tropical tree crops research. ■

Origins, varieties and practices

Coffee quality is currently defined as the absence of physical defects and off-flavours. In practice, this means that coffee is sorted and subsequently classified in different quality grades. These simple criteria are used by all those involved, but are inadequate.

In fact, coffee quality needs to be evaluated according to a range of interdependent physical, chemical and organoleptic characteristics. The chemical composition of green beans provides a rough idea of cup quality,



and can be used to grade coffee. Numerous factors are involved: species, genotypes, growing environment (soils and techniques) and postharvest processing. They all contribute to a degree of variability in quality.

Whatever the variety, the chemical composition of clones or hybrids is directly related to their organoleptic characteristics. In particular, flavour precursors such as caffeine, chlorogenic acids, trigonelline, sucrose and amino acids are essential, as CIRAD and the Institut des forêts (IDEFOR) in Côte d'Ivoire recently demonstrated: the new Robusta clones bred for their chemical composition have better organoleptic qualities.

CIRAD and the Kenyan Coffee Research Foundation (CRF) are applying this knowledge in testing new varieties obtained by crossing with rust-resistant Catimor lines. The initial results show that certain Catimors with high caffeine and chlorogenic acid contents reduce acidity and increase bitterness. Breeding rust-resistant hybrids with good organoleptic qualities thus means evaluating all the available Catimor lines for their resistance to the disease and their chemical characteristics.

Height above sea level, shading, soil type and climatic conditions influence bean chemical composition. The effects of height above sea level and shading have been studied on several varieties in six regions of Honduras, in conjunction with the Instituto Hondureño del Café (IHCAFE). Planting at high altitude delays ripening, enabling better cell filling, which results in higher levels of fats and sucrose, a major aroma precursor. Shading plays a similar role: by delaying ripening, it favours better bean size and increased sucrose contents. The organoleptic characteristics of these varieties are currently being analysed.

Ripening, the last stage before harvesting, has to be complete. CIRAD and the Asociación Nacional del Café (ANACAFE) in Guatemala have monitored the changes in bean chemical components depending on the harvesting period. They showed that mature beans either have maximum aroma precursor, sugar and amino acid contents or minimum levels of aroma formation inhibitors such as chlorogenic acids.

These different studies have determined the influence of genetic, agronomic and technological factors on quality and laid the foundations for producing distinctive coffees, which are increasingly sought after by consumers. In fact, as with grapevines in recent years, it should be possible to associate varieties with specific origins—regions characterized by their soil, climate and height above sea level—and with particular crop practices to ensure optimum quality. This research will undoubtedly lead to better quality; it should result in improved techniques, particularly for drying and post-harvest storage. It should also open the way for the creation of "pure origin" and "vintage" coffees.

Nematodes, a coffee tree parasite in Central America

Nematodes, particularly the *Meloidogyne* genus, cause substantial yield losses in Latin America. Various populations collected in Central America and Brazil have been characterized based on their enzymatic phenotype, morphology and pathogenicity on different coffee varieties. This work, carried out at the CIRAD nematology laboratory in Montpellier in conjunction with the Institut français de recherche scientifique pour le développement en coopération (ORSTOM), the Programa Cooperativo Regional para la Protección y la Modernización de la Caficultura en Guatemala (PROMECAFE) and the Fundación Salvadoreña para Investigaciones del Café (PROCAFE), is the subject of a thesis. It was funded by the French Ministry of Foreign Affairs and the European Union. The populations studied were highly varied. Some may be new species and others, which had not previously been seen on coffee, proved highly pathogenic. This research has helped to steer Arabica breeding for pest resistance in Central America.

Recent results also show that obtaining distinctive coffees is dependent on everyone involved in the commodity channel, from producer to roaster. Recommendations have to strike a happy medium between economic constraints, agronomic output and cup quality.

Cocoa black pod

Genetic diversity of *Phytophthora*

Until 1979, *Phytophthora palmivora* was seen as the only cause of cocoa black pod. Since 1980, however, three other species of the fungus —*P. megakarya*, *P. capsici* and *P. citrophthora*— have also been found to be causal agents of the disease. The extent of the damage varies depending on the country, ecological zone and *Phytophthora* species. This problem is regularly studied by CIRAD and research organizations in Papua New Guinea, Vanuatu, São Tomé, Cameroon, Côte d'Ivoire and Trinidad, and European industrialists also contribute.

P. megakarya is found in Cameroon, Nigeria and Ghana, which suffer heavy pod losses. The species has never been isolated in Côte d'Ivoire, the world's leading cocoa producer, but its existence near the Ghana-Côte d'Ivoire border is a serious threat to Ivorian cocoa growing, which prompted CIRAD to undertake research on the pathogen, in conjunction with researchers from the Institut de recherche agricole pour le développement (IRAD) in Cameroon. This work is described in a thesis. The scientists involved have studied the genetic diversity of *P. megakarya* and developed a way of assessing resistance in cultivated cocoa trees.

Prior analysis of the genetic diversity and structure of *P. megakarya* isolate populations from six countries in central Africa—Cameroon, Gabon, São Tomé—and West Africa—Nigeria, Togo, Ghana—was carried out using isozyme studies and RAPD molecular markers.

Thirteen isozyme systems and nine RAPD primers were chosen to characterize 161 isolates. Thirty-six groups were distinguished with isozymes and 44 with RAPD markers. The isolates were split into two clearly distinct main groups. The West African isolates made up a homogeneous group and those from central Africa a heterogeneous group. There was a small intermediate group comprising isolates sampled in Cameroon, near the Nigerian border, which had bands specific to both central and West Africa. They were the result of genetic recombination. The isolates from Gabon and São Tomé formed separate groups, but some genotypes found in each of these groups were also found in Cameroon. They may, therefore, have been from Cameroon, although specific genotypes were also found in those two countries.

The marked imbalance in the ratio of the two sexual forms of the fungus suggested the

Analytical mapping of Ivorian coffee and cocoa plantations

A study is under way in Côte d'Ivoire to identify the ecological and human factors that contribute to optimum coffee and cocoa yields. It is being conducted in conjunction with the Ivorian Bureau national d'études techniques et de développement (BNETD) mapping and remote sensing centre.

Twenty-two variables were studied in over 600 cocoa and coffee plots in the two pilot zones, Daloa and Soubré. They were then integrated into a geographical information system using digitized maps and a field survey. Yields from the two crops proved to be strongly linked to the planting material, upkeep, shading intensity and insect damage.

The system was passed on to the BNEDT for processing and satellite image classification. The results and their potential applications for mapping all the Ivorian cocoa and coffee plantations are to be published.

predominance of asexual multiplication. However, recombinations apparently occur in the species, and Ibule, in Nigeria, may be a diversification centre for the West African population.

Phytophthora megakarya would seem to be of African origin, whereas the cocoa tree comes from the Americas. It is likely that the fungus initially developed on native African plants such as the kola tree, which is also a member of the Sterculiaceae, and then spread to cocoa, which proved to be a particularly susceptible host. The separation of *P. megakarya* into two genetically distinct groups can be put down to the isolation of native plants in two refuge zones—Nigeria and Cameroon—after the ice age some 18 000 years ago.

An inoculation test was conducted on cocoa leaf disks to characterize host-parasite relations. The clone classifications for resistance were identical, irrespective of the strain used. However, the aggressiveness of the strains was seen to vary.

The leaf test was then compared with an artificial inoculation test on fruits, and with field rot rates for clones and progenies. The resistance evaluated by the leaf test was generally correlated to the field rot rate for a clone or progeny, and the environmental correlations were not significant. The leaf test could thus be used, under certain conditions, for early nursery selection of clones or hybrid families less susceptible to the disease.

Oil palm physiology

Drought and yields in Sumatra

The agroclimatic conditions in North Sumatra are highly suitable for oil palm. Rainfall is evenly distributed throughout the year, and totals 2 890 mm on average. Sunshine levels are estimated at around 2 000 hours per year, as at the Marihat research station. Other zones, such as Lampung in the south, often have a dry period from July to November. Since 1972, the dry period has been particularly marked every 3 to 5 years, due to the El Niño climatic phenomenon, in which case water deficits are severe, reaching 400 to 600 mm, and annual rainfall is unevenly distributed. These periods of climatic imbalance cause substantial reductions in FFB yields, sometimes up to 60%, in the following 2 years.

Under an agreement between CIRAD and the Indonesian Oil Palm Research Institute (IOPRI), the effects of a water deficit have been studied on clones planted by IOPRI in 1992 at the state-owned PTPN Bekri estate near Bandar Lampung. Physiological, biometric and phenological measurements were taken on three clones in the middle of the dry season and compared with data collected at the Marihat station.

Leaf photosynthesis measurements taken from 7 to 16 h showed that at that time of year, gas exchanges were reduced to a minimum: for all three clones, maximum nett photosynthesis reached barely a quarter of that recorded at the Marihat station, and fell as the day went on, eventually stabilizing at very low levels that only compensated for respiratory losses. This sharp drop in photosynthetic activity was closely linked to stomatal closure, which evolved at the same rate as photosynthetic assimilation; the phenomenon suddenly became more marked after 8 h as a direct result of the increased atmospheric water vapour deficit, which reached 20 millibars. Previous work had demonstrated the depressive effect of a deficit of over 17 millibars on oil palm photosynthesis. The drying out of the different soil layers proved to be the main cause of the very low level of stomatal opening seen at that time of year. In particular, a ferralitic hardpan prevented root development below a depth of 2.40 m.

Mini-palm oil mills in Africa

With market liberalization and the recent development of smallholdings, a large number of mini-palm oil mills have been set up in Africa in the last 5 years. This emerging sector has been evaluated by CIRAD experts. Of the studies carried out, that of Mini-palm Oil Mills in Central and West Africa, ordered by the Caisse française de développement (CFD), describes some 15 units in five countries. It includes a highly detailed description of the technologies used, a method for evaluating technical and economic performances, a typology of extraction units and national production sectors, a list of the main production constraints encountered and proposals for improving operating conditions. The study was backed up by CIRAD support for the creation of an oil palm technology service at the Beninese Institut national de recherche agronomique, at the Pobé oil palm research station.

The sensitivity of the clones studied to water vapour deficit varied. Clone MK 93 was the least sensitive to atmospheric deficit. This character could be used to breed material more suitable for areas with prolonged droughts.

Along with gas exchange measurement, the phenology of two clones was studied at Bekri. In oil palm, inflorescence maturation takes from 2.5 to 3 years, from floral primordium to harvesting. As dry periods have previously been several years apart in this region, it is theoretically possible to monitor the effect, month after month, of a dry period on the sex differentiation of the primordia formed at the time and on young inflorescence development—or abortion. This study could be compared with the observations currently being carried out by the Beninese Institut national de la recherche agronomique at its oil palm research station in a zone where water deficits occur every year.

Meteorological data obtained in the region for 1994, which saw a water deficit similar to that in 1997, have also been used to forecast future carbon assimilate deficits in inflorescences. The 1994–96 yield data for the same region were integrated into a model and carbon deficit distribution over the next 3 years quantified, enabling estimates of future yields in oil palm plantations.

Copra oil and presscake quality

Hot oil immersion drying

Copra, an oil-bearing raw material, is the main coconut product. It is prepared under very basic conditions and is thus of poor quality, producing unsatisfactory oil and cake when pressed. These products are at a disadvantage on the market and the whole sector suffers as a result. Many projects have been drawn up in the past in an attempt to improve copra quality: improved drying techniques, rapid moisture content evaluation tests, and definition of quality criteria applicable to marketing.

With a view to solving the problem, CIRAD has chosen an original approach based on an avoidance strategy, hot oil immersion drying (HOID). The technology originated in Indonesia, and involves extracting oil from the fresh meat of the nut. The process has traditionally been used on a small scale in Indonesia, and its efficiency and productivity had to be optimized without adversely affecting the inherent quality of the desired products, oil and proteins.

The HOID option has been studied extensively in the past 5 years. The initial work concentrated on identifying, understanding and assessing the extent of the processes involved in HOID: determining the main factors, studying matter and energy exchanges, establishing drying kinetics.

In a second stage, these fundamental results were used to apply the process on both a small and an industrial scale. A small oil extraction unit with a capacity of 40–200 kg of oil/day was designed, built and tested at CIRAD. At the same time, an industrial pilot unit was designed with a view to adapting a conventional copra mill to the new process. This project is due to be carried out in conjunction with a major industrial group in the Philippines.

The last aspect of the research was the changes in product quality during HOID. In effect, in this process, the extracted oil is recycled roughly five times for frying, hence is heated for 1 to 2 h. This meant that there was a risk of deterioration, notably hydrolysis, oxidation and colour change.

Analyses were carried out during the production trials using the small-scale unit. The quality of the oil obtained was evaluated for the following: free acidity, peroxide value, polar compound content and dynamic viscosity. The oil characteristics remained excellent, even after 10 HOID cycles: golden colour, less than 1% free acidity, less than 5% polar compounds. This oil is of much higher quality than crude copra oil and can be consumed without prior refining. It has a shelf-life of over a year, which is exceptional for this scale of production.

The oil produced after HOID has quite different organoleptic characteristics from the coconut oil produced by small-scale African producers using the wet process. There was therefore some concern that it might not be appreciated by consumers were the new technology to be transferred to these countries. The acceptability of HOID oil was tested in Benin by CIRAD and the Centre national de nutrition et d'alimentation appliquées, at the université nationale du Bénin. Of 61 Beninese regular coconut oil consumers, 43 found the HOID oil better than traditional coconut oil, and all of them appreciated its long shelf-life.

The HOID process thus reduces the time taken to extract oil from fresh nuts to a few hours, compared to several months with the conventional process. Saving this amount of time means top quality products that have not suffered any deterioration. The oil obtained is free of acid and colour contamination and does not need refining, which is costly in terms of energy, inputs and investment. The presscake produced using this technology is mycotoxin-free and has a good shelf-life. It can therefore be used as animal feed.

Rubber tapping panel dryness

Franco-Thai cooperation on molecular physiology

After fungal diseases of leaves and roots, rubber tapping panel dryness is the most serious constraint on latex production. It is a physiological problem of which not all the causes are understood. It is generally associated with over-tapping and can affect entire plots; highly productive clones are particularly susceptible. A growing problem, it is of concern to planters worldwide.

Since 1993, CIRAD, ORSTOM, the Rubber Research Institute of Thailand (RRIT) and the University of Mahidol have been working together in Thailand on molecular characterization of latex production in rubber, based on an understanding of tree physiology. The research has covered coagulation, oxidative stress and latex regeneration and has focused on the tapping panel dryness (TPD) syndrome with a view to developing an early diagnosis technique.

An exploration of latex proteins by electrophoretic screening provided a distinction

between healthy trees and those in the early stages of TPD. It is not yet possible to distinguish biochemically between necrotic TPD and that caused by over-production. Early detection of the latter involves "latex diagnosis", a test developed by CIRAD to monitor the evolution of the various biological parameters of latex and clone production with time.

A more specific study looked at the expression of genes coding for the enzymes involved in coagulation mechanisms. It transpired that the gene coding for hevein was expressed less in the event of over-production due to over-stimulation, which was not the case with necrotic TPD. Such molecular parameters could be integrated into latex diagnosis to increase its early detection capacity.

Similarly, it was also shown that the under-expression of the genes coding for catalase and superoxide-dismutase, enzymes involved in oxidative stress within the laticifers, was linked to the occurrence of TPD caused by over-production.

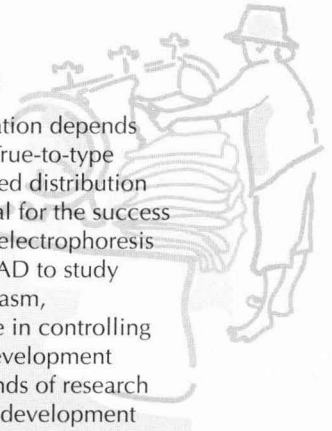
Necrotic TPD is irreversible, and is still impossible to characterize at molecular level.

The glutamine synthetase gene, which is involved in latex regeneration, proved to be highly over-expressed after ethylene stimulation. It is therefore important to characterize the promoter of this gene, which is sensitive to ethylene. It could be an initial candidate for genetic transformation in rubber trees. The prospects for transformation by *Agrobacterium tumefaciens*, which have been studied on different tissues, are promising. They are based on the progress made by CIRAD in regenerating plantlets from somatic embryos.

To this end, a study is under way on the expression of different genes involved in latex coagulation and regeneration or in oxidative stress. The research involves cloning the genes: specific laticifer promoters such as hevein and promoters whose expression is induced by ethylene.

A new contract between CIRAD and RRIT has completed the cooperation agreement on the field transfer of plants produced by *in vitro* culture. The agreement will strengthen the links between this research and field trials on the response to hormonal stimulation and the possibilities of reducing tapping frequency.

Rubber clone conformity testing by electrophoresis



The productivity of a rubber plantation depends on the genetic origin of the trees. True-to-type multiplication and closely controlled distribution of high-yielding clones are essential for the success of planting projects. Isoenzymatic electrophoresis on starch gel was first used by CIRAD to study the diversity of Amazonian germplasm, and has since been adapted for use in controlling the quality of day-to-day rubber development operations. It can satisfy the demands of research institutes, planting companies and development organizations. Since its development by CIRAD in 1991, the portable electrophoresis laboratory has been used for numerous appraisal or technology transfer missions in rubber-growing countries in Africa, Asia and South America.

Fruit and Horticultural Crops

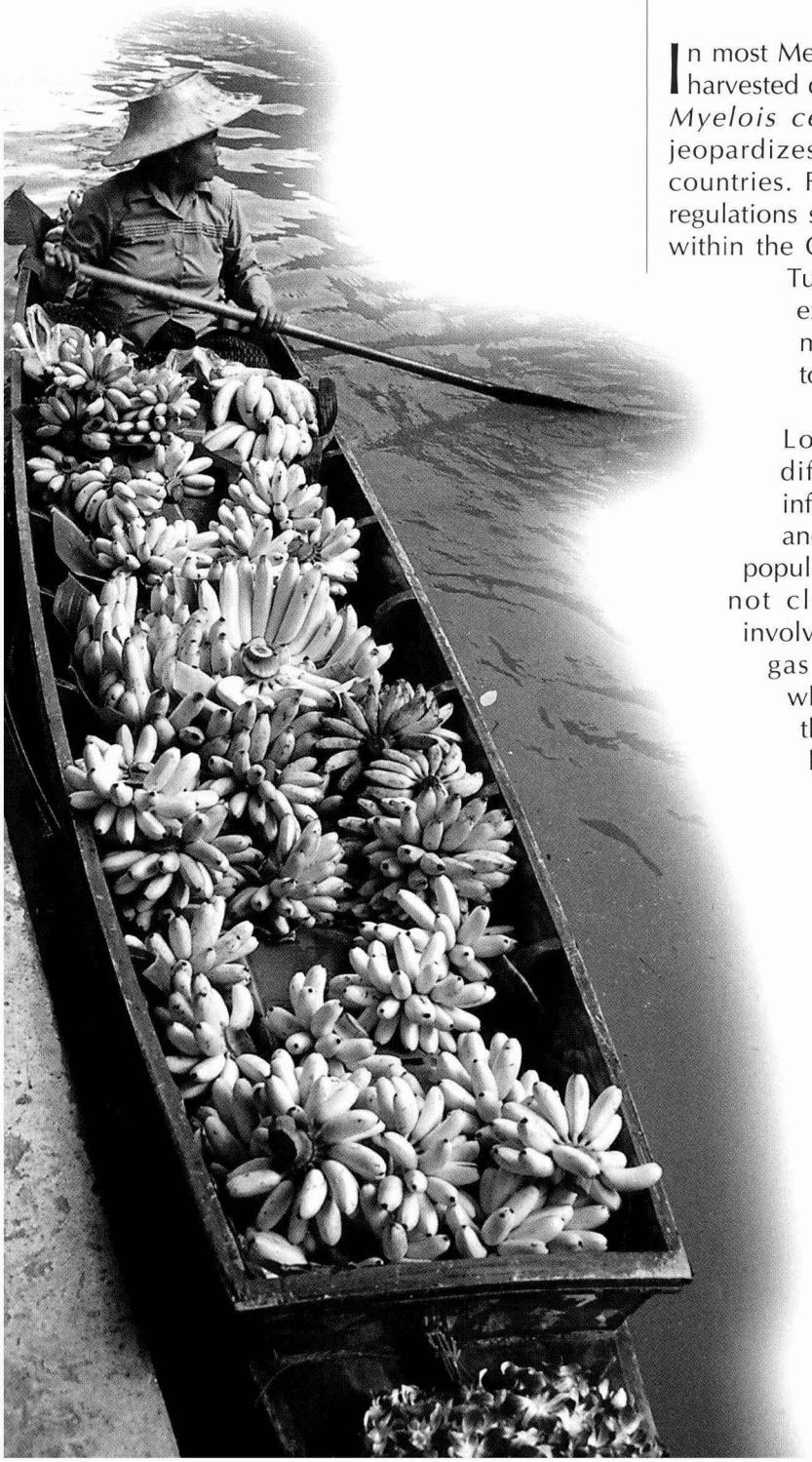
The significant results obtained over the past year by the Fruit and Horticultural Crops Department highlight the effectiveness of its new strategies in meeting the challenges of agricultural diversification, food security and economic development in partner countries.

Economic and forward analyses are under way modelled on a study carried out in the Lesser Antilles. The results help explain complex and varied diversification processes, with all factors underlying regional economic development taken into account.

Integrated strategies have been developed that are environmentally friendly and promote product quality, while remaining cost-effective for farmers. Specific crop management approaches are associated with pest and disease control. These new trends are reflected in the studies currently under way, e.g. disinfestation of dates, integrated control of mango black spot disease and onion pink root rot. Considerable research and innovation resources are required to improve disease and pest resistance and produce healthy plant material. The Department has thus developed plant breeding, genetic transformation and somatic embryogenesis techniques, and there has been considerable progress on somatic embryogenesis in banana.

In addition, the Department has been focusing specifically on nutritional and sanitary aspects of fruit and vegetables in order to address consumers' rising concern about food safety and nutritional aspects of these crops.

*Finally, it is essential to establish international partnerships and cooperative links to be able to deal effectively with the complex situation, the challenges and to quickly meet the objectives set out. This strategy is being applied on a national level in France through strengthening of the partnership with the French Institut national de la recherche agronomque (INRA). Internationally, the Pro*Musa *banana programme is commendable and should give rise to new ventures.* ■



Dates

Microwave disinfestation

In most Mediterranean countries, 15–20% of all harvested dates are infested by the date pyralid, *Myelois ceratoniae* Zellers, a fruitfly that jeopardizes export of this fruit to developed countries. For instance, European Union (EU) regulations specify that imported dates marketed within the Community cannot be pest infested. Tunisia, the world's leading date exporter in terms of sales, will have to meet these requirements as its exports to EU countries are rising steadily.

Local date packagers use several different processes to control insect infestation. Fumigation, a simple, quick and inexpensive technique, is the most popular, but its effects on date quality are not clear. The most common method involves treatments with methyl bromide, a gas with excellent pesticide efficacy which penetrates the fruit and destroys the insects. However, this compound has a major drawback—it is toxic to humans and breaks down the ozone layer, and is thus banned in a growing number of countries.

CIRAD, in collaboration with the French Centre national de la recherche scientifique (CNRS), INRA, and the Tunisian Degache date research centre, have determined the specific effects of methyl bromide fumigation and developed a new microwave disinfestation technique. The Ecole nationale supérieure d'agronomie et des industries alimentaires (ENSAIA, Nancy, France), the Ecole nationale supérieure des industries agricoles

et alimentaires (ENSIA, Massy, France), along with the Mes and Caustiers companies, provided scientific and technical support for this project.

Methyl bromide fumigation is detrimental to the nutritional quality of dates, i.e. it decreases the nitrogen content by about 25% and free amino acids by 50%. In addition, this treatment modifies the aroma of the fruit and eliminates some aroma components.

CIRAD has focused on the dielectric properties of dates and developed an alternative thermal process involving microwave treatments (2 min at 65°C). This was found to be effective in destroying date pyralid eggs and larvae. Date quality factors and how they change during the drying process are not markedly affected, nor are texture, colour and aroma components. The energy required to process 50 kg of dates was estimated to be 2 kW. Moreover, this treatment reduces the activity of the enzyme responsible for browning, as well as that of peroxidase, which gives dates a bad flavour. Microwave disinfestation thus preserves date quality better than other processes and is as cost-effective as fumigation, although the initial investment is about 50% higher.

Hence, this technique offers many obvious benefits, i.e. the dates are freed of pests without altering the main quality features or using harmful gases. Microwave-treated dates also attract a higher market price as the natural fruit colour is not modified.

CIRAD has patented this novel process and entrusted Caustiers, a manufacturer in Languedoc-Roussillon (France), with the right to use it industrially—this company delivers ready-for-service date processing plants. The process should soon be marketed.

Citrus nurserymen's conference

The fifth international citrus nurserymen's conference was held in March 1997 and attended by 260 growers from 39 countries and four French overseas departments and territories. Many nurserymen present were from countries in the Mediterranean region and the Americas, while others came from sub-Saharan Africa, Asia and the Pacific. Two workshops were held—one on biotechnologies and the other on disease detection and prevention—which promoted dialogue between scientists and professional citrus nurserymen.

In conjunction with the conference, CIRAD published *Pépinières et plantations d'agrumes* (Citrus Nurseries and Plantations) in its Collection Techniques. This reference manual is useful for nurserymen propagating fruit or ornamental plants to obtain certified elite plantlets which are subsequently marketed. Advanced citrus research results were taken into consideration in drawing up this manual.

As a follow-up to this conference, the journal *Fruits* published (1997) a special issue on citrus disease detection and prevention, and another issue on biotechnologies is planned for publication in 1998.

Mango black spot disease

An integrated management strategy

Mangos are becoming very popular in developed countries, with their import prices increasing by more than fivefold over the last 10 years. Mango black spot, a bacterial disease whose causal agent is an *Xanthomonas* strain, is one of the main threats to this crop. It attacks all aerial organs, causes premature fruit fall and has a detrimental impact on mango quality. The disease is prevalent in Asia, Australia, the Indian Ocean region, and eastern and southern Africa. For instance, in 1996, almost 10% of potential mango crops were destroyed by the disease in South Africa, i.e. a profit loss of around $US 1 million.

As no satisfactory chemical methods are currently available to control mango black spot disease, some affected countries have adopted a prevention strategy, i.e. dissemination of healthy and relatively resistant plant material from nurseries, and promotion of cropping techniques that hinder the development of this disease. The causal agent is also associated with the pepper tree (*Schinus terebenthifolius* Raddi), which grows throughout the tropics and subtropics, especially around mango orchards.

A study aimed at determining the epidemiological status of populations of this *Xanthomonas* strain on pepper trees was thus carried out in collaboration with the University of Kansas (USA) and the Institut national agronomique Paris-Grignon (INA-PG, France). Two different populations of this pathogen infesting mangos and pepper trees were identified using discriminatory molecular tools, including an avirulent gene. The strains analysed were obtained from laboratory collections and also from a mango orchard in Réunion surrounded by pepper trees, i.e. ideal conditions for these bacteria to spread from host to host.

Interactions between the pathogen and the two hosts were investigated. It was found that the bacteria were best able to multiply, induce standard disease symptoms and produce a secondary inoculum (a source for future infections), on their original hosts.

Microscopic analysis of interactions of both pathogen strains with mangos revealed high bacterial multiplication after inoculation of strains derived from mango trees, resulting in a typical black spot facies. In contrast, inoculation of strains obtained on pepper trees prompted a defensive reaction in mangos (i.e. cankers) which hindered spread of the causal agent.

These results highlighted that *Xanthomonas* strains common to pepper trees have a minimal impact on mangos. Integrated management strategies could therefore be considerably improved to control mango black spot disease in countries where outbreaks occur. Nevertheless, further studies will be required to obtain details on certain epidemiological and diagnostic aspects related to the pathogen.

Embryogenesis in banana

A new micropropagation technique

Bananas are propagated vegetatively, and ratoons are traditionally used as starting material in banana plantations. Alternatively, in recent years planters have had considerable success in using micropropagated plantlets as planting material. The advantage of these plantlets, which are obtained in the laboratory by *in vitro* culture, is that they are disease-free, very hardy, and available year-round.

CIRAD has been instrumental in promoting banana micropropagated plantlets by conducting research on their agronomic use, development of acclimatization and *in vitro* propagation techniques, and by controlling somaclonal variations. Vitropic (a subsidiary enterprise) has been producing and marketing micropropagated banana plantlets for 10 years.

A new banana propagation method involving somatic embryogenesis to obtain clones is currently being developed. CIRAD has been focusing research on embryogenesis for more than 10 years. Laboratory studies are being carried out in Montpellier in close conjunction with field research in Martinique. Bananas originating from somatic embryos have interesting novel characteristics, over and above the usual advantages of micropropagated

material. Production costs are reduced by using somatic embryos as proliferation rates are much higher in comparison to conventional micropropagated plantlets. Another advantage of this technique is that plant quality can be controlled, which means that the grower is certain of the agronomic value of the material planted. Using the embryogenesis technique, it is possible to test plant samples in the field before the whole batch is distributed to the grower. The technique can be used with traditional banana cultivars or improved varieties.

At its Rivière Lézarde experimental station in Martinique, CIRAD is carrying out a series of trials aimed at determining the agronomic acceptability of this new material. Initial results with cv Grande Naine dessert bananas indicated that they had rates of vegetative development, flowering and production comparable to conventional micropropagated material. These are the first successful agronomic tests that have been carried out on this technique, but further testing will be required to completely check its validity. Indeed, it will be important to certify that the quality of plants produced by this technique and tested in the research laboratory will not be altered when grown on a commercial production scale. Prior to routine use of the technique, other tests are therefore being performed on larger and larger areas as part of a validation project coordinated by CIRAD and Vitropic, with the support of the French Agence nationale de valorisation de la recherche (ANVAR).

Over the medium and long term, development of somatic embryogenesis also offers new prospects in banana breeding. This technique can be used by breeders as a complement to their standard strategies. Recently, CIRAD demonstrated the technical feasibility of genetic transformation with banana embryogenic cell suspensions. The Centre is also involved in a varietal improvement programme, within the framework of an EU project, partially based on the fusion of protoplasts derived from embryogenic cell suspensions using various cultivars.

Pro*Musa*

Pro*Musa*, the Global Programme for *Musa* Improvement, was jointly launched by the international banana research community, the International Network for the Improvement of Banana and Plantain (INIBAP), the Common Fund for Commodities (CFC) and the World Bank. This initiative was set up in Guadeloupe (March 1997) subsequent to international meetings organized by INIBAP and the World Bank.

Specialized working groups were set up: four on the main banana pest and disease constraints (leaf spot diseases, Panama disease, nematodes, and viruses), and one on genetic improvement and biotechnologies. CIRAD is actively involved in these working groups.

Pro*Musa* foreshadows the world agricultural research system within which the Consultative Group on International Agricultural Research (CGIAR), advanced research institutions and national agricultural research systems collaborate towards common objectives.

Controlling onion pink root rot

New cropping systems

In the Sudano-Sahelian zone of northern Senegal, the soil-climate conditions in Gandiolais are suitable for growing vegetables. Due to its remote location, this region is unfortunately obliged to focus its efforts on producing vegetables with a long shelf-life. Onions are thus grown intensively for urban markets, but the production quality is not consistent.

CIRAD, in collaboration with the Institut sénégalais de recherches agricoles (ISRA) and in partnership with onion growers, has implemented a project combining cropping system and environmental analyses with thematic studies, especially pathological and physiological investigations. The main factors limiting onion yields were first identified, and then techniques adapted to local conditions were proposed to help increase production and enhance quality.

In a study on crop yield build-up processes, the impact of onion pink root rot (caused by the soil fungus *Phoma terrestris*) on the size of onion bulbs and yield was demonstrated and quantified. An epidemiological study highlighted significant between-field differences in the expression of this disease throughout the year. Temperature variations directly affected the infectious potential of the soil. At the end of the hot season, the top soil layers were found to be less suitable for disease development than the deeper horizons.

Control methods were thus developed and tested—the strategy was to try to side-step and/or compensate for the effects of the disease, or control the pathogen. Some farmers' practices promote the disease, e.g. peeling onion bulbs at harvest, tilling at the onset of the cool cropping season, and transplantation. Other practices reduce the effects of the disease on crop yields, e.g. twofold higher planting densities than recommended, and 40% higher than standard watering rates. The following technical innovations were tested: chemical control using dazomet and puddling roots in benomyl; cultural control by managing water and mineral supplies, modifying the cropping calendar, choosing plant material, and preparing plants; thermal control by solarization with plastic films; and biological control by mycorrhization.

Based on the results of the above assessments, CIRAD developed two cropping systems adapted to cropping conditions overshadowed by onion pink root rot.

Partnership with INRA

INRA and CIRAD decided to increase research collaborations on tropical vegetable crops within the framework of an agreement signed in 1996.

Exchanges of research scientists are currently under way. For instance, an INRA phytobacteriologist based at a CIRAD station in Réunion is developing molecular biology tools to diagnose tomato bacterial wilt, while a CIRAD virologist is carrying out a study at INRA in Guadeloupe aimed at characterizing tomato geminiviruses.

The following three joint projects are in progress: breeding to create leafminer-resistant tomato and melon varieties; improvement of operational sequences to crop tomatoes for industrial markets; modelling the development of protected tomato crops under tropical conditions.

A policy group was formed with economists from both institutions. There are regular information exchanges between scientists, particularly between CIRAD vegetable agronomists and INRA plant breeders.

The first system involves adapting traditional onion cropping techniques in order to reduce the disease incidence. The usual strategy is retained (i.e. producing nursery plantlets and then transplanting them), while the growing conditions (new or chemically-treated soil, reduced sowing rates and late transplantation), field cultivation and crop monitoring conditions are specified. In the prevailing socioeconomic environment, this system could be adopted by farmers because it improves field productivity without increasing costs or substantially modifying traditional cropping practices.

The second and more innovative system requires additional time, equipment and training investments, and would therefore only be feasible under better marketing conditions. This strategy combines practices that increase labour costs (more frequent irrigation and field disinfestation) and the use of special equipment for direct seeding or hydroponics.

Gandiolais vegetable growers, who are naturally curious and strive to improve their crop production, responded positively to this project. They were fully involved in the research activities, i.e. marshalling their resources, helping to interpret the results and draw up proposals for adapting the system to local conditions.

Lesser Antilles

Agricultural diversification measures

Agriculture is still mainly based on banana and sugarcane in the Lesser Antilles. These crops face international market competition, especially from Latin American countries, despite the protective measures set out in the Lomé Agreements. Attempts to diversify crops in this region have been relatively unsuccessful. Banana is still the main source of income for farmers, attracting investment and resources.

Specialist farmers, however, are currently threatened by the worldwide free trade trend, as promoted by the World Trade Organization (WTO), and the resulting price volatility. It is thus essential to diversify agriculture in the West Indies before the problems become unmanageable. CIRAD, in collaboration with the French Ministry of Cooperation and the Instituto Interamericano de Cooperación para la Agricultura (IICA), set up a study to assess the competitiveness of agriculture in this region. Several subsectors were investigated, i.e. livestock products, fruit, vegetables, flowers and food crops on the islands of Dominica, Grenada, Guadeloupe, Martinique, Saint Kitts-Nevis, Saint Lucia, and Saint Vincent and the Grenadines.

Increased cooperation with Asia

Since 1994, there has been a sharp increase in cooperative links with Asia on fruit and horticultural products, supported by the French Foreign Office.

Bilateral research and development-support projects are under way in Vietnam where two CIRAD-FLHOR agents are based: one at the South Vietnamese National Fruit Crop Research Institute, working on citrus and tropical fruit; and the other as a consultant for the Ministry of Agriculture and Rural Development in Hanoi, developing projects on fruit and horticultural crops in North Vietnam.

This multilateral cooperation focuses on strengthening partnerships with the Asian Vegetable Research and Development Center (AVRDC). An associate research scientist based in Taiwan is investigating tomato bacterial wilt. A senior research scientist will soon join the AVRDC Peri-urban and Homestead Vegetable Production Program with the aim of developing a regional work group.

Overall, the fresh fruit and flower export subsectors will not be able to meet the international competition over the long term. Their competitive potential is limited with respect to export prices, volumes and quality. Despite the fact that labour costs are low in the Lesser Antilles, their international market competitiveness is hampered by low farm productivity, a lack of postharvest technical expertise, the fragmented nature of the supply, unstructured subsectors, a weak marketing potential, and very high shipping costs. Enhanced development and promotion of flowers and fruit for the local tourist market, along with fruit processing, are the most realistic areas for diversification.

Vegetable and food crop subsectors have the most promising diversification potential. These products are primarily targeted for domestic markets, which means there is less competition and lower quality standards than on international markets. However, the production capacity for

these crops is limited, there are marked agro-technological shortcomings, and trading is not very professional.

Livestock production (pigs, sheep and goats) has an important socioeconomic role on small-holdings and medium-sized farms, but this activity is currently not cost competitive. However, with the support of public authorities, this area could be developed to compete with imported products over the medium and long term.

These results were presented to regional decision-makers, farmers and manufacturers during a seminar held in Guadeloupe. All the participants endorsed a programme combining regional and national activities. Technical and financial incentives are planned to attract entrepreneurial investment for diversification projects, to promote these products on domestic and export markets, to take full advantage of the tourist trade, and to facilitate the transfer of technology developed through research. In the action plan, it is recommended that scientific institutions promote contractual relationships with farmers and agro-industries, while developing downstream research in collaboration with professional stakeholders.

A regional programme and various national sub-projects will thus be drawn up on this basis within the framework of a partnership between the public authorities and professional and research organizations. It will subsequently be presented to national authorities and funding agencies. Several measures are planned, e.g. setting up an investment fund and insurance system, promoting agrifood industries that utilize local products, creating controlled-origin labels for products, and complying with international export standards.

Animal Production and Veterinary Medicine

The goal of the Animal Production and Veterinary Medicine Department is to renew its strategies and methods in order to better address two important challenges: increasing and intensifying livestock production, and promoting sustainable management of natural resources in rangelands and protected areas.

A comprehensive survey is under way on the competitiveness of livestock subsectors in sub-Saharan Africa. Indeed, it is essential to be able to foresee production changes on this rapidly urbanizing continent, as the demand for animal products is increasing constantly. All of the social and commercial functions of these products are being taken into account. The initial results highlighted that intensive production systems involving short-cycle livestock species can be expected by the year 2020. Research on such species will therefore have a substantial impact.

In the animal health field, the Department collaborated in major projects to eradicate rinderpest and contagious bovine pleuropneumonia. It was also consulted on setting up a network for monitoring infectious diseases and on developing new laboratory disease control techniques.

CIRAD scientists also used genetic engineering technology to develop a new vaccine against peste des petits ruminants.

The Department designed a unique method to locate high-risk zones for trypanosomosis based on its research on trypanosomes and tsetse flies.

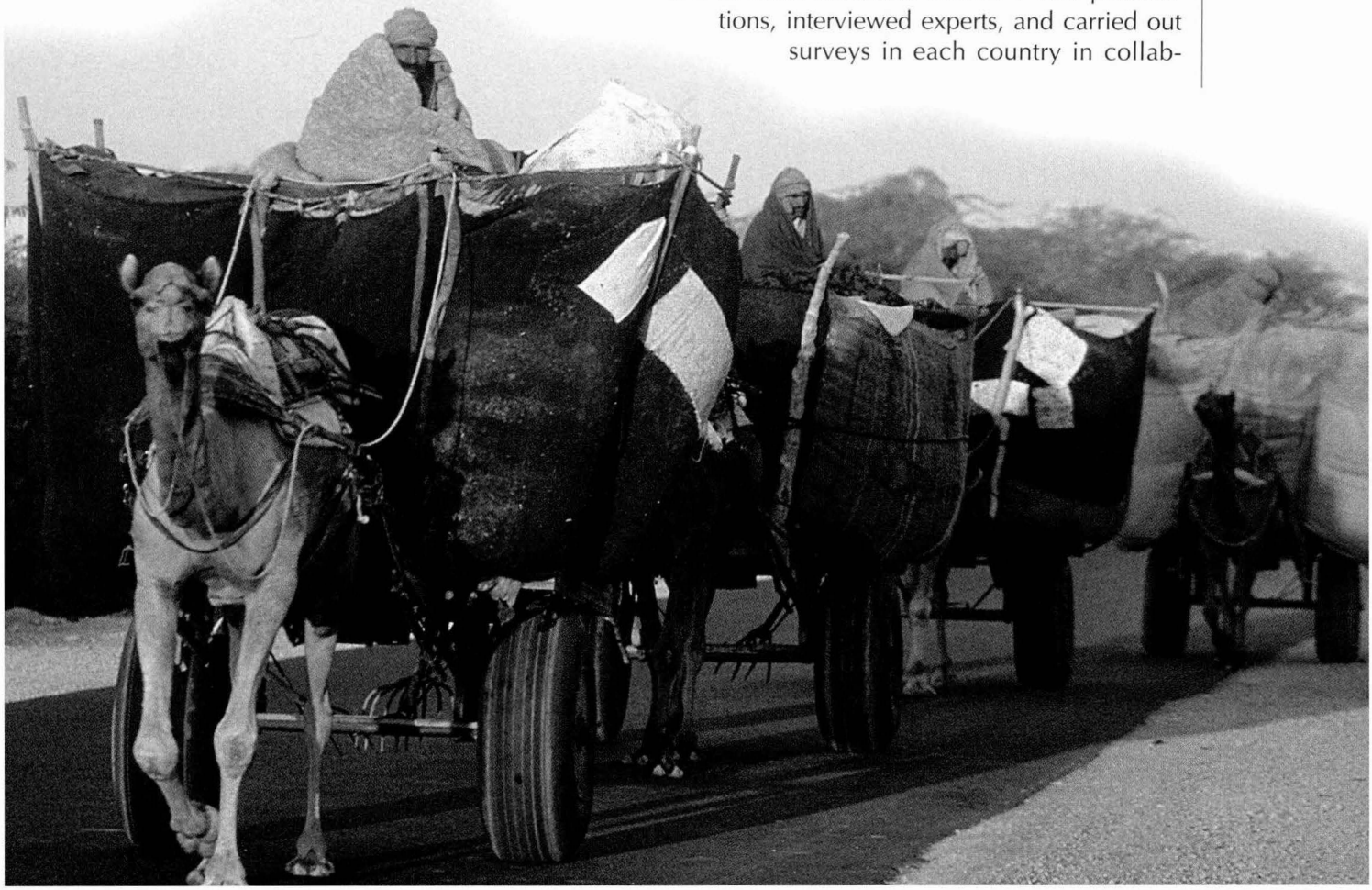
Studies are also under way to investigate interactions between livestock production and the environment. In New Caledonia, development-oriented research projects were conducted on tropical deer production and biodiversity conservation management. CIRAD is tapping its experience in this field to promote participative natural resource management. ■

Subsector competitiveness

Livestock production in sub-Saharan Africa

The French Ministry of Cooperation asked CIRAD to conduct an in-depth survey of livestock subsectors in 50 sub-Saharan African countries. All activities (including hunting) associated with the production and consumption of edible animal proteins were assessed. The French Bureau pour le développement de la production agricole (BDPA) collaborated in part of this survey.

A full overview of the situation was drawn up for the 30-year period from 1964 to 1994. The CIRAD team reviewed almost 1 800 publications, interviewed experts, and carried out surveys in each country in collab-



oration with extension agents. Key countries were identified where field surveys could be undertaken to update some of the data in the second phase. In the third phase, all of the information collected will be summarized to be able to predict changes in the subsector that will occur by the year 2020 to meet potential needs. A few conclusions can already be drawn on the basis of the first phase results.

In Africa, livestock subsectors fulfil a broad range of functions, including manure production, and providing a source of income, savings and employment. They are an integral part of social life, and promote trade in the form of loans, gifts and even marriage grants. Labour and manure alone account for one third of the value of all products marketed. A herd of 1 000 head of cattle can meet the needs of a single family in Australia, whereas almost 80 families can live off the same sized herd in sub-Saharan Africa, with a higher level of productivity. Economists often underestimate the importance of these functions as they only take the market value of the products into account.

There is a very broad range of products to assess—meat, milk and leather. They are highly diverse and often undergo multiple treatments between the source and final processing stage. This high diversity also masks the importance of the subsector.

The economists analysed world trade patterns with respect to these products. CIRAD built up a database on the different types of production, imports, exports, consumption of all animal products in sub-Saharan Africa by comparing FAO and World Bank statistics with those from CIRAD surveys. Global sales figures for the livestock production subsector are very high, i.e. 2.2-fold higher than figures for cereals. Sub-Saharan African countries account for 2% of the world market in terms of exports, and 3.2% for imports. Daily per-capita animal protein consumption is declining, with a mean of only 11.2 g, whereas world consumption has increased from 20 g to 26 g in the last 30 years. The gross domestic product (GDP), a standard of living indicator, also declined. Finally, beef consumption dropped in favour of pork and poultry consumption.

Seven different zones with distinct food consumption habits were identified. The Horn of Africa, which is dry with extensive grasslands, has the highest protein intake, with 14 g of animal proteins consumed daily, half of which are derived from dairy products. Conversely, the animal protein intake of people inhabiting savannah and forest regions around Zaire is only 4 g daily, i.e. mainly wild-game products. This low rate is surprising as livestock production has increased markedly in the last 30 years: 65% for cattle and 400% for poultry, which is a record. This overall production rate increase has not improved social welfare conditions, as it is still lower than the population growth rate. Urbanization has also upset the demand balance by prompting differences in standards of living between urban and rural dwellers.

CIRAD at the 8th International Symposium on Veterinary Epidemiology and Economy

The 8th International Symposium on Veterinary Epidemiology and Economy took place in Paris from 8 to 11 July 1997. This was the first time that the Symposium was held in a French-speaking country. More than 1 000 people attended and 400 papers were presented. CIRAD scientists presented papers on several different studies which attracted considerable attention. Methods developed by CIRAD were the focus of a plenary conference entitled "From ecopathology to agrosystem health". These methods take all agronomic, epidemiological and socioeconomic factors into account that could have an impact on any local problem under investigation.

Experiments carried out in tropical regions were presented to illustrate the approach. In Senegal, a data collection technique was developed to study small ruminant population dynamics. In Chad, a national disease-monitoring network is currently being set up. In Burkina, trypanosomosis risks for livestock are assessed, taking agropastoral practices into consideration.

This initial overview provides a basis for forecasting demand patterns up to the year 2020. If the GDP increases by 1.2% yearly (the global rate of increase is currently 3–4%), with a population increase of 2.6/1000 and steady urban growth, then the African demand for animal products will be as high as 7.3 million t. Africa, at the current technical development rate, will have to import as much as it now produces to meet this demand.

Livestock production will indeed have to be intensified. At the end of this initial phase, CIRAD recommended setting up an action plan in priority zones modelled on a marketing analysis method used by the Boston Consultancy Group (BCG). These recommendations are based on an analysis of constraints and technical opportunities, and indicate that targeted operations should be carried out, while taking the underlying social conditions into account.

Laser, a ruminant production monitoring software aid

This new *Laser* software program is a follow-up to the DOS programs *Panurge* and *Pikbeu* that were previously developed by CIRAD to monitor livestock population numbers and growth rates in the field.

In many projects, it is essential to analyse all factors relating to livestock production, while assessing productivity and production constraints. In longitudinal surveys, animals are monitored from birth to death. Accurate, detailed and diversified animal-production data can be obtained in such surveys, and the *Laser* program enables users to manage the separate data. It also manages Access databases (version 2.0 and 7.0) with the Windows user interface. *Laser,* which is programmed in Visual Basic 5.0, is open-ended and can be adapted to address the needs of different livestock production systems. Special modules can also be added to calculate weight at standard ages, productivity indices, and monitor livestock health and experiments in the field. With this database, demographic parameters can be predicted, and herd growth simulation programs such as *WinMod* can also be used concomitantly.

Infectious disease epidemiology

Eradication of rinderpest in Africa

The Pan-African Rinderpest Campaign (PARC), has been under way for 10 years and has had a positive impact, with a marked improvement in the overall epidemiological situation. CIRAD is one of the technical and scientific consultants for this EC-funded programme.

Note that mass vaccinations should be conducted in the first phase of any campaign aimed at eradicating an infectious disease like rinderpest. The vaccination programme is halted once the disease has disappeared. Thereafter, to ensure that the pathogen will no longer spread, a monitoring system is set up to quickly detect any new disease cases. Control operations are conducted immediately to eradicate confirmed rinderpest foci.

This disease has now been controlled in western Africa and the vaccination programme is drawing to a close. Recently, the disease was still prevalent in several countries east of Sudan, but it could soon be controlled and vaccinations subsequently stopped. Rinderpest has also been eradicated from Chad and the Central African Republic, but these two countries will have to take serious protection measures along their western borders to prevent reinfection from southern Sudan. The civil war in Sudan hampers the setting up of an efficient vaccination programme in this country.

These countries can tentatively be considered to be rinderpest-free when the disease has not been clinically detected for 2 years or more, as stipulated by the Office international des épizooties (OIE). Veterinary services are required within each country to monitor the status of this disease and to carry out surveys. These services are responsible for declaring any disease resurgence, noting when

vaccinations are stopped, conducting border controls, and supervising quarantines.

CIRAD was asked to prepare the next phase of this rinderpest eradication programme. Proposals will thus be put forward for setting up and developing disease monitoring networks, with the active involvement of livestock farmers, public-service technicians and veterinarians, private laboratories and veterinarians (whose numbers are increasing substantially). Effective organization, logistics and communications resources will thus be required.

In addition to rinderpest, these networks will monitor other infectious and parasitic diseases that have a serious impact on human and animal health.

It should also be pointed out that CIRAD, within the framework of the PARC project, is investigating the role of wildlife in the epidemiology of rinderpest in Africa.

Peste des petits ruminants

A more reliable recombinant thermostable vaccine

Peste des petits ruminants (PPR) is a highly contagious virus disease. In its most standard form, PPR is clinically similar to rinderpest, characterized by severe diarrhea and erosive lesions of various mucous membranes. It is a respiratory disease since acute bronchial pneumonia often accompanies the other clinical signs. Morbidity and mortality rates can be as high as 80%, especially in young livestock, thus explaining why this disease is now considered to be a major disease of goats and sheep in all endemic zones, i.e. south-western Asia to the Middle East, and in all African countries between the Sahara and the Equator.

The virus that causes this disease belongs to the same group as viruses responsible for measles, distemper and rinderpest. The rinderpest vaccine was used for a very long time to control PPR because of the antigenic closeness of these diseases. CIRAD, nevertheless, developed an attenuated homologous vaccine against PPR at the end of the 1980s. International organizations such as FAO and OIE are starting to recommend the use of this vaccine. Specific tests are available that differentiate between PPR and rinderpest viruses, but serological distinctions cannot be made between vaccinated and infected animals, thus nullifying the results of epidemiological studies. The standard rinderpest vaccine and the homologous PPR vaccine are heat-sensitive and therefore have to be refrigerated. However, in endemic areas, veterinary services do not always have refrigeration facilities available for vaccine storage. CIRAD decided to develop a thermostable PPR vaccine using genetic engineering technology to insert vaccinating protein genes of the PPR virus into the genome of a thermostable vector. The most common is the vaccinia virus, or the cowpox virus, which is readily produced and administered by scarification. Unfortunately, the residual pathogenicity of this virus in humans, especially immunodeficient subjects, is a major handicap. Scientists thus now prefer to use other viruses of the same family (Poxviridae) with a more limited host spectrum. CIRAD research scientists decided to use the capripoxvirus, which causes goat pox, sheep pox and lumpy skin disease. This virus can be stored at 37°C for 20 days in freeze-dried form. Just prior to use, it is dissolved in distilled water and remains stable for 2.5 h at 45°C.

In studies carried out at CIRAD, two PPR virus proteins were inserted into the genome of a capripoxvirus strain (KS1). Two recombinant clones were then tested on goats. Preliminary results indicated that these clones protect livestock against PPR and goat pox, two diseases with overlapping enzootic zones. This new vaccine thus protects livestock against both of

these diseases with a single injection, which is also a considerable economic advantage. These studies, funded by the French Ministry of Cooperation, have now been under way for 2 years. Further experiments are being carried out to try to develop a final product.

Franco-Indian collaboration on camel breeding

Melatonin levels were determined for the first time in camels. This hormone influences the seasonal regulation of sexual activity in well-known domestic species affected by short days, e.g. sheep and goats, and by long days, e.g. horses. Camels are sexually active from November to April. Scientists have found that melatonin is involved in this regulation. The overall aim is to adjust camel calving to a period that is more favourable for the survival of the young.

This research was conducted in collaboration with the Indian National Research Centre on Camel (NRCC) at Bikaner in Rajasthan and INRA (Tours, France). The studies were carried out by an Indian research scientist working at CIRAD's laboratories in Montpellier (France), with funding from the French Ministry of Foreign Affairs.

CIRAD has had a long-standing relationship with NRCC, which is one of the foremost camel research centres in the world. In 1997, CIRAD surveyed the camel production situation in Rajasthan and found that in this region camels are mainly used for draught, with little consumption of camel meat. Two project requests were filed simultaneously: one to the European Union on mineral nutrition, in collaboration with the University of Bari (Italy); the other to the Indo-French Centre for the Promotion of Advanced Research (IFCPAR), in collaboration with INRA, which is developing the molecular tools required to draw up a genetic map for camel species.

Livestock trypanosomosis

Identifying key zones for control

Trypanosomes, which are pathogenic to livestock and transmitted by tsetse flies, are still a major barrier to livestock production in sub-Saharan Africa. Vector populations are generally treated in programmes to control parasitic infections, but treatment strategies have changed. Large-scale tsetse fly eradication campaigns are no longer undertaken because of the high costs, low sustainability and the fact that they are not environmentally friendly. Future projects will focus on priority zones for control operations, selected for their development potential or epidemiological status. Reliable technologies will therefore be needed to be able to quickly pinpoint these zones.

In Burkina, a comprehensive survey was undertaken by CIRAD and partners, including the French Centre national de la recherche scientifique (CNRS), the Centre international de recherche-développement sur l'élevage en zone subhumide (CIRDES), and the Institut de l'environnement et des recherches agricoles (INERA) of Burkina. It was carried out in an agro-pastoral zone south of Bobo Dioulasso. Detailed information was obtained through a series of surveys on areas colonized by tsetse flies, pathogenic trypanosomes, and cattle-movement patterns. These data were matched with high-resolution SPOT satellite data.

Savannah tsetse fly species were found to be declining in highly agricultural zones of western Africa. In the study zone, the two riparian species, i.e. *Glossina palpalis gambiensis* and *G. tachinoides,* live in shrubby areas along rivers and streams. The respective biotopes of these two species are well known: humid wide gallery forests for *G. palpalis gambiensis,* and narrower gallery forests for *G. tachinoides,* a species that is quite resistant to drought. Entomologists assumed that

tsetse fly populations should have decreased in the study zone, which is located in a heavily farmed frontier area. Indeed, the cropfields sometimes extend to the river edges and the gallery forests are partially degraded, but this expansion may be limited by the lack of soils with suitable structure. The landscape is not altered along the edges of waterways where the soils are not favourable for cropping. Wild hosts upon which tsetse flies feed are becoming scarce, whereas the number of grazing cattle is increasing. A comparative study carried out at 15-year intervals revealed that tsetse fly densities had increased in these gallery forests.

The livestock infection risk, however, cannot be determined solely on the presence of tsetse flies, as these vectors do not carry the same trypanosomes in all regions—some trypanosomes are pathogenic to cattle, while others are hosted by reptiles but not cattle. These different parasites have been identified with molecular biology tools, i.e. polymerase chain reaction (PCR). Scientists involved in this programme have thus been able to draw up a spatial distribution map for trypanosomes hosted by tsetse flies. This map indicates that the situations differ markedly in the two zones, even though they are only about 10 km apart. In the first zone, tsetse flies feed preferentially on cattle—to which they transmit pathogenic parasites. In the second zone, they mainly feed on wild reptiles and host non-pathogenic trypanosomes.

The disease transmission risk is therefore closely related to the probability that tsetse fly populations hosting pathogenic parasites will encounter livestock. The most dangerous sites are livestock corridors and watering points. Herders' and farmers' practices are crucial in determining whether or not such vector/livestock contacts will occur. For instance, Peul herders move herds of more than 400 head of cattle along the borders of farming zones, with small-scale transhumance movements, and water their animals in gallery forests colonized by tsetse flies. In contrast, farmer-herders have smaller livestock herds that are mainly reared for hauling water from wells to meet the needs of villages and camps, which means they do not go into tsetse fly biotopes.

The epidemiological system is therefore dependent on rangeland practices. Farming systems were characterized and livestock in the zone was completely inventoried and georeferenced. All the data were incorporated within a geographical information system, highlighting zones where trypanosomes, tsetse flies and cattle overlap.

This trypanosome-risk study was more comprehensive than standard host-vector-parasite epidemiological surveys, as agroecological and agro-economic aspects were also taken into account. It is now important to identify indicators that could help in identifying key zones for control operations.

Pig farming in the West Indies

Advanced technologies benefit smallholders

In 1985, when CIRAD was called in for its first appraisal mission in Haiti, local authorities were looking for ways to replace the pig population that had been slaughtered to control an African swine fever epidemic. The US Ministry of Agriculture and the Instituto Interamericano de Cooperación para la Agricultura (IICA) had introduced new high-producing breeds. However, the low-protein and high-cellulose pig feed available in rural areas was unsuitable for these breeds, which were modified for industrial-scale production. Pigs nevertheless represent an important source of income for smallholders, and most livestock in Haiti is produced on smallholdings. These farmers therefore have to be closely involved in any projects aimed at replenishing the pig population.

CIRAD proposed a procedure for introducing a rustic breed of pigs that reproduces easily and

quickly, and has no special feed requirements. In this project, funded by the French Ministry of Cooperation and the Caisse française de développement (CFD), CIRAD carried out studies for the first 12 years in collaboration with the French Institut national de la recherche agronomique (INRA) and other French pig research centres, including the Station de pathologie porcine de Ploufragan and the Centre des coopératives de production animale (CCPA) in Osny. Other French partners, i.e. BDPA and Fertile, have joined the project since 1993 and formed a temporary enterprise group.

A population of rustic Creole pigs (of Iberian descent) from Guadeloupe was supplied by INRA's Centre de recherche agronomique Antilles-Guyane (CRAAG). INRA also provided access to highly prolific rustic Chinese Meishan and Jiaxing breeds, i.e. a litter produced by these Chinese sows can include as many as 20 piglets. These Chinese sows were bred with Gasconne boars monitored by the French Institut technique du porc (ITP). Finally, this genotype was chosen as the female line for hybridizations with Creole boars. All introduced animals have to be certified specific-pathogen-free (SPF) in order to meet the very strict US livestock health requirements. Each animal was therefore submitted to a complex health control: sows of Creole descent were sent from Guadeloupe to the Centre national d'études vétérinaires et alimentaires (CNEVA) at Ploufragan, where they were inseminated and reared in sterile isolator bubbles. The piglets were sent to Port au Prince by air, and then quarantined on Ile de la Tortue. The Chinese sows came from INRA's Magneraud research station near Surgères (France). They were inseminated with Gasconne semen and reared at CCPA, another French centre for the production of SPF pigs. In 1987, 65 SPF Creole pigs and 117 SPF Sino-Gasconne pigs were sent to Haiti.

An industrial pig farm was built with an all-in all-out production system, similar to that set up at the Magneraud station. New rearing standards were defined on the basis of temperature, relative humidity and local rainfall conditions. Special stalls were set up to facilitate mating, gestation, farrowing, weaning and piglet bulking. A production rate of 21.6 piglets/sow/year can be achieved, which is a better result than obtained in Réunion, where standard Large-White breeds were introduced.

Overall, 90 000 piglets were produced in 10 years and disseminated in rural areas throughout Haiti. There was a population of 1 300 000 pigs in the country prior to the African swine fever epidemic —there is currently, during the final renewal phase, a population of 750 000 pigs. This pig farm is recognized for its high SPF quality tropical pig production.

Biodiversity in New Caledonia

There are more plant species in New Caledonia than throughout metropolitan France, and it also has more native animal species than most other regions worldwide. A sustainable natural resource management programme should be set up since human activities are currently threatening these environments. CIRAD has undertaken several projects which are being funded within the framework of a management mandate through development contracts and private agreements. The Centre is providing scientific and technical support to help manage various game species such as deer and notous, and for the production of local species such as Rusa deer and Ile des Pins snails. It is also involved in conservation programmes for some protected bird species, e.g. the Kagu and the Ouvéa parakeet.

In addition to these field activities, CIRAD, in collaboration with Iles Loyauté province and the Ligue pour la protection des oiseaux, organized a small international seminar on the conservation of Ouvéa parakeets. CIRAD, in collaboration with French organizations, i.e. CNRS, the Centre national du machinisme agricole, du génie rural, des eaux et des forêts (CEMAGREF), and the Office nationale de la chasse (ONC), was also involved in a consultancy and programming mission, funded by the three provinces, on the management of feral goat populations. CIRAD has just signed an agreement with Nord province to study a sustainable natural resource management plan in the Aoupinié mountains and along the eastern coast. This project aims to promote more rational use of natural forests and local wildlife by local inhabitants.

Forestry

In the light of the high pressure on forest areas and resources, as exemplified by the extent of the recent forest fires in Southeast Asia and the share taken by Asian operators in the Congo river basin area and the Amazon, international public opinion is encouraging sustainable management strategies to conserve tropical forests. Many Southern countries are striving to improve the situation concerning forestry rights, decentralization and forest management.

The Forestry Department, in cooperation with its national, regional and international partners, is investigating trends in forestry legislation, and economic and fiscal policies, along with their impacts. This includes studying forest resource management decentralization and delegation strategies, and operational sequences that promote cost-effective management of tropical forest ecosystems. Based on local conditions, the Department is developing methods for creating and restoring forest stands, in addition to wood processing and upgrading techniques that make optimal use of the raw material.

These scientific and technical activities are founded on regularly updated knowledge bases. They are focused on autecology, i.e. study of the ecology of individual organisms of a species in relation to their physical environment, medium-term dynamics of forest ecosystems, genetic diversity patterns, and the anatomy and intrinsic properties of wood. They also involve information management systems, decision-making and negotiating tools.

A wide range of topics can be investigated as many staff members are stationed in the field, with one third of the Department's engineers and research scientists working abroad. In 1997, this trend was logically extended via an increase in the number of forestry trainees supervised at CIRAD.

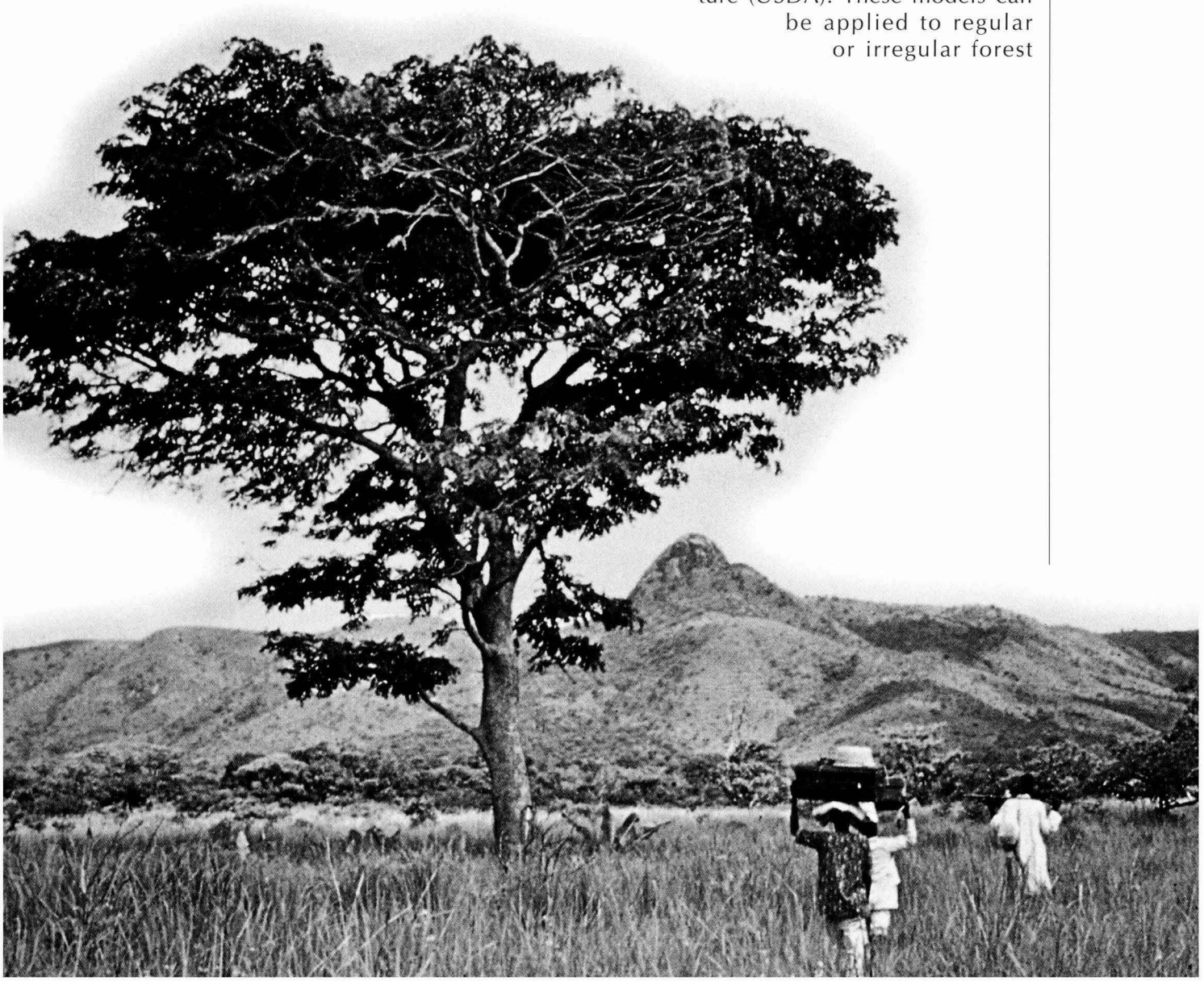
The 11th World Forestry Congress, held at Antalya (Turkey), provided an opportunity to outline strategical and practical progress that has been made on dry and humid tropical forests (both natural and man-made). The main topics discussed were modelling, sustainable management criteria and indicators, technological qualities of quick-growing plantation species, forest stands managed by rural communities, and agroforestry parks.

1997 also involved extensive discussions and planning devoted to the management restructuring process under way at CIRAD. In 1998, the Forestry Department, which formerly included four research programmes and seven research units, has been restructured into three programmes, i.e. Natural Forests, Trees and Plantations, and Forest Products. ■

Silvicultural management

Modelling dense tropical rainforests

Temperate regions have long benefited from many different forestry models specifically developed for these climatic conditions. Some have been used operationally, e.g. in USA by the United States Department of Agriculture (USDA). These models can be applied to regular or irregular forest



stands, with a wide range of tree species and ages, to simulate temporal changes and production on the basis of different management strategies.

Considerable progress is still necessary in mixed forests, especially in the tropics, as the available information on basic biological processes is incomplete. There are few established databases —which contain only a few measured variables, i.e. generally tree diameters at breast height and sometimes (but rarely) the Cartesian coordinates, and never more than about 15 years of background information.

In 1991, CIRAD set up a modelling programme on forest dynamics in order to tap the exceptionally high quantity of data collected at one of its experimental sites in a dense tropical rainforest. Two models have already been developed within the framework of this programme: a "stand + distribution" type matrix model, which is suitable for simulating simple silviculture situations; and a distance-dependent "tree" type model to simulate highly complex forest operation criteria. The latter model was adjusted and assessed using data from the silviculture station at Paracou in French Guiana. Trees in a forest stand are assigned life-cycle rules described by growth, mortality and recruitment submodels for 3-year time intervals.

The growth model is based on a "potential x reduction" type model specifically adapted to forests of French Guiana. It simulates growth of a tree relative to its trunk diameter at time *t* and its immediate environment, as described by two competition indices: one accounts for the pressure a tree is subjected to at the onset of the growth period, while the other represents recent changes in this pressure. The model is highly efficient as 15 species groups that are homogeneous in terms of growth are taken into consideration. Four mortality models predict standing dead, and primary, secondary and complex fallen trees in forests. A recruitment model is useful for managing numbers of new trees that appear on 100 m^2 plots according to the area available within the stand.

The tree model was translated into SmallTalk-80 computer language, using the multiagent system technique, by a scientist of the Laboratoire des formes et d'intelligence artificielle (LAFORIA) at the Université Paris VI. The Selva simulator derived from this translation has a user-friendly interface. Users can thus monitor virtual temporal changes in a stand and each tree therein on the basis of maps and graphs. A wide range of operations can also be undertaken at any time to assess potential silvicultural situations. The different tests demonstrate that simulated stands perform suitably regardless of the intensity of imposed disturbances. However, their reactivity is low in comparison to stands simulated by the matrix model, even though they are adjusted on the basis of the same data.

This type of model is of considerable immediate interest for the scientific community, and for forest management staff over a longer term. Various improvement strategies have currently been adopted, e.g. collection of new data on the experimental site and more efficient use and analysis of available information.

Dense African rainforests

Transfer of research results

Development processes could be accelerated by providing access to information on national and international scientific resources. Exchanges of know-how will also bring stakeholders together and enhance project organization. Compiling and disseminating information are thus cooperative activities.

Forest fires in Southeast Asia (1997)

The forest fires that ravaged Indonesia in 1997 were uncontrollable because they spread from several different combustion sources through lowland regions of southeast Sumatra and southern Kalimantan, on the island of Borneo. Many peat bogs throughout these regions caught fire and burned slowly, producing high quantities of smoke. Large primary forests were relatively unharmed, unlike the logging zones. On-going investigations should soon identify what areas were destroyed in relation to vegetation types, and combustion sources according to local interests. El Niño, the climatic phenomenon, was not the only factor responsible for this disastrous situation. Suitable means of prevention could be developed after taking human activities into consideration.

For almost 30 years, CIRAD has conducted many research projects on rainforest ecosystems in central and western Africa. The FORAFRI project, funded by the French Fonds d'aide et de coopération (FAC), was set up in 1996 to pool research results, tap and make optimum use of this knowledge by disseminating information to regional stakeholders in this subsector. The Indonesian Center for International Forestry Research (CIFOR) is also involved in FORAFRI by coordinating an identical project in English-speaking countries in this part of Africa. The compilation phase, which also includes training activities, is almost finalized. The documents produced are being checked by a scientific and technical committee, which includes representatives from CIRAD, CIFOR, FAO, the World Conservation Union (IUCN), the Association technique internationale des bois tropicaux (ATIBT), along with African national research services.

In 1997, various information documents were compiled in order to give African users—teachers, scientists, industrial entrepreneurs and managers—access to these resources. Around 20 publications, on countries or specific topics, resulted from this work.

The investigations led to an overall understanding of forest-stand dynamics in the Central African Republic, Côte d'Ivoire and Gabon, and forest management in Cameroon, Gabon and Guinea. In-depth information was also obtained on several topics, e.g. evaluating the resource, silviculture, statistical analysis techniques and technological features of commercial African woods.

Publications from the scientific community were also documented to widen the scope for investigations. Around 14 500 English and French references are now classified in a database compiled from Agritrop and Sésame data repositories, in addition to the main tropical databases.

Measurement data from permanent experimental stations in the Congo, Côte d'Ivoire, Gabon and the Central African Republic were also corrected for integration in the database. Old resource inventories were classified. Finally, more than 1000 maps were listed in another interactive database. Aerial photographs and satellite images were also inventoried.

In 1998, a website will be set up and hosted by CIRAD's WWW server to enable transfer of this information via the Internet. This is an important step towards establishing a system to promote regionalization of research on sustainable forest management, in collaboration with the Conférence des responsables de recherche agronomique en Afrique de l'Ouest et du Centre (CORAF) and FAO's Forestry Research Network for Sub-Saharan Africa (FORNESSA).

Information and expertise can also be transferred via training offered to NGOs in the subregion, research scientists, management staff, teachers and professional operators. For instance, a management initiation session was held in the Congo, and extended through a training course on renewable resource management and forest management, offered in Cameroon in collab-

oration with Dschang University. Moreover, a workshop, jointly coordinated by CIFOR, CIRAD and CORAF, was held in Gabon on participatory management strategies for large forests. These activities were keyed to other projects of the Centres régionaux d'enseignement spécialisé en agriculture (CRESA), coordinated by the Agence francophone pour l'enseignement supérieur et la recherche (AUPELF-UREF).

All of these ventures comply with the main objectives of regional environmental projects stewarded by the European Union, the United States Agency for International Development (USAID), and the World Bank. They could thus be extended and promoted in the near future.

Eucalyptus plantations in the Congo

Fertilization, use and sustainable production

Since 1978, hybrid eucalyptus trees have been grown in clonal plantations in the coastal savannah regions of the Congo; they now cover a 43 000 ha area. The stands are logged after 7 years growth, yielding about 100 m^3/year of pulpwood. The plots are then systematically replanted with new better-performing clones created through the genetic improvement programme of the Unité de recherche pour la productivité des plantations industrielles (UR2PI), a Congolese association initially founded in collaboration with CIRAD. A specially-adapted fertilization strategy is required to enable intensive sustainable pulpwood production on the chemically-poor ferralitic soils that prevail in this region. Many fertilization experiments were therefore carried out on these stands. To underpin this research, studies were undertaken to investigate variations in the assimilation of major minerals by the eucalyptus clone most frequently grown in the plantation. This parameter was studied during growth, differentiating the wood, bark, branches, leaves and roots.

The mineral uptake dynamics were found to differ markedly depending on the element involved. Calcium and phosphorus are thus almost constantly absorbed throughout the rotations. The calcium assimilation dynamics observed are common to most eucalyptus species, highlighting that the stand requires a continuous supply of this element. The observed assimilation patterns for phosphorus are unique, as eucalyptus trees have a marked capacity to remobilize this element during tissue aging. The prodigious consumption of phosphorus noted in this clone could be explained by the fact that there are high reserves of this mineral in soils after reforestation.

Magnesium and potassium are mainly mobilized during the juvenile growth phase. There is low accumulation of mineral per tonne of dry matter produced as compared to levels generally recorded in eucalyptus plantations, indicating that this clone has a very high conversion capacity for these elements. Intermediate results were obtained for nitrogen mobilization, with high needs in 2–4 year old trees.

The results of fertilization tests carried out in the Congo revealed a very poor response of trees to phosphate inputs, whereas applications of potassium and nitrogen significantly increased tree growth in the plantation. Only nitrogen fertilization was found to be efficient in 2 year old stands. The dynamics of sampled soil nutrients were also in agreement with these results. Further tests could now be undertaken, for instance, to assess the effects of moderate dolomite inputs during planting on the growth of eucalyptus clones. Once the mineral requirements are quantified for all ages of tree, fertilizer

applications could be accurately adjusted in terms of quantities of fertilizing units, while enhancing the mineral balance by applying different elements at specific dates.

The effects of logging strategies on nutrient export from the ecosystem can be determined by assessing quantities of minerals accumulated in different parts of 7 year old trees. Per-hectare levels of minerals exported with pulpwood are around 80 kg of nitrogen, 20 kg of phosphorus, 30 kg of potassium, 25 kg of calcium and 15 kg of magnesium. Stripping the bark off logs at the site considerably reduces the export of phosphorus, and also calcium and magnesium, which is even a more important factor as mineral deficiency is high in these soils. Marketing large branches for use as fuelwood was found to have very little impact. In contrast, hauling whole trees out to the edges of the plantation plots is not recommended, as this will induce twofold higher mineral export in comparison to the removal of pulpwood only.

These quantified results can be applied throughout the production process, i.e. from tree planting to timber harvest, thus enhancing sustainable of pulpwood production.

An agroforestry decision-support guide

CIRAD research scientists were involved in editing the *Guide d'aide à la décision en agroforesterie* (Agroforestry Decision-support Guide), a composite guide published by the French Groupe de recherche et d'échanges technologiques (GRET). What agroforestry projects should be carried out, and based on what criteria? What methods should be used in the field? The first volume reviews possible approaches, from the analysis to the planning phase, along with technical options and plant production. The 46 factsheets in the second volume deal with tools required for field operations conducted in partnership with the rural community, including: how to identify specific needs in order to come up with tailored solutions; how to organize a project, from programming to assessment; how to exchange information and communicate in order to pinpoint and define the technical options; and how to manage a nursery and select species.

Agroforestry in Burkina

Multiple-purpose live hedges

In Burkina, the impact of both humans and livestock is responsible for high soil and forest degradation. An interesting agroforestry solution involves growing live hedges of trees or shrubs, sometimes edged with rows of herbaceous vegetation, which can serve a wide range of purposes.

These hedges can be grown along contour lines, ditches or bunds, or even on the many rocky ridges found in the central-northern region of the country. Hedges are especially efficient for controlling water-induced soil erosion, and they also act as windbreaks and thus limit wind erosion. These natural structures are cost-effective and provide sustained protection. They prevent livestock from wandering, especially during the dry season when farmers are obliged to protect market garden crops with branches and woven dead twigs. They are useful for land-use planning as they indicate land and road boundaries.

Live hedges give rise to a wide range of different products that can be utilized by farmers and provide them with a supplementary source of income, e.g. fuelwood and timber, forage, and edible and medicinal products.

With the aim of determining which species are the best adapted to local conditions, CIRAD, in partnership with the Burkina Institut de l'envi-

ronnement et des recherches agricoles (INERA), set up about 20 experiments in different ecological zones around the country (Djibo, Gonsé, Boni and Dinderesso).

Propagation tests highlighted that sowing is not always successful because of the climatic risks, weed infestation, and attacks by insects and other pests. Regardless of the multiplication technique and plant spacing tested, and even with the best survival results (more than 80% of the plants), gaps in the hedges had to be replanted to ensure that they would remain impenetrable. The hedge can be trimmed low 2–3 years after planting to make it more solid and difficult to penetrate. Subsequent maintenance trimming (but to a higher level) will keep the protective hedges from spreading too much, and will also make them denser. Hardy species that respond well to successive trimming were chosen on the basis of these tests: *Acacia nilotica* var. *adansonii,* grows vigorously but is sensitive to soil hardening, *Bauhinia rufescens* grows more homogeneously at all sites, *Acacia senegal, Ziziphus mauritiana,* as well as *Prosopis juliflora,* flourish on sandy free-draining soils.

In shrub hedges grown to control, good results were obtained with *Grewia bicolor, Anogeissus leiocarpus,* and especially *Guiera senegalensis* in terms of sturdy growth and soil protection, as a result of the continuum of dense roots under the hedge canopy and the high quantity of leaf litter produced.

Wood production was also quantified for different types of live hedges. The results showed that, in the Sahelian region, an 8 year old hedge planted in double rows with a honeycomb design, at 0.5 m plant spacing and never cut back, produced 9 kg/linear metre of wood with *Ziziphus mauritiana.* In the same planting conditions, *Acacia senegal* produced 13 kg of wood, *Azadirachta indica* 34 kg, *Acacia nilotica* var. *adansonii* 41 kg, *Prosopis juliflora* 72 kg and *Cassia siamea* 181 kg. In the same hedges, but trimmed back to 0.3 m at 2 years old and then to 0.8 m at 5 years old, wood production was substantially lower, i.e. 15 kg for *Azadirachta indica,* and as low as 2–5 kg for the other shrubs in the northern Sudanian zone. In the southern Sudanian zone, the same hedge, composed of *Grewia bicolor, Guiera senegalensis* and *Anogeissus leiocarpus,* produced 6–16 kg of twigs. These data highlight that hedges have a considerable production potential and are an important source of fuelwood and construction wood for rural communities.

On-farm management conditions will now have to be defined in order to determine the best compromise between growth and wood pro-

Genetic mapping of eucalyptus and the paper industry

Reforested eucalyptus zones are extensively utilized by the paper industry. Processing wood into paper pulp requires the chemical extraction of lignin, a polymer that accounts for about 25% of the biomass, using a costly and polluting industrial process. A major challenge is therefore to create eucalyptus varieties with lower lignin contents.

Breeding to obtain such varieties could be accelerated by locating genes directly involved in the lignin biosynthesis chain and by assessing the quantitative and qualitative effects of various alleles. Using the polymerase chain reaction - single strand conformation polymorphism technique (PCR-SSCP), three out of five previously cloned and sequenced genes were located on genetic maps drawn up for *Eucalyptus urophylla* and *E. grandis.* Once the molecular markers are determined, the chemical composition of each wood could be matched with the different allelic forms observed.

duction, use of hedges and the intercrop response. Analyses are thus under way to investigate this potential and to complete an overall review of the topic.

Wood production, technology, and processing

Biomechanical contributions

Tree biomechanics is a research field open to scientists specialized in plant biology, modelling complex systems, and the mechanics of materials and structural mechanisms. This approach is therefore both biological, i.e. understanding tree development and function, and mechanical, i.e. determining the performance of wood material and of the tree as a structure.

Inherent forces in wood are thus responsible for technological problems associated with different processing operations: development of end splits, or even complete splitting of logs after crosscutting and sawing into balks, appearance of cracks and warping of wood after sawing, drying defects due to the presence of reaction wood—which has very special properties that induce performance variations.

CIRAD, in collaboration with the Mechanics and Civil Engineering Laboratory of the Université Montpellier II, has many objectives, ranging from non-consumptive and sustainable forest management to industrial wood processing.

These biomechanical criteria are taken into account when developing diagnostic tests to help in selecting trees or decision-support tools for silvicultural operations. Studies are under way in the Congo, focusing on eucalyptus trees for clonal selection in plantations, in collaboration with UR2PI. In South Africa, a study carried out in collaboration with the Council for Scientific and Industrial Research (CSIR) and the industrial group Safcol aims to determine the cause of resin cracks that occur along the lengths of pine *(Pinus elliotii)* tree trunks. This defect, which is very common in pines growing remote from their native areas, has dramatic effects on finished wood products.

At the request of the Agence de l'environnement et de maîtrise de l'énergie (ADEME) and the French Ministry of Agriculture, and in collaboration with the French Institut national de la recherche agronomique (INRA), CIRAD has been designing models to simulate the mechanical genesis of wood and predict the behaviour of this material, and defects that could appear during sawing.

Studies on tree biomechanics are also essential for selecting woods on the basis of their qualities and potential uses. With the overall aim of optimizing wood processing, a project was set up as part of the European Cooperative Research Action for Technology (CRAFT) programme in collaboration with the University of Vigo (Spain), the Centro de innovación y servicios tecnológicos de la Madera (CIS) of Ourense, and Galician sawyers. The main goal is to upgrade and make efficient use of small-diameter plantation woods (especially eucalyptus) in Galicia (Spain).

Conditions for processing and using woods could also be more accurately defined by taking their biomechanical features into account. This strategy has been adopted in a project under way in Uruguay, in collaboration with the Laboratorio Tecnológico de Uruguay (LATU), aimed at promoting the development of plantation woods. In Morocco, critical mechanical factors concerning the use of eucalyptus wood as utility poles were investigated in collaboration with the

Ecole forestière marocaine de Salé and the Laboratoire de génie civil de Casablanca.

Several new techniques, e.g. mechanically stabilizing round woods by axial drilling and progressive mechanical stress relaxation through heat treatment, will soon be implemented.

Biomechanical studies—taking the limits of wood into consideration and tapping the qualities of each species—help to determine optimal ways for using this material, from the plantation to the manufacturing stage.

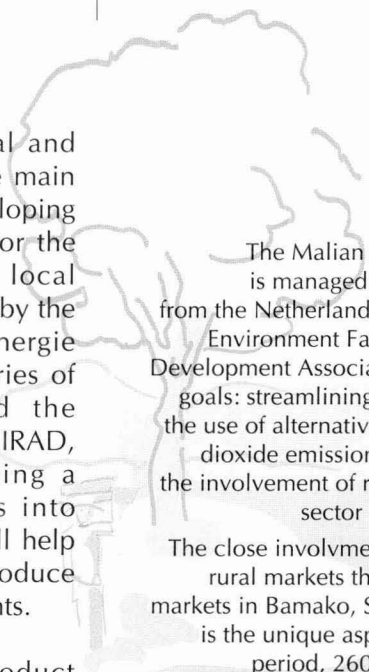
Effluents and energy production

Activated wood charcoal

Due to a lack of resources, industrial and small-scale processing sectors are the main sources of groundwater pollution in developing countries. This pollution is responsible for the chronic shortage of drinking water for local inhabitants. As part of a programme set up by the group Agriculture pour la chimie et l'énergie (AGRICE)—created by the French Ministries of Agriculture, Research, Industry and the Environment and managed by ADEME—CIRAD, along with two partners, is developing a technique to process woody biomass into activated wood charcoal. This material will help control water pollution and thereafter produce energy, while destroying entrapped pollutants.

Wood charcoal is a very important product in Southern countries. The physico-chemical properties of this carbonization residue can be enhanced considerably through activation. Activated charcoal, however, is not a natural product, i.e. a chemical treatment is required, using costly special processes that cannot be undertaken by traditional techniques.

CIRAD has improved traditional charcoal production processes, while developing relatively cost-effective techniques that take local technological and resource potential into account. This will enable efficient use of the abundant woody biomass resources, especially short-rotation coppices and unused agricultural by-products such as triticale and sorghum straw. If the pyrolysis parameters are optimized, i.e. the heating rate, temperature and duration of the final temperature plateau, carbonization alone, without any chemical treatment, will improve the adsorption capacity of charcoal. Laboratory tests were carried out on a wide range of different agricultural by-products and forest products to identify species or agricultural waste products with the highest activation potential.



Domestic energy in Mali

The Malian Domestic Energy Strategy project is managed by the World Bank, with funding from the Netherlands cooperation agency, the Global Environment Facility (GEF), and the International Development Association (IDA). There are two overall goals: streamlining fuelwood supply and promoting the use of alternative fuels to reduce airborne carbon dioxide emissions; adapting logging and fostering the involvement of rural communities and the private sector in domestic energy management.

The close involvment of local operators in setting up rural markets throughout areas that supply urban markets in Bamako, Ségou, Koutiala, Mopti and Kayes is the unique aspect of this project. Over a 4-year period, 260 rural markets should be created, while drawing up supply guidelines. This will be linked with the adoption of more efficient carbonization techniques and alternative fuels, along with the distribution of improved stoves fuelled with wood, charcoal, kerosene and liquid propane.

Efficiency levels (i.e. specific surface of charcoal) of 300–400 m^3/g of material can be obtained by current charcoal processing techniques. In comparison, specific surface levels of industrially produced activated charcoal are generally around 1 000 m^3/g of material. The fact that contaminated charcoal is ultimately used for fuel purposes compensates for the lower initial efficiency capacity.

Levels of various pollutants, e.g. organic fatty acids, agroindustrial residues, slaughterhouse effluents, agrifood wastes and liquid manures, were analysed by the French Institut supérieur agricole de Beauvais. Research scientists at the Université de technologie de Compiègne (France) then developed a measured blend of activated carbon, contaminated water and air. Incineration of this polluted carbonated mixture fulfils a dual function—energy production and degradation of entrapped pollutants.

This cost-effective pollution control system has already attracted the interest of African water treatment companies and industrial enterprises producing high quantities of waste, e.g. African and Asian palm-oil producers, and olive-oil industries in Mediterranean countries.

Food Technology and Rural Systems

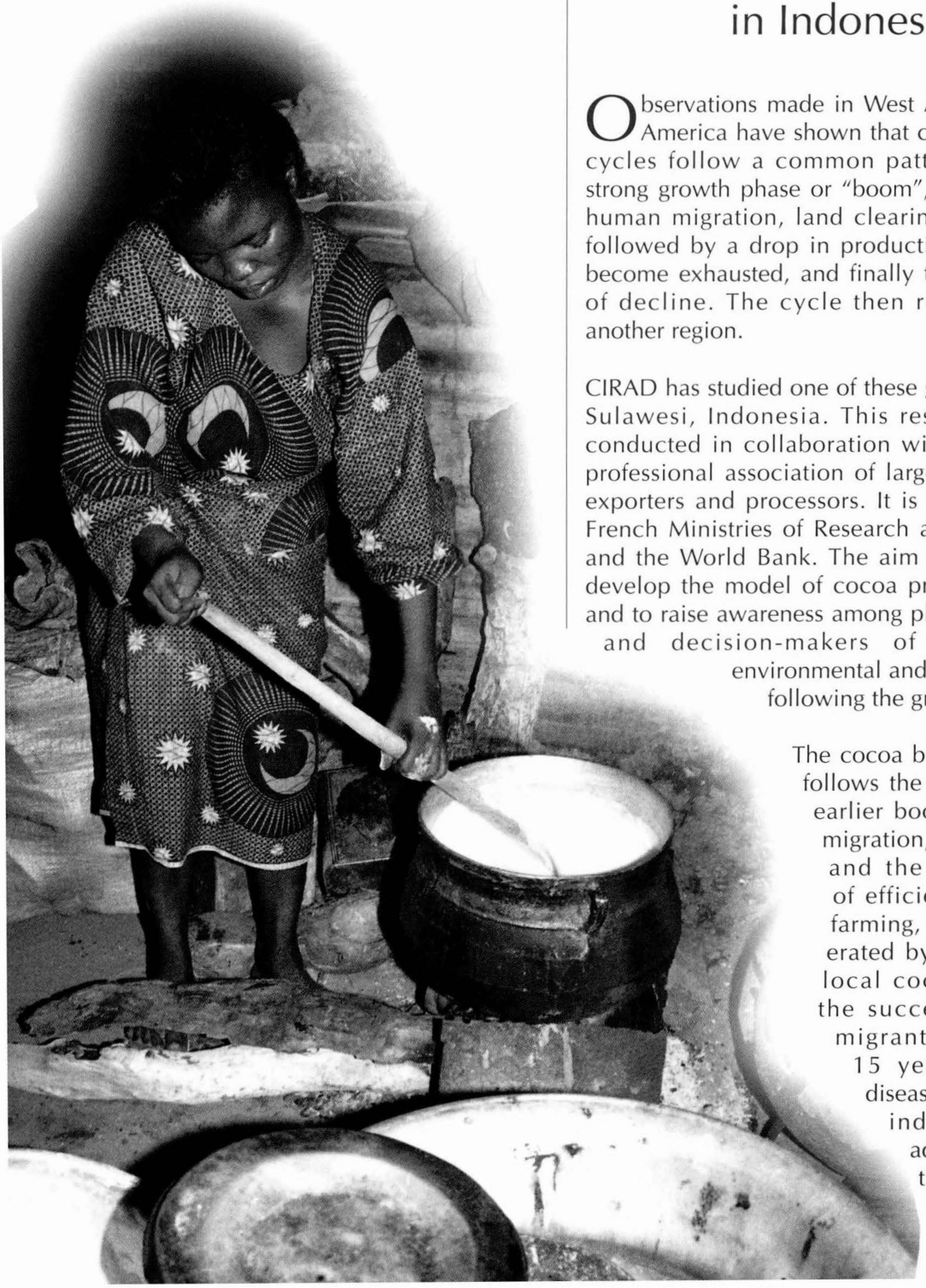
Throughout the world, the role of the State is being reduced, the influence of local authorities is increasing, and producer organizations are being set up. A new approach to the role of state institutions and public authorities and the type of support they provide for individual and community initiatives is required. Credit, extension and applied research services also need to be adapted. In this context, access to reliable information is extremely important.

The Food Technology and Rural Systems Department has oriented its research towards the development of decision-making systems for rural development operators. These systems are designed for use on farms and in food-processing businesses and can also be applied to groups, associations and service industries. They set out to clarify the choices available to decision-makers by anticipating the development of regional economies.

The research-action initiatives carried out in different areas over the past few years have demonstrated the need for a better coordination of projects in view of regional development. Regional development is now a major subject of research and this has led to the creation of a new department "Territories, Environment and People". ■

The economics of raw materials

The cocoa boom in Indonesia



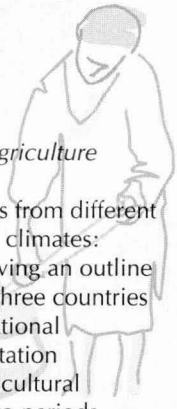
Observations made in West Africa and South America have shown that cocoa production cycles follow a common pattern. There is a strong growth phase or "boom", associated with human migration, land clearing and planting, followed by a drop in production as resources become exhausted, and finally there is a period of decline. The cycle then repeats itself in another region.

CIRAD has studied one of these growth phases in Sulawesi, Indonesia. This research is being conducted in collaboration with ASKINDO, a professional association of large-scale planters, exporters and processors. It is financed by the French Ministries of Research and Cooperation and the World Bank. The aim is to check and develop the model of cocoa production cycles and to raise awareness among planters, exporters and decision-makers of the risks of environmental and economic crises following the growth phase.

The cocoa boom in Sulawesi follows the same pattern as earlier booms: large-scale migration, forest clearing, and the establishment of efficient smallholder farming, which is accelerated by an increase in local cocoa prices and the success of the first migrants. After about 15 years, pests and diseases appear which indicate that the advantages of cultivating newly-

cleared forest land are over. The effect of deforestation and the expansion of cocoa cropping on ecosystems result in the pests of indigenous forest species attacking cocoa trees. Sulawesi also has its own specificities: the rich alluvial soils on the plains allow a certain independence from the forests; the flood of migrants to neighbouring Malaysia facilitates the transfer of information and expertise; and, lastly, the green revolution in rice production has increased the use of inputs. In the context of a free competitive market with low taxation, this combination of ecological, economic and historical assets has led to the intensive development of newly-cleared land in Sulawesi where very high yields are obtained, with an average 2 200 kg/ha of commercial cocoa on the plains and almost 1 500 kg/ha on the hills.

Public policies and agriculture



The publication *Politiques publiques et agriculture* (Public Policies and Agriculture) presents the government policies of three countries from different continents with contrasting geoeconomic climates: Cameroon, Mexico and Indonesia. Following an outline of the structural differences between the three countries and the similarities in terms of the international competition that they face, the implementation of government policies is described. Agricultural policies are characterized and divided into periods on the basis of an historical analysis of the relationship between various sector-based policies and general economic policies. Several indicators of the effectiveness of these policies are presented. The analysis underlines the strategic importance of policies that encourage productive investment and especially reinvestment of profits from sector-based growth, whatever the natural potential or limitations of a particular country. This historical reappraisal identifies the lack of flexibility in current policies and indicates where changes could be made.

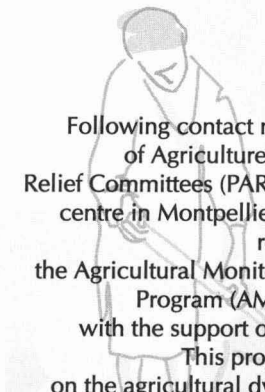
Microeconomic analyses are being carried out to compare the cocoa production cycle with the production cycles of coffee, cloves and rubber.

Support for Madagascan producers

The creation of a service industry

In 1995, after the withdrawal of the State from the agricultural advisory sector, a project to improve animal health, financed by the Caisse Française de Développement (CFD) was set up in the peri-urban zone of Antsirabé in Madagascar. In this area of poultry and pig production, CIRAD has been working with the centre for applied research and rural development (FIFAMANOR), formerly responsible for veterinary care, to provide animal health care until private veterinarians have become established.

The livestock enterprises were relatively unproductive as a result of health problems, poor diet, and generally unsatisfactory rearing conditions. A project was launched to help solve the nutritional problems. This project now operates almost as a private business that provides technical advice and sells feed additives—minerals, trace elements, vitamins and antibiotics—to finance its activities. Its main activity is to advise farmers on making compound feeds. The farmers use locally available raw materials—cereals, bran, oil cake, roots and tubers, and tuna meal. The technicians carry out nutritional and hygiene analyses of these raw materials and calculate the most effective and economic feed formulation. This service is inexpensive for farmers who then make up the compound feeds themselves on their farms. A French company, Guyomarc'h Nutrition Animale, supplies a number of additives and



Support for planning in Palestine

Following contact made by the Palestinian Ministry of Agriculture and the Palestinian Agricultural Relief Committees (PARC), an NGO, with the Agropolis centre in Montpellier and the Languedoc-Roussillon regional Chamber of Agriculture, the Agricultural Monitoring and Development Support Program (AMODESP) was set up in Palestine with the support of the French Consulate General. This project aims to provide information on the agricultural dynamics in Palestinian territories and to respond to a request for advice on planning. It operates on a local and district level and in the territories as a whole. At each level, mechanisms for dialogue are tested. The project began in 1997 in the Naplouse district, with a zoning of the area, the creation of an agricultural database, and the organization of training to support local development. The project should be extended to other districts over the next few years.

provides support for the analyses and the training of technicians. The business also gives advice on animal breeding and building design, and provides an economic monitoring service for livestock enterprises.

Six hundred farmers now use these services. The project involves 340 pig farms and 140 poultry farms with 50 000 layers and an annual production of 15 m eggs. The region of Antsirabé, which used to import eggs, now exports them. The increase in production has led to lower prices for consumers. Some breeders, for whom livestock production was an additional activity or a way of saving money during periods of inflation, are now professional producers.

This project needs to develop so that the sale of its different services will fully cover its running costs, thus ensuring its long-term viability. Similar services will be set up in other regions of Madagascar and the manufacture of concentrated feeds adapted to local needs will be developed using raw materials that are available locally.

Adding value to local food crops

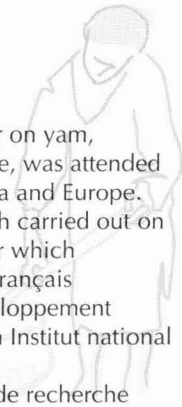
The production of yam chips for urban markets

In the countries in the Gulf of Guinea yam is a popular food, even among town dwellers. The towns are supplied with fresh tubers. Large tuber varieties are convenient for fresh use but they require good cropping conditions. For fresh tuber production, in general, postharvest losses are considerable, supply is irregular, and transport costs and consumer prices are high.

Over the last 15 years, a sector supplying yam chips has been developed in southwest Nigeria, Benin, and to a lesser extent, in Togo. The yam chips are obtained by parboiling and sun drying peeled tubers. They are then crushed and ground into flour which is used to make a dough called *amala*. A regional project brought together the international research organizations—Faculté des sciences agronomiques de l'Université nationale du Bénin (FSA-UNB), National Root Crops Research Institute (NRCRI) in Nigeria, and Institut national des cultures vivrières (INCV) in Togo—in association with CIRAD-CA and the International Institute of Tropical Agriculture (IITA) to identify the strengths and weaknesses of the sector. A multidisciplinary team of agronomists, technology specialists, nutritionists and socioeconomists surveyed consumers, restaurateurs, retailers and producers, and analysed the yam chip processing technology.

Amala is now eaten regularly by people in towns, particularly in southwest Nigeria and southern Benin. It is eaten more often than ground yam and is appreciated for its taste and ease of preparation. *Amala* has even become the staple food for towns in southwest Nigeria. Yam chips keep for several months, their low water content

Yam: an ancient plant and crop for the future



In Montpellier in June 1997, a seminar on yam, an ancient plant and crop for the future, was attended by 120 participants, mainly from Africa and Europe. An assessment of the scientific research carried out on this plant was presented at the seminar which was organized by CIRAD, the Institut français de recherche scientifique pour le développement en coopération (ORSTOM), the French Institut national de la recherche agronomique (INRA), and the Conférence des responsables de recherche agronomique en Afrique de l'Ouest et du Centre (CORAF). Although there has been relatively little research carried out on yams, their production and consumption is increasing steadily. This initiative is the first stage of a research and development strategy to promote yams, to strengthen their role in food security, and to develop urban markets. The seminar proceedings will be published soon.

Good luck *Akassa*

Burkina is a maize-producing country and is looking for ways to add value to this crop by marketing new products. In neighbouring Benin, about 40 maize-based food products are eaten on a regular basis: semolina, mash, yoghurt, *akassa* and *ablo*. The Aval project, financed by the French Ministry of Cooperation, aims to develop local food-processing know-how in West Africa. It has been encouraging exchanges of recipes between restaurateurs from Benin, Burkina and Senegal since 1994. The idea is that the best way to promote and integrate these recipes into new food habits is via the restaurants. A documentary film *Bonne chance* Akassa (Good Luck *Akassa*) was made of this operation with the Periscoop agency. It was distributed on national television in Benin, Burkina and Senegal and was presented at the international agricultural video meetings in Saint-Hyacinthe, Canada, in January 1998.

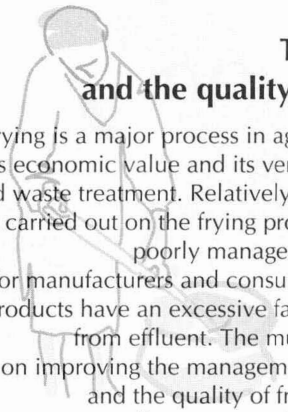
means that transport costs are reduced, and their price is competitive compared to other starchy products. In addition, small tuber varieties, such as Kokoro, are suitable for this kind of processing because they are easier to dry. They also do well in poorer soils and are less labour intensive. A second research and development phase is planned to make yam chipping more commercially viable and to encourage other yam-producing countries to adopt this technology. Insect damage during storage needs to be controlled, the blanching and drying processes need to be improved, and additional uses need to be found for the flour.

Smallholder farming

Marketing small-scale cheese production in Brazil

Increasing competition has led Brazilian smallholders to search for new commercial routes and to try to establish specific niche markets.

Over the last few years, in the state of Sergipe in the Nordeste, milk production has moved into the relatively unproductive semi-arid zones due to the presence of three different marketing routes, i.e. farm, small-scale and industrial. In 1994, CIRAD, the Empresa Brasileira de Pesquisa Agropecuária (EMBRAPA), and the rural development business Empresa de Desenvolvimento Agropecuário (EMDAGRO), carried out an analysis of dairy producers and an assessment of product marketing. This assessment demonstrated the significance of small-scale cheese production, which accounts for 40–60% of the milk collected. Research has not been carried out on these small dairies which are not recognized legally and do not receive support for development. However, they do have a number of advantages: they are scattered in rural areas; they are close to producers who are paid in cash; and they return the whey to the producers for fattening pigs.



The frying process and the quality of fried products

Frying is a major process in agrifood industries due to its economic value and its versatility: cooking, drying and waste treatment. Relatively little research has been carried out on the frying process which is generally poorly managed. This causes problems for manufacturers and consumers: high energy costs, products have an excessive fat content, and pollution from effluent. The multidisciplinary congress on improving the management of the frying process and the quality of fried products, organized in Montpellier in November 1997, demonstrated the recent advances that have been made in understanding this processing method, its traditional and non-traditional applications (such as drying oleaginous fruits and abattoir waste before pressing and extracting oil), product quality, equipment, environmental awareness, and global trends relating to fried product consumption, particularly in urban areas. Frying was confirmed as being a complete process that is versatile and has potential for creating new products. The congress was organized by CIRAD as part of the 1997 Chevreul days, under the auspices of Agropolis International, in collaboration with the French Ecole nationale supérieure des industries agricoles et alimentaires (ENSIA), and with a number of professional associations, such as the Association française pour l'étude des corps gras (AFECG), Association des chimistes ingénieurs des industries agricoles et alimentaires (ACIA) and Group français de génie des procédés (GFGP). It was attended by about 100 scientists and manufacturers.

Local operators and state authorities were informed of the results of this research. The existence and significance of these dairies and the importance for producers of the coexistence of several commercial channels have been recognized. Discussions were begun on integrating the dairies in a dairy production development plan for Sergipe. A transitional arrangement to be implemented over several years is now being negotiated. The aim is to identify the strengths and weaknesses of small-scale cheese production so that appropriate regulations can be established.

In 1997, two studies were carried out in the capital Aracaju on the hygiene quality of milk and cheese, and on consumer perception of this quality. Hygiene problems were observed, which could be caused by poor milking practices, inappropriate methods of transporting the milk, and the proximity of pig farms. The milk collection round provides a sociotechnical network that could be used for disseminating specific advice. In addition, the development of this sector implies that the public authorities will guarantee water quality and provide electricity. The survey on the perception of quality in towns showed that the product is appreciated by consumers from all social classes. They like the taste and the appearance, and are satisfied with the local distribution system, but express some reservations about hygiene quality.

These comments can equally be applied to other products that are processed on farms or in rural areas, such as honey, fruit juice, conserves and pork meat products. In June, more than 400 people—farmers, entrepreneurs, local politicians and researchers—took part in the first meetings on rural agro-industries in the Nordeste region. These meetings, organized with the Brazilian Ministry of Agriculture, CPATSA, EMBRAPA and SEBRAE, a Brazilian support service for small businesses, allowed different experiences to be compared. The meetings also demonstrated the importance of promoting innovative local products and setting up different regulations adapted to these products.

Management, Common Services and Laboratories, and Documentation

Development research is faced with the challenge of keeping pace with the rapid scientific progress that characterizes the end of the 20th century. How can the revolutionary advances made in biological, economic and social sciences be applied more widely? One of the aims of the GERDAT research units and the jointly run laboratories is to respond to this concern, by managing new techniques, carrying out fundamental research, and developing the methodologies required by other departments for their scientific projects. The relevance and quality of the research carried out by these units is confirmed by the increasing demand for their expertise from CIRAD scientists and partners from the North and South.

The plant biotechnology laboratory is widely recognized for its research on the genome mapping of tropical species and consequently it now works in cooperation with the world's foremost laboratories. As a result of its research in tropical graminae, the laboratory is participating in a European project on the study of cereal genomes (EGRAM) with the Institut français de recherche scientifique pour le développement en coopération (ORSTOM). This year was also marked by major advances in polyploid genome analysis using in situ *hybridization and, in genetic engineering, with the development of transformation vectors using flexible cassettes.*

Progress has been made in plant modelling with the creation of virtual functional plantations. For example, the management of forest resources or agricultural production can now be simulated using a combination of the AMAP plant architecture simulation software, geographical information systems and functional process models. Modelling is also extremely important in the economic and social sciences, both for the analysis of natural resource management, and as an aid to agricultural policy decision-making.

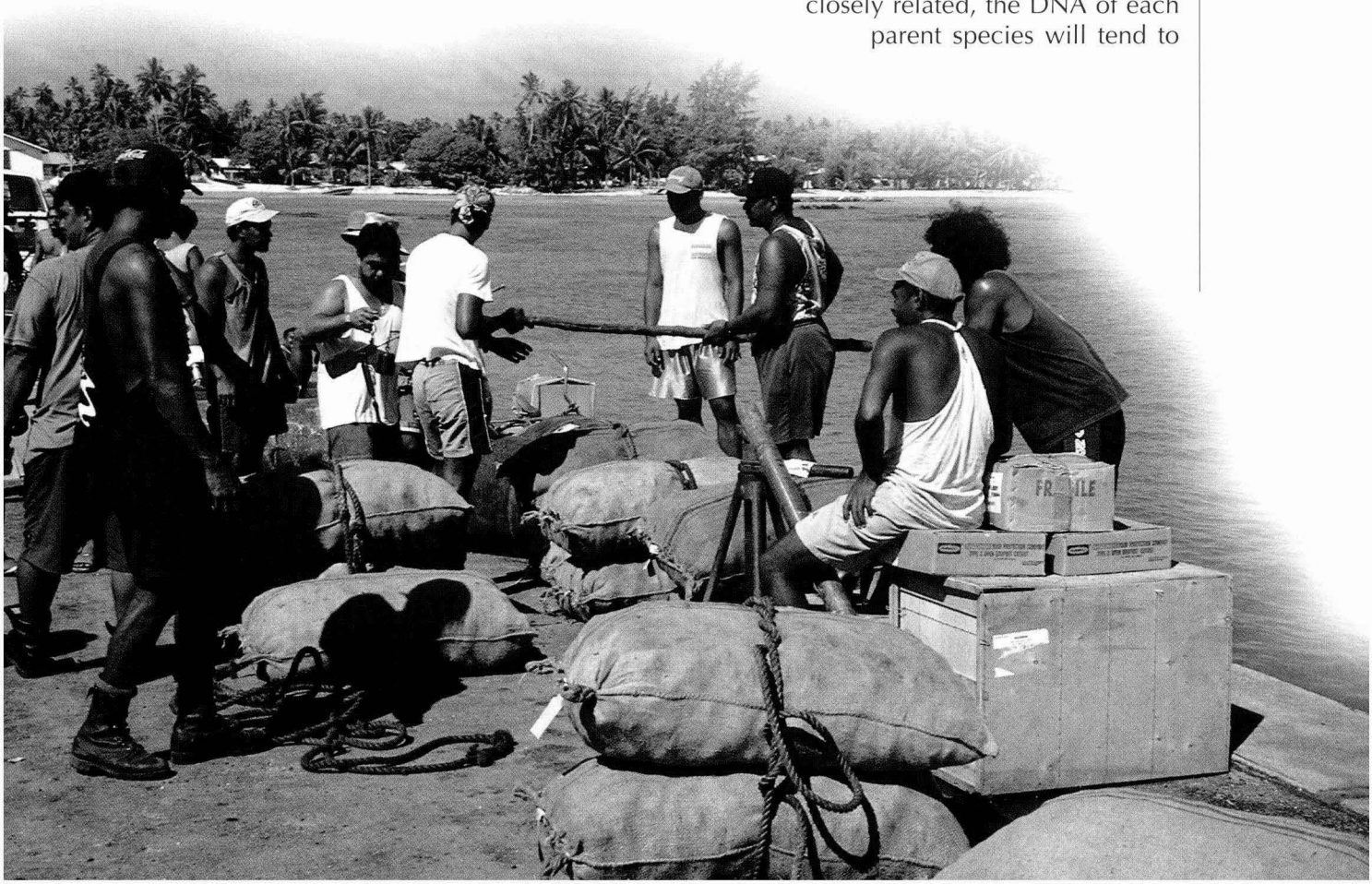
During the course of the year, the Department's research scientists were involved in discussions on CIRAD's scientific reorganization. A consensus was reached to form a new department bringing together expertise from all the different disciplines. This department will be responsible for setting up a system for transferring basic knowledge, methods and expertise so that CIRAD's development-oriented research is effective. ■

In situ *genome hybridization*

Monitoring introgressions on sugarcane and banana

Increasing genetic variation through interspecific crosses is a key factor in improving sugarcane and banana cultivars. *In situ* genome hybridization helps explain the introgression process that occurs in these crosses. It is also used for monitoring the development of this process.

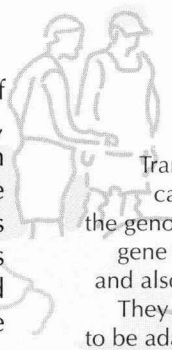
This technique allows the chromosomes from different species in interspecific hybrids to be identified. It consists of hybridizing all the DNA from both parent species, which is marked with a distinct fluorochrome, on hybrid chromosome preparations. If the species are not closely related, the DNA of each parent species will tend to



combine with the chromosomes or parts of chromosomes that it contributed to the hybrid, which will be shown by the different colours. In this way, *in situ* genome hybridization can be used to determine the exact structure of genomes from interspecific hybrids. This technique is particularly useful for research on polyploid hybrid genomes because it overcomes the problem of allelic determination which occurs when using conventional molecular marker analysis. The technique is used on sugarcane clones and some banana cultivars.

Sugarcane cultivars, whose chromosome number ranges from 100 to130, originate from crosses that were carried out early this century between the sugar-yielding species *Saccharum officinarum* (2n = 80) and the wild species *S. spontaneum* (2n = 40–128). *In situ* hybridization makes it possible to distinguish between the chromosomes of these two species. It shows that the proportion of genome from the wild species varies depending on the cultivar. It also reveals that, contrary to accepted theories, there are exchanges between the chromosomes of the two species. Thus,10% of the R 570 clone genome and 20% of the Nco 376 clone genome are made up of complete chromosomes from the species *S. spontaneum*. Ten percent of the chromosomes of both of these clones are combinations of chromosomes from *S. officinarum* and *S. spontaneum*.

Many banana cultivars are triploid, most of which result from a natural hybridization between *Musa acuminata* with the A genome (2n = 22) and *M. balbisiana* with the B genome (2n = 22). Cultivars are said to belong to either the AAB or the ABB genome group depending on their phenotypic resemblance to each of these species. New triploid clones can also be created by crossing. Analyses using *in situ* genome hybridization prove that it is possible to distinguish between A and B genomes. This research will continue in order to identify the part that comes from each of these genomes in the make-up of natural and artificial triploid clones.



Flexible transformation vectors

Transformation vectors are genetic constructions capable of introducing a fragment of DNA into the genome of a host cell. They ensure that the useful gene they are carrying is expressed in the host cell and also carry a gene for selecting transformed cells. They are made up of several elements which need to be adapted to each transformation programme and to the host plant's system of expression. Thus, the promoter, which regulates the expression of the useful gene, differs depending on whether the gene is expressed in every cell or limited to a particular organ, but also depending on whether the plant to be transformed is a monocotyledon or a dicotyledon.

For 4 years, CIRAD has been creating vectors for different types of plants. This has led to the development of vectors based on flexible cassette systems. These make it easy to replace the modules carrying the useful genes, the promoter, the terminator, and the carrier or selection genes so that each plant can be given what it needs. CIRAD now has all the necessary expertise to achieve the objectives of its genetic transformation programme. It has already created transgenic coffee, rice and maize using these vectors.

Computer images and remote sensing

Modelling and interpreting radar signals

The AMAP software is mainly used to produce computer images of plants, but it can also be applied to other areas of research such as agroforestry and remote sensing. With remote sensing, AMAP is used to simulate and interpret the interaction between radio waves and plant architecture. This involves simulating the radiative transfer or radar echo in the plant cover. AMAP can also be used to simulate a 3-dimen-

sional forest environment when it is combined with a geographical information system, i.e. data from satellite images using synthetic aperture radar produces a virtual representation of the zone being studied. This is achieved by recreating a landscape that integrates a numeric model of the land and tree models to give a "virtual reality" plantation from which different parameters can be estimated.

These two techniques are being developed at the Maison de la télédétection by the Centre national du machinisme agricole, du génie rural, des eaux et des forêts (CEMAGREF), the Ecole nationale du génie rural, des eaux et des forêts (ENGREF), and CIRAD. Electromagnetic specialists from the French Centre d'études spatiales de la biosphère (CESBIO) in Toulouse, and managers from the Office national des forêts (ONF) are also involved.

In order to make data from synthetic aperture radar more accessible, AMAP was coupled with a signal model so that the information transmitted by the signal could be understood more clearly. The Amap2sar software is the result of this research. It is a metrological instrument that works on AMAP plant models. It provides the means for obtaining data for a group of trees and a range of parameters that are extremely difficult or impossible to measure on the ground, e.g. total number of branches, leaves or needles, distribution by size, height or orientation of branches, volume, weight, etc. Amap2sar is an extremely powerful analytical tool. It was acquired by the European Space Agency (ESA), in order to study the influence of forest architecture on the propagation of waves in a natural environment. It could also be applied to the study of signals of a different nature, e.g. as optic signals.

Preliminary research has been carried out to validate these models. This involved combining synthetic aperture radar data with AMAP architectural growth models within a geographical information system. For each plot, the radar data indicate the average age of the plant population and the overall biomass, and the geographical information system shows tree species and density. The plot is simulated using AMAP to provide much more precise information that is very important for forest management: number of branches classified in terms of diameter, vertical distribution of biomass, volume and distribution of boles, branches, leaves or needles.

The existing model now needs to be developed to include the heterogeneity within populations and the variability of conditions at different sites. In the future, it will be possible to map several parameters relating to forest resources, such as compartmentalized volume and biomass, number of individuals, architecture, etc. These parameters are particularly useful to foresters and planters who manage large-scale plantations, especially of natural rubber and oil palm in tropical regions and conifers in temperate countries.

It is now recognized that satellite images cannot be interpreted correctly in isolation. Modelling, using the techniques described above, is necessary for a full interpretation of the signals. This research means that radar images will be used much more effectively, especially for obtaining quantitative data. This is particularly important for remote sensing in tropical areas where it is difficult to obtain optical images because of meteorological conditions.

Functional structural plant models

A combined model

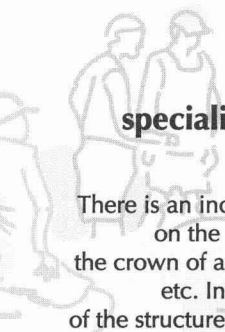
Functional models have great potential. Virtual experiments can replace lengthy and expensive trials, in particular trials involving perennial plants.

Models that are actually being used are restricted to a few annual plants such as maize, wheat, cotton and tomato. They are often inadequate when applied to cropping conditions that differ from those for which they were designed. This weakness is largely because they are based on oversimplistic representations of vegetation. Models that integrate the architectural, topological and geometric dimensions of plants are clearly needed.

The development of a model combining plant architecture and functional processes is a priority for future research. CIRAD is a specialist in this field, having botanists, agronomists, mathematicians, computer specialists and ecophysiologists with considerable experience of the analysis, description and simulation of plant architecture.

Models that combine plant architecture and functioning can be divided into two categories. Those in the first category are very precise in terms of time, topological description and plant geometry. The methodology involves bringing together multiple processes, such as photosynthesis and transpiration, that are distributed throughout the plant, occur at different times, and are sensitive to environmental variations. Computer simulation has a key role in this methodology. The first model of this type was developed for coffee to simulate transpiration and sap flows at a split-second level. Analogous research, which also includes a calculation of the carbon balance, is being carried out on coconut and oil palm as part of an interorganization thematic research programme with the Tree Crops Department. The second category concerns more general models that operate over a longer time scale, e.g. a year, and provide a more global overview. Computer simulation is important here too, although mathematical analytic formulation is possible in simple cases. These models can be used to obtain general results on plant development and to design methods for changing the level of organization (from the level of the individual tree to that of the population) by a rational simplification of plant structure. This formulation can also be used to propose trials to test the model or to evaluate its parameters. A model of this type was developed and used for cotton in collaboration with the Annual Crops Department.

In both cases, the models developed so far are only prototypes. The aim is to create a more general modelling system, capable of integrating new information on organomorphogenetic and functional processes. This research will be conducted in close collaboration with the different CIRAD departments and national and international research organizations. In France over the last few years, a number of joint research projects have been set up with teams from CIRAD and the Institut national de la



AMAPMOD, specialized software for the analysis of plant architecture

There is an increasing amount of agronomic research on the organization of different entities within the crown of a plant: branches, growth units, flowers, etc. In forestry, for example, detailed analysis of the structure and functioning of the crown can lead to better management of bole quality (density of knots, straightness).

CIRAD has responded to this need by developing a specialized software package, AMAPMOD, to provide research scientists with computer and mathematical tools specifically designed for the analysis of plant architecture. AMAPMOD makes it possible to put together plant databases and explore them using graphic visualization algorithms and appropriate statistical models.

AMAPMOD is now used by a number of CIRAD research programmes, notably as an aid to an interorganization thematic research project on perennial plant improvement, as well as by INRA teams and research centres in Germany, Argentina and New Zealand. With this software, CIRAD is proposing a preliminary standard for the measurement and analysis of plant architecture.

recherche agronomique (INRA). In 1997, projects were set up with the INRA and the Ecole nationale supérieure agronomique de Montpellier (ENSAM) research laboratory for plant ecophysiology in conditions of environmental stress; with the IMAGIS team from the Institut national de recherche en informatique et en automatique (INRIA) to study the modelling of light interception as the basis for modelling functional processes. International agreements have already been signed with the United States Department of Agriculture (USDA) for research on annual plants, and with the University of Göttingen in Germany, for research on perennial plants.

In 1997, plant architecture and functional modelling moved from the exploratory stage to one where more complete and integrated models are being developed. These have great potential for use in tropical agronomy.

Agricultural policy and economics

Institutional changes and development

In 1992, CIRAD organized an international seminar on institutional economics in order to sum up current theories and stimulate a wide-ranging discussion on economic reforms involving structural adjustment policies and liberalization. The debates inspired researchers and a number of different areas were covered: the institutions that are needed for efficient market organization, the transition from a subsistence economy to a market economy, the efficiency of state decisions and decentralization. CIRAD produced coherent proposals on these three topics and, as a result, has been asked by the French Ministry of Foreign Affairs, Cooperation, and *Francophonie* to help formulate French policy on privatization of some export sectors in Africa.

In France and francophone countries, markets have long been analysed as a series of exchanges of a given product through its processing cycle, from the raw material to final consumption. This work has highlighted market failures, such as: lack of accurate information, rent seeking, fraud, the power of markets over farmers. Regulations and new ways of organizing markets need to be introduced in order to make transactions more transparent, reduce the risk of fraud, and make anticipation easier. Economists have, therefore, been trying to promote an economic system based on conventions and contracts as a way of reconciling competition and efficiency.

The recent development in institutional economic theories in France—theory of conventions, theory of regulation—explains the transition from a subsistence to a market economy. Economic policy measures based on these theories could be proposed to guarantee market efficiency. Strategies for dismantling state regulatory bodies and replacing them with organizations that make transactions easier and cheaper could also be developed. Experiments based on this approach were carried out successfully in Costa Rica from 1993 to 1996, as part of the CADIAC project.

Decentralizing power from the State is clearly one of the main institutional reforms likely to improve economic performance. If decentralization is to be effective, people need to have the opportunity to express their preferences democratically. From an economic point of view, it is better to encourage local people's involvement in decisions that concern local infrastructures than for central administrations to impose fixed policies. In Niger, for instance, agricultural development projects, in which investment policies are based on local initiatives and decision-making, have resulted in better economic growth.

Small island economies

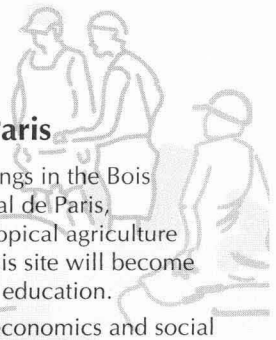
The impact of financial transfers on agricultural activities

There is considerable interest in small island economies, not only for their geopolitical importance—demarcation of territories and marine resources—but also in terms of economic development strategies. Their competitiveness is inherently penalized because of small internal markets and the high costs of accessing international markets. Dependence on financial transfers (grants from the home country or from international organizations, transfer of migrant salaries) has a major impact on island economies. As a result, they share a common problem, which differs slightly according to individual situations.

CIRAD's research in this field mainly concerns the evaluation of the impact of financial transfers on agricultural activities. The analyses focus on the use of public grants and private funds. The aim is to determine the conditions in which the transfers could benefit the agricultural community as a whole and not just a few privileged individuals. This research is being conducted in Vanuatu and Polynesia in collaboration with the coconut programme, in Réunion as part of an investigative analysis, and in Guadeloupe to help the Chamber of Agriculture develop a departmental plan for agricultural development on the island. This research should help reorient agricultural support policies.

Preliminary results show that the heavy dependence of island economies on external financial aid encourages dependency and stifles local initiatives. With limited resources, island economies lack diversity. Financial transfers also raise incomes artificially which has a long-term detrimental effect on the production sector in general, and on agricultural activities in particular. In Polynesia, for example, copra production is relatively unprofitable compared to salaried employment in other sectors despite the fact that the price paid to copra producers is heavily subsidized. The price support policy for copra, which is produced by a large number of small-scale planters, has an important social role because it is a way of redistributing public funds more fairly than is the case for other agricultural products such as bananas, which are grown by a few large producers.

The second phase of this research has now begun. It concerns the microeconomic factors that affect migration in Guadeloupe. The aim is to identify the factors that cause a family to send one or more of its members away from the island



The campus at the Jardin tropical in Paris

CIRAD occupies a group of buildings in the Bois de Vincennes, at the Jardin Tropical de Paris, which formerly accommodated tropical agriculture and forestry research institutes. This site will become a campus for research and further education.

It will be devoted to research on economics and social sciences within environmental and development fields worldwide. It will bring together several research laboratories and educational bodies with scientific links, i.e. the Centre international de recherche sur l'environnement et le développement (CIRED); the Institut d'études du développement économique et social (IEDES); an INRA team with expertise on economic models; the association SOLAGRAL that specializes in food security issues; CIRAD's economics, policies, and markets programme as well as a branch of its environmental and resource management programme; the Aire-développement team. Other research or educational organizations and teams should join the site in the near future.

In addition to research and educational activities, the campus will host an investigative group to study food and environmental issues. Cultural activities will also be organized.

and to determine to what extent money sent from relatives who have emigrated contributes to the family budget, particularly for financing agricultural activities.

Local resource management

Village hunting in east Cameroon

Hunting is practised in every forest village in Cameroon. The question of how it is "managed" by villagers is extremely important to the authorities responsible for the conservation of Cameroon's hunting heritage. Surveys have, therefore, been carried out to identify the traditional methods for managing fauna.

The surveys show that hunting is regulated by numerous rules. These determine who has the right to hunt, where, at what time of year, and which weapons are authorized or prohibited. Thus, only villagers or their parents and friends can hunt on village land. There is no free access to family-owned hunting grounds. Hunting is not allowed in the same area for 2 consecutive years, which means that hunting pressure is not concentrated in one place. Traps are usually used used for 6 months while the rest of the year is for fishing. The animals that are caught are taken round the village and eaten collectively. Profit from the sale of game is used for social purposes.

A study to monitor hunting in one particular village over a year was carried out as part of an economics thesis. It provided the basis for the design of a virtual ecosystem capable of simulating the viability of village management methods. The virtual world is made up of a geographical information system controlled by an artificial intelligence model. In this way, the dynamics of blue duiker antelope populations can be simulated from data collected on the ground and from documentation relating to the species' ethology. Different rules for the management of fauna are then applied to the model

A negotiated management plan for resources in the Indian Ocean

Since 1996, a consortium that includes the main French research centres working in tropical countries - the Institut français de recherche pour l'exploitation de la mer (IFREMER), ORSTOM and CIRAD - and a German research organization, GOPA, has been working for the Indian Ocean Commission's regional environment programme, with funding from the European Union. The aim of the first phase of this programme, which concerns Madagascar, Mauritius, the Seychelles, the Comores and Réunion is to evaluate the coastal resources, their state, uses and management of the five countries. The objective of the second phase is to set up pilot projects to promote the integrated management of coastal areas on a local and regional level. At the same time, the third phase sets out the legal and institutional conditions for a planned integrated management at Commission level.

The consortium is helping to identify objectives and implement a management strategy following negotiations between the different parties. It is analysing the environmental management policies and making proposals (information systems, observatories, assistance in negotiation, institutional analysis, etc.) that can be applied to this process. The consortium's approach is based on partnerships with research centres, universities and agronomy colleges in the region. In 1997, CIRAD was mainly involved in pilot projects in the Seychelles, that focused on a single bay, and in the Menabe region in Madagascar, and it also helped set up a regional policy.

and their effects on the dynamics of the antelope populations can be observed on a map.

This research has made it possible to combine artificial intelligence with a geographical information system. It was carried out in collaboration with the Universities of Dschang and Yaoundé. The tools developed as a result of this research will be useful for environmental managers as well as for researchers working in ecology or the social sciences. Interdisciplinary partnerships with the Cameroon universities will ensure that the methods and results will be passed on to local people.

Madagascar and Chad

Emergency aid to control locust pullulations

Madagascar is under threat from a plague of migratory locusts *Locusta migratoria capito*. At least 2 million ha are affected and the locusts are still advancing. This situation has arisen as a result of abandoning preventive control measures and the lack of effective control methods. It is likely to last for several years despite the action now being taken. When control measures are implemented late (half way through the year even though the situation was already serious in 1996) they are less effective. Their impact is only likely to be felt in a year's time.

CIRAD has played a major role in coordinating the emergency aid set up by FAO and implementing the Madagascan government's control programme. It has helped organize the aerial and ground spraying campaign in the south and southwest of the country. It has also carried out site investigations to evaluate the extent of damage and to determine the likely evolution of infestations. Control measures will be implemented throughout 1998. A research-development project has been developed so that once the current invasion has been checked, a surveillance system and preventive control measures will be put in place. A publication entitled *Eléments d'archives acridiennes à Madagascar* (Elements from acridian archives in Madagascar) was published with the support of the French Ministry of Foreign Affairs. Useful information was found in the archives belonging to the Madagascan locust control service (the last plague on the island lasted for 18 years) that could help improve the surveillance of the migratory locust on the main island.

Since August 1997, Chad and northern Cameroon have also been under attack by plagues of the African subspecies of migratory locust *Locusta migratoria migratorioides*. Locust specialists from CIRAD have been working in the region to control the invasion, under the aegis of FAO and with the support of the French Ministry of Foreign Affairs. Information was collected and analysed to determine the causes of these infestations which occur every 5–10 years. Measures have been proposed to improve the surveillance of the migratory locust in this region.

CIRAD at a Glance

Organization chart

Departments

Committees

Research coordination

Regional representatives

CIRAD worldwide

Budget and personnel

CIRAD training

Organization Chart

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Bernard Bachelier

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Alain Pavé

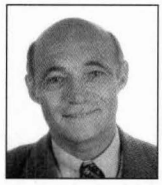
Secretary General
Michel Eddi

Director, Research
Michel Dron

Director, External Relations
Henri Rouillé d'Orfeuil

Director, Montpellier Research Centre
Gérard Matheron

Department Directors



CIRAD-CA
Hubert Manichon

CIRAD-CP
Patrice de Vernou

CIRAD-FLHOR
Jean-Pierre Gaillard

CIRAD-EMVT
Joseph Domenech

CIRAD-Forêt
Jacques Valeix

CIRAD-TERA
Jean Pichot

CIRAD-AMIS
Vincent Dollé

# of CIRAD in 1998

Accounts and Finance
Marc Gélis, Manager

Human Resources
François Fort, Manager

Installations and Maintenance
Didier Servat, Manager

Internal Auditor
Antoine Bourgeois

French Overseas Departments and Territories
François Pointereau, Delegate

Representatives
(see page 83)

Scientific and Technical Information

Jean-François Giovannetti, Delegate

Information and Documentation
Lucile Grasset

Publications
Martine Séguier-Guis

Information Technology
Joël Sor, Delegate

Research Administration

Deputy Director
Jacques Meunier

Research Coordination

Crop and environment management
Eric Malézieux

Plant improvement
Dominique Nicolas

Plant protection
Appointment pending

Animal production
Philippe Lhoste

Technology
François Challot

Economics and sociology
Jacques Weber

Applied mathematics and biometrics
Xavier Perrier

Forward and Strategic Studies
Marie de Lattre-Gasquet

Training Service
Marc Roesch

External Relations

Africa, Indian Ocean
Daniel Annerose

Latin America, Carribean
André de Courville

Asia, South Pacific
Jean-Luc Renard

International organizations, Middle East
Pierre-Luc Puglièse

Overseas representatives
(see page 83)

Economic partnerships
Christian Brunin

Development partnerships
Alain Guyot

Communication:
Publicity
Anne Hébert
Press relations
Benoît Catrisse

CIRAD Departments in 1998

Annual Crops Department
CIRAD-CA

Hubert Manichon, Director
Rolland Guis, Deputy Director, Partnerships and Cooperation
Hervé Saint Macary, Deputy Director, Scientific Coordination
Léandre Mas, Assistant Director, Head, Management Support Service
Jean-Luc Khalfaoui, Consultancy and Operations Bureau

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

Tree Crops Department
CIRAD-CP

Patrice de Vernou, Director
Denis Despréaux, Deputy Director, Scientific Affairs
Michel Aubry, Assistant Director, Head, Management Support Service
Christian Picasso, Consultancy and Operations Bureau

Michel Barel, Head, Cocoa Programme
Daniel Duris, Head, Coffee Programme
André Rouzière, Head, Coconut Programme
Yves Banchi, Head, Rubber Programme
Bertrand Tailliez, Head, Oil Palm Programme

Fruit and Horticultural Crops Department
CIRAD-FLHOR

Jean-Pierre Gaillard, Director
Jacky Ganry, Deputy Director, Scientific Affairs
Christian Altairac, Assistant Director, Head, Management Support Service
Jean-Paul Meyer, Consultancy and Operations Bureau

Thierry Goguey, Head, Fruit Trees Programme
Hugues Tézenas du Montcel, Head, Banana and Plantain Programme
Hubert de Bon, Head, Horticultural Products Programme (temporary appointment)

Animal Production and Veterinary Medicine Department
CIRAD-EMVT

Joseph Domenech, Director
André Martin, Deputy Director
Didier Richard, Assistant Director, Scientific Affairs
Jean-Vital Decloquement, Assistant Director, Head, Management Support Service
Gérard Duvallet, Head, Teaching and Training service
Léon Letenneur, Consultancy and Operations Bureau

François Monicat, Head, Rangeland and Wildlife Management Programme
Bernard Faye, Head, Animal Production Programme
Jean-Jacques Tulasne, Head, Animal Health Programme

Forestry Department
CIRAD-Forêt

Jacques Valeix, Director
Eric Loffeier, Deputy Director, Scientific Affairs
Yves Danglehant, Assistant Director, Head, Management Support Service
Patrick Durand, Consultancy and Operations Bureau

Bernard Mallet, Head, Trees and Plantations Programme
Christian Sales, Head, Forest Products Programme
Jean-Guy Bertault, Head, Natural Forests Programme

Territories, Environment and People Department
CIRAD-TERA

Jean Pichot, Director
Jean-Philippe Tonneau, Deputy Director, Scientific Affairs
Léandre Mas, Assistant Director, Head, Management Support Service

Bruno Losch, Head, Smallholder Farming Programme
Alain Angé, Head, Land and Resources Programme
Guy Faure, Head, Savannah and Irrigated Systems Programme
Alain Leplaideur, Head, Humid Tropics Programme

Department of Advanced Methods for Innovation in Science
CIRAD-AMIS

Vincent Dollé, Director
Jacques Schwendiman, Assistant Director, Scientific Affairs
Vincent Fabre-Rousseau, Assistant Director, Head, Management Support Service
Alain Chauchard, Consultancy and Operations Bureau

Anne-Lucie Wack, Head, Agrifood Systems Programme
Florent Maraux, Head, Agronomy Programme
Jean-Christophe Glaszmann, Head, Biotechnology and Plant Genetic Resources Programme
Michel Griffon, Head, Economics, Policies and Markets Programme
François Houlier, Head, Plant Modelling Programme
Xavier Mourichon, Head, Crop Protection Programme

CIRAD Committees in 1998

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Marie-Laure Micoud, representing the Minister for the French Overseas Departments and Territories

President, Institut national de la recherche agronomique
Guy Paillotin

External members
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Eugène Terry, World Bank, USA
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Research Coordination in 1998

Crop and Environment Management

Coordinator
Eric Malézieux
Adviser
Guy Trébuil

Scientific Committee
Chairperson
Jean-Claude Rémy, ENSA Montpellier

External members
Alain Capillon, INA-PG
Bruno Delvaux, Université catholique de Louvain-la-Neuve
Jean-Marc Meynard, INRA, INA-PG
Bernard Saugier, Université Paris XI
Bernard Seguin, INRA
Franck Warembourg, CNRS

CIRAD members
Departmental representatives

Plant Improvement

Coordinator
Dominique Nicolas
Adviser
Hélène Joly

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Yves Chupeau, INRA
Michel Delseny, CNRS, Université de Perpignan
Serge Hamon, ORSTOM
Antoine Kremer, INRA
Pierre-Louis Lefort, GEVES

CIRAD members
Departmental representatives

Plant Protection

Coordinator
Appointment pending
Scientific Committee
Appointment pending

CIRAD members
Departmental representatives

Animal Production

Coordinator
Philippe Lhoste

Scientific Committee
Chairperson
Bernard Hubert, INRA

External members
Alain Bourbouze, IAM
Jean Chantal, ENV Toulouse
Antoine Cornet, ORSTOM
Jean-Baptiste Coulon, INRA
Edmond Tchakérian, Institut de l'élevage
Jacques Thimonier, ENSA Montpellier

CIRAD members
Departmental representatives

Technology

Coordinator
François Challot

Scientific Committee
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Antoine Gaset, ENSC Toulouse

External members
Jean-Claude Brosse, Université du Maine
Yves Darricau, UNIDO
Jean-Yves Dréan, ENSIT
Pierre Germain, ENSAIA
Christiane Mercier, Danone group
René Urien, CEMAGREF
Jean-Anne Ville, ORSTOM

CIRAD members
Departmental representatives

Economics and Sociology

Coordinator
Jacques Weber

Scientific committee
Appointment pending

CIRAD members
Departmental representatives

Applied Mathematics and Biometrics

Coordinator
Xavier Perrier

Scientific Committee
Chairperson
Yves Escoufier, Université Montpellier II

External members
Bruno Goffinet, INRA
Richard Tomassone, INA-PG

CIRAD members
Departmental representatives

Regional representatives

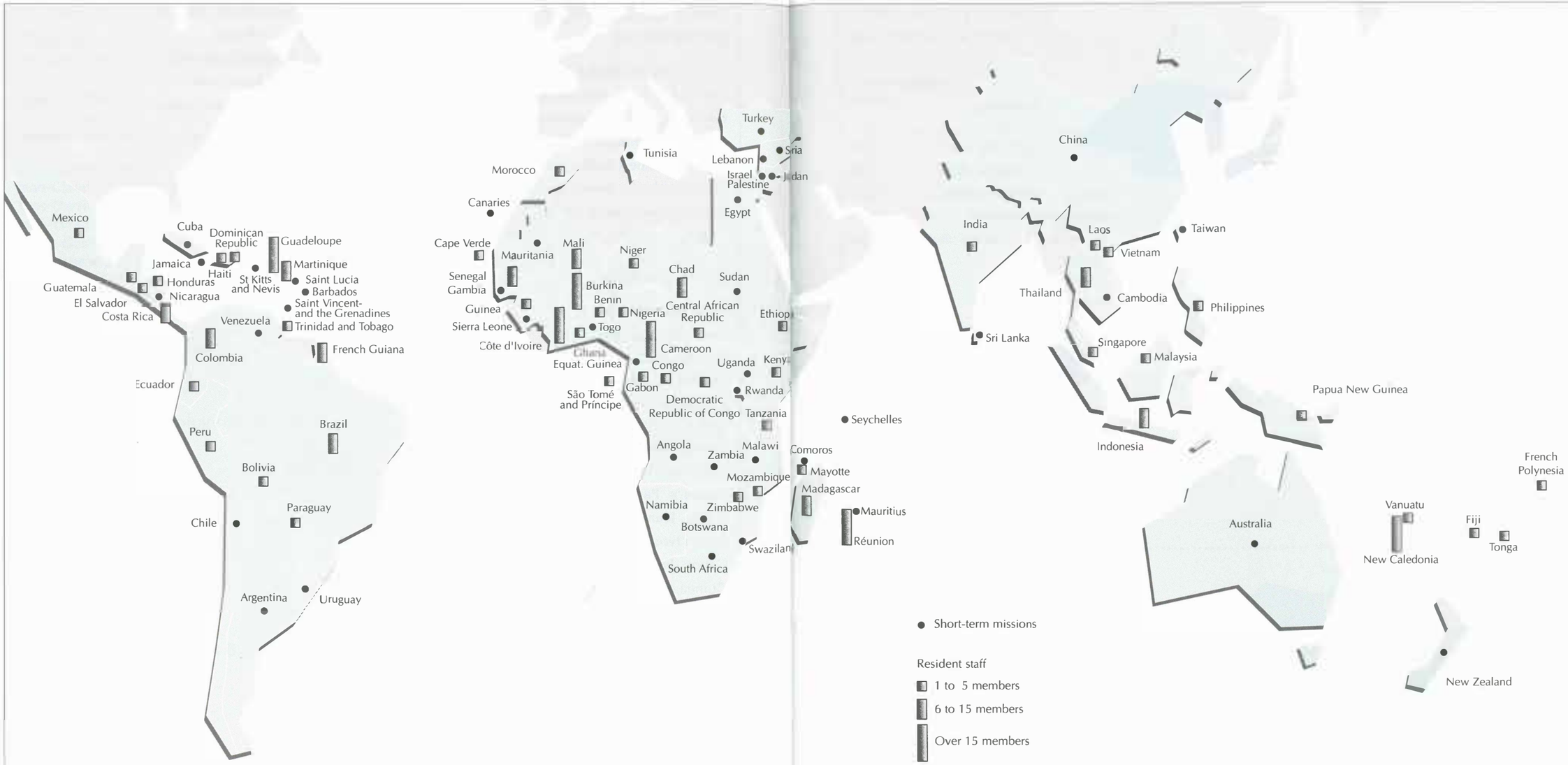
French Overseas Departments and Territories

French Guiana, **Michel Trébel,** Delegate
French Polynesia, **Vincent Baron,** Correspondent
Guadeloupe, **Emmanuel Camus,** Delegate
Martinique, **Philippe Melin,** Delegate
Mayotte, **Gilbert Vallée,** Correspondent
New Caledonia, **Daniel Bourzat,** Director
Réunion, **Paul Gener,** Delegate

Other Countries

Benin, **Pierre Silvie**
Brazil, **François Bertin**
Burkina, **Jacques Dubernard**
Cameroon, **Jean-François Poulain**
Caribbean islands, **Emmanuel Camus** (based in Guadeloupe)
Chad, **Didier Bouchel**
Colombia, **Alain Pinon**
Comoros, **Paul Gener** (based in Réunion)
Congo, **Jean-Marc Bouvet**
Côte d'Ivoire, **Jacques Teissier**
Gabon, **Franck Enjalric**
Guinea, **Jean Servant**
Indonesia, **Gabriel de Taffin**
Madagascar, **Jean-Louis Reboul**
Mali, **Jacques Dubernard** (based in Burkina)
Mauritius, **Paul Gener** (based in Réunion)
Niger, **Jacques Dubernard** (based in Burkina)
Senegal, **Jean-Louis Messager**
Seychelles, **Paul Gener** (based in Réunion)
South Africa, **Jean-Paul Loyer**
Thailand, **Jean-Claude Vincent**
United States, **Jill Barr**
Vanuatu, **Bernard Dolacinski**
Vietnam, **Jean Bourdeaut**
Zimbabwe, **Dominique Dulieu**

CIRAD worldwide



Budget and Personnel in 1997

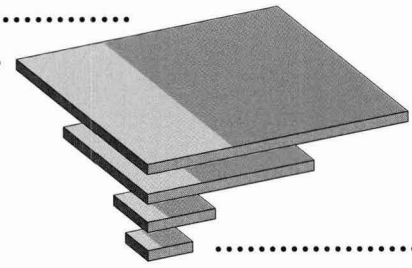
Income and expenditure

Income

BCRD* subsidy 67%

Other income 33%

* Civil research and development budget



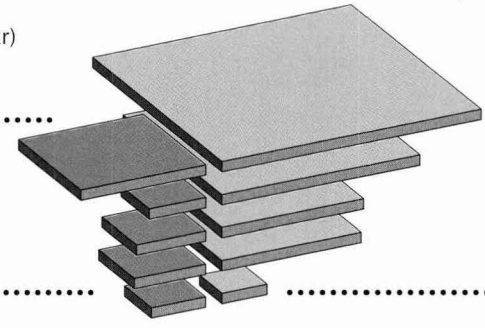
Expenditure
(FFr million)

Personnel exp.	679.30
Operating exp.	278.20
Other expenses	51.20
Investments	20.00
	1 028.70

Distribution of staff by category and location

534	Senior staff, France,
585	Other staff, France
366	Senior staff, overseas (including French overseas departments and territories)
317	Other staff, overseas (including French overseas departments and territories)
1 802	

Missions
(equivalence in researcher year)



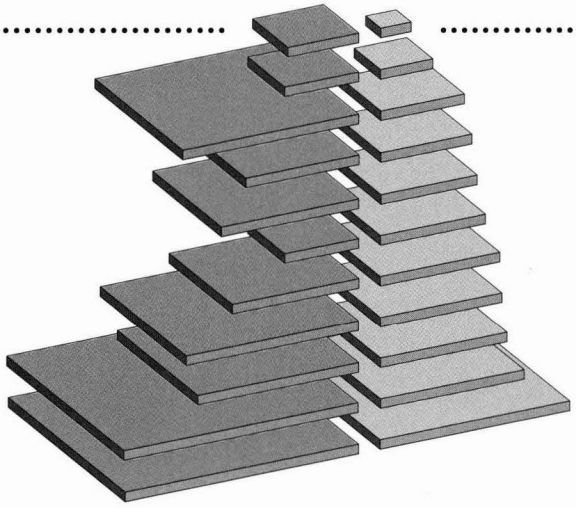
41.9	Africa, Indian Ocean 166
8.6	French overseas depart. and terr. 97
12.9	Latin America 50
13.6	Asia, South Pacific 48
7.9	Others 5
84.9	**366**

Geographical distribution of senior staff overseas, including French overseas departments and territories

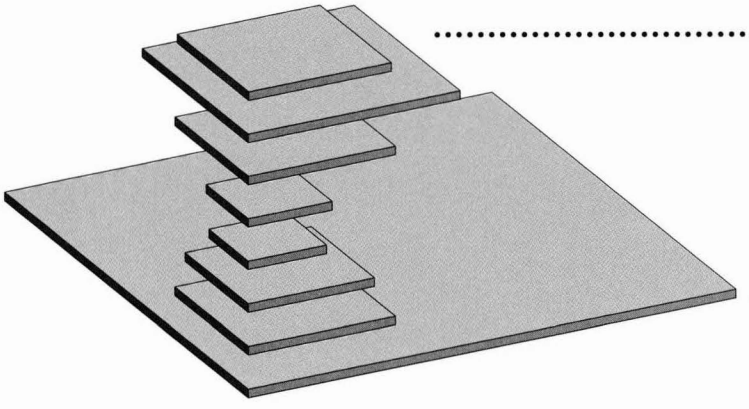
CIRAD training in 1997

Distribution by discipline and type of training

Degree-oriented training		Professional training
11	Biometrics	2
12	Remote sensing	6
67	Economics and sociology	15
28	Administration and management	18
41	Plant protection	20
12	Scientific and technical information	24
35	Computing	31
64	Animal production	32
56	Plant improvement	35
119	Technology	45
118	Agronomy	78
563		**306**



Distribution of trainees by geographical origin



Northern Africa	48
Western Africa	104
Central Africa	51
Eastern Africa	18
Southern Africa, Indian Ocean region	16
Latin America, Caribbean	38
Middle East, Asia, South Pacific	51
Europe	543
	869

Annexes

CIRAD addresses

List of acronyms

CIRAD Addresses

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Fax: 01 43 94 73 11

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Papeete
Tahiti
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Fax: (689) 42 46 93

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Fax: 05 90 25 24 92

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97202 Fort-de-France Cedex
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Fax: 05 96 63 07 24

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97600 Mamoudzou
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Fax: 02 69 61 21 19

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M. le directeur
BP 73
Païta
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Fax: (687) 35 32 55

Réunion
M. le délégué
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Burkina
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Ouagadougou 01
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Fax: (226) 30 76 17

Cameroon
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Yaoundé
Telephone: (237) 21 25 41
Fax: (237) 20 29 69

Chad
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List of Acronyms

AARD, Agricultural Agency for Research and Development, Indonesia

ACIA, Association des chimistes ingénieurs des industries agricoles et alimentaires, France

ADB, Asian Development Bank, Philippines

ADEME, Agence de l'environnement et de la maîtrise de l'énergie, France

AFECG, Association française pour l'étude des corps gras, France

ANACAFE, Asociación Nacional del Café, Guatemala

ANVAR, Agence nationale de valorisation de la recherche, France

ASARECA, Association for Strengthening Agricultural Research in Eastern and Central Africa, Uganda

ASKINDO, Indonesian Cocoa Association, Indonesia

ATIBT, Association technique internationale des bois tropicaux, France

AUPELF-UREF, Agence francophone pour l'enseignement supérieur et la recherche, France

AVRDC, Asian Vegetable Research and Development Center, Taiwan

BCG, Boston Consulting Group, United States

BDPA, Bureau pour le développement de la production agricole, France

BNETD, Bureau national d'études techniques et de développement, Côte d'Ivoire

CEMAGREF, Centre national du machinisme agricole, du génie rural, des eaux et des forêts, France

CERF, Centre d'essais, de recherche et de formation, Réunion

CESBIO, Centre d'études spatiales de la biosphère, France

CFD, Caisse française de développement, France

CGIAR, Consultative Group on International Agricultural Research, United States

CIAT, Centro Internacional de Agricultura Tropical, Colombia

CIFOR, Center for International Forestry Research, Indonesia

CIRDES, Centre international de recherche-développement sur l'élevage en zone subhumide, Burkina

CIRED, Centre international de recherche sur l'environnement et le développement, France

CIS-Madera, Centro de Innovación y Servicios Tecnológicos de la Madera, Spain

CMDT, Compagnie malienne pour le développement des textiles, Mali

CNEVA, Centre national d'études vétérinaires et alimentaires, France

CNRS, Centre national de la recherche scientifique, France

CORAF, Conférence des responsables de recherche agronomique en Afrique de l'Ouest et du Centre, Senegal

CPATSA, Centro de Pesquisa Agropecuária do Trópico Semi-Arido, Brazil

CRF, Coffee Research Foundation, Kenya

CSIR, Council for Scientific and Industrial Research, Ghana

EMBRAPA, Empresa Brasileira de Pesquisa Agropecuária, Brazil

EMDAGRO, Empresa de Desenvolvimento Agropecuário, Brazil

ENGREF, Ecole nationale du génie rural, des eaux et des forêts, France

ENSAIA, Ecole nationale supérieure d'agronomie et des industries alimentaires, France

ENSAM, Ecole nationale supérieure agronomique de Montpellier, France

ENSIA, Ecole nationale supérieure des industries agricoles et alimentaires, France

ESA, European Space Agency, France

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

FIFAMANOR, Fiompiana Fambolena Malagasy Norveziana, Madagascar

FSA-UNB, Faculté des sciences agronomiques de l'Université nationale du Bénin, Benin

GEF, Global Environment Facility, United States

GFGP, Groupe français de génie des procédés, France

GRET, Groupe de recherche et d'échanges technologiques, France

ICRA, Institut centrafricain de recherche agronomique, Central African Republic

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

IDA, International Development Association, France

IDEFOR, Institut des forêts, Côte d'Ivoire

IEDES, Institut d'études du développement économique et social, France

IER, Institut d'économie rurale, Mali

IFCPAR, Indo-French Centre for the Promotion of Advanced Research, India

IFREMER, Institut français de recherche pour l'exploitation de la mer, 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

INCV, Institut national des cultures vivrières, Togo

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

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

INRA, Institut national de la recherche agronomique, France

INRAB, Institut national de recherche agronomique du Bénin, Benin

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

INSA, Institut national des sciences appliquées, France

IOPRI, Indonesian Oil Palm Research Institute, Indonesia

IRAD, Institut de recherche agricole pour le développement, Cameroon

IRRI, International Rice Research Institute, Philippines

ISRA, Institut sénégalais de recherches agricoles, Senegal

ITP, Institut technique du porc, France

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

IUCN, World Conservation Union, Switzerland

LAFORIA, Laboratoire des formes et d'intelligence artificielle, France

LATU, Laboratorio Tecnológico de Uruguay, Uruguay

NRCC, National Research Center on Camel, India

NRCRI, National Root Crops Research Institute, Nigeria

OIE, Office international des épizooties, France

ONC, Office national de la chasse, France

ONF, Office national des forêts, France

ORSTOM, Institut français de la recherche scientifique pour le développement en coopération, France

PARC, Palestinian Agricultural Relief Committees, Palestine

PROCAFE, Fundación Salvadoreña para Investigaciones del Café, El Salvador

RRIT, Rubber Research Institute of Thailand, Thailand

SACCAR, Southern African Centre for Cooperation in Agricultural Research, Botswana

SEBRAE, Serviço Brasileiro de Apoio a Micro e Pequenas Empresas, Brazil

SOLAGRAL, Solidarités agricoles et alimentaires, France

UR2PI, Unité de recherche pour la productivité des plantations industrielles, Congo

USAID, United States Agency for International Development, United States

USDA, United States Department of Agriculture, United States

WTO, World Trade Organization, Switzerland

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