

# Cirad 1996



CIRAD



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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.

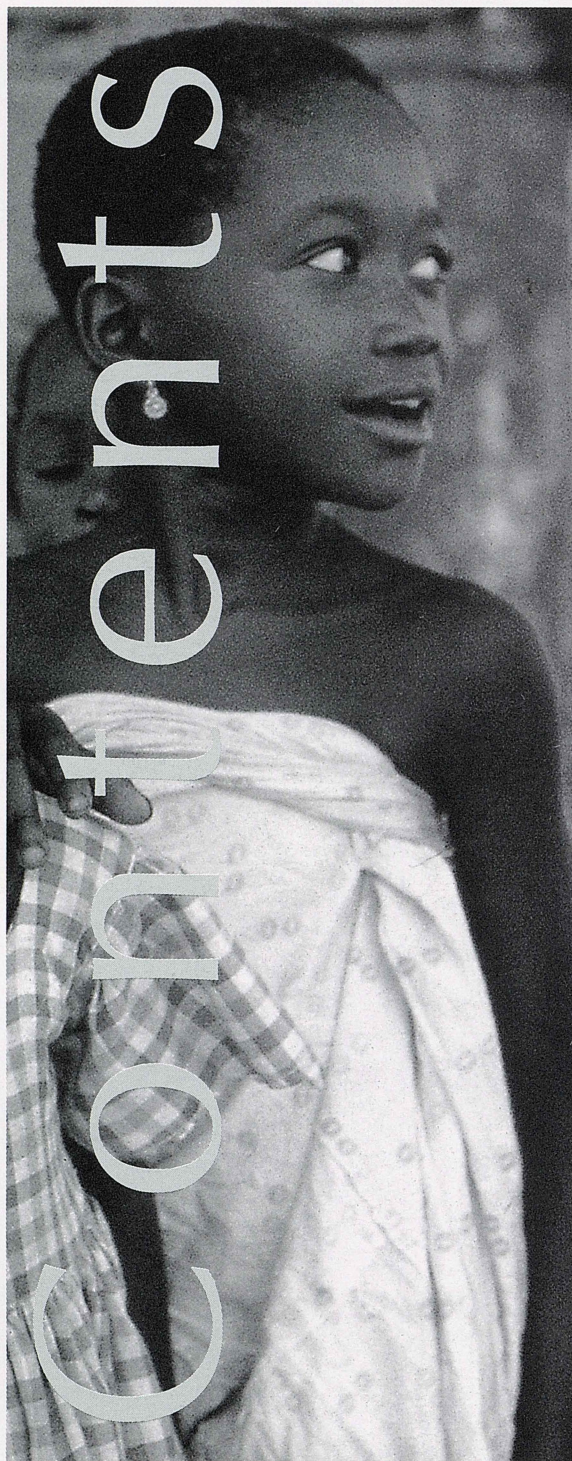
The Centre employs 1800 persons, including 900 senior staff, who work in more than 50 countries. Its budget amounts to approximately 1 billion French francs, more than half of which is derived from public funds.

CIRAD is made up of seven departments: CIRAD-CA (annual crops), CIRAD-CP (tree crops), CIRAD-FLHOR (fruit and horticultural crops), CIRAD-EMVT (livestock production and veterinary medicine), CIRAD-Forêt (forestry), CIRAD-SAR (food technology and rural systems), and CIRAD-GERDAT (management, common services and laboratories, and documentation). CIRAD operates through its own research centres, national agricultural research systems, or development projects.



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## ***The President's Message***

*While our experience has shaped us, the future is ours to forge. CIRAD conducts research in more than 50 different countries, collaborating with many different and rapidly-evolving partner institutions on a wide range of themes. To meet the inherent challenges of this dynamic situation, the Centre must be prepared to deal with predictable transitions, while pursuing other changes that are deemed necessary. In this context, a Forward and Strategic Studies Unit was established at the General Administration level in 1996.*

*After three terms of office as Chairman of the Scientific Advisory Committee, André Berkaloff, who I would like to thank personally for his determination and wise advice, pointed out that the balance between forward planning and external reviews of CIRAD departments should be enhanced to facilitate management decision-making. The Forward and Strategic Studies Unit will explore ways to establish this balance, while collaborating in the management restructuring process currently under way at CIRAD—as synergy between these two parameters is essential.*

*The Forward and Strategic Studies Unit develops, implements, and provides methodological support for the analysis of future requirements and related strategies, while assisting in decision-making on important issues at the Centre. In addition, it collaborates with CIRAD research units, the Scientific Advisory Committee, and other French and foreign partners on different themes. The challenge is to work together as a group in assessing possible future changes.*

*Forward and strategic analyses will help in understanding the dynamics of economic and social progress, along with rapid scientific and technological development, and clarify links between these factors.*

*How will the situation evolve concerning stakeholders in Southern countries and development-oriented scientific research institutions? How can CIRAD, a French scientific research centre, participate in setting up fully-qualified joint research teams with scientists from Europe and the South? What economic stakeholders are open to collaboration with CIRAD?*

*What is the status of CIRAD, a development-oriented research organization, within the international scientific community—which is characterized by constantly changing know-how and techniques, with a wide range of ethical and ecological implications?*

*How can Southern countries be efficiently involved in sustainable production, processing, distribution, and marketing of plant- and animal-based products? What options will CIRAD, as a French state-owned body, choose to help answer these questions?*

*In its first year, the Forward and Strategic Studies Unit will assess the long-term prospects for cocoa in order to improve CIRAD's research priorities concerning this crop, and carry out a study of food industries for a group of French educational and research institutions. Strategic analyses will focus on CIRAD's relations with private companies, which are the main instigators of economic development in Southern countries, with the overall aim of establishing partnerships with these companies.*

*It is my sincere hope, beyond assisting in decision-making and research programming, that these activities will sharpen our awareness and foresight—enabling us to successfully meet the human, economic, and scientific challenges we will have to address in the 21<sup>st</sup> century.*



Guy Paillotin  
President





*Restructuring CIRAD's management*

## Renewing CIRAD's Management for a better response to partners' needs

*Discussions under way in 1996 on CIRAD's organization and operations highlighted a key point—that its unique status is not being fully tapped and its organization is not very clear. A restructuring plan was therefore initiated to overhaul and modernize its management, streamline the organization, and increase operational flexibility, thus reflecting CIRAD's aim to enhance its responses to increasingly complex development requests. This restructuring, which is to take effect in 1998 through several phases involving close consultation with staff, is within the scope of CIRAD's scientific strategy set out in the agreement on objectives signed with the French government in 1996.*



CIRAD WAS CREATED BY THE FRENCH government in 1984 as a state-owned body specializing in development-oriented agricultural research for the tropics and subtropics. Its main mission is to contribute to the economic and social development of these regions. The management status and guidelines established at the beginning were well founded, as confirmed in a recent appraisal of the organization undertaken by the Comité national d'évaluation de la recherche (CNER). This review highlighted that CIRAD has a fully-justified unique position on the French scientific research scene, conducting "high-quality basic (e.g. molecular biology) and applied scientific research".

As a decentralized public institution, CIRAD is operationally flexible and dynamic, two features that have facilitated modernization of its research structures and enabled it to increase collaborations with partners worldwide.

*The increasingly complex demand for CIRAD's services*

Besides its undeniable assets, CIRAD is constrained by some organizational and operational shortcomings. After more than a decade of operation, the Centre is not yet reaping the full benefits of its uniqueness; and its extremely complex hierarchical structure curtails smooth operations and impedes interaction with its partners.

The restructuring plan is aimed at streamlining CIRAD's organization and implementing joint management tools. The Centre's overall research thrusts remain valid: improving production subsectors and tropical farm-product processing technologies; sustainable land and

natural-resource management; and taking stakeholders' behaviour relative to their economic and administrative environments into better consideration. Research inputs for each of these thrusts will be useful in diagnosing situations and ultimately coming up with suitable responses.

This restructuring will promote multidisciplinary interaction, thus enhancing the Centre's efficiency in meeting the increasingly complex nature of requests.

A single-line structure will be adopted in the management streamlining process, i.e. CIRAD staff members will each report to a sole director, irrespective of their occupation and location.

There will be only three hierarchical levels in the new organization chart, which should provide better flexibility and transparency: the General Administration, responsible for defining strategies, coordination, arbitration, and control; the Departments, which will plan activities and synchronize CIRAD's supply with partners' demand; and the programmes, i.e. operational units that will conduct research and development projects in response to specific questions.

*Unifying projects*

CIRAD has therefore adopted a plan to update programme responsibilities. Discussions and analyses that began in late 1996 should lead to the creation of a few programmes as early as 1997, with three main orientations: subsectors, ecoregions, and scientific themes.

The nature of potential partnerships will be closely related to these three orientations: first, subsector professionals, i.e. farmers,

craftspeople, large-scale processors, suppliers, and traders; second, management and development bodies, e.g. farmers' associations, local and national governments; and third, scientists—including research institutions, universities, and commercial research agencies.

The "subsector" focus covers specific areas in which CIRAD has developed expertise, thus giving it a comparative advantage over other tropical agricultural research centres. The

"ecoregional" focus addresses development-oriented economic challenges. For every ecosystem (savanna, humid tropical, etc.), specific requests will be formulated for the management of farm, forest, and rangeland areas, and only environment-friendly operational procedures are to be used. Through its "scientific themes", CIRAD can address future scientific issues: agronomic, biological, and socioeconomic conditions for a doubly-green revolution, and development of the food processing sector.

### When CIRAD was founded...

*CIRAD was established in 1984 following the consolidation of nine tropical research institutions of different status, e.g. associations governed by the law of 1901, state-owned bodies, and private agencies. These former institutions were specialized in various subsectors: food crops, citrus and other fruit, cotton, coffee and cocoa, oil crops, rubber, forestry, livestock production and veterinary medicine, and farm machinery. CIRAD pooled all of these subsectors and provided France with a development-oriented research body that could offer fully adapted responses to new requests from countries in the South.*

*The scope of research conducted by some of these initial institutions was modified with the creation of CIRAD departments, especially Food Technology and Rural Systems, Annual Crops, and Tree Crops.*

*A new culture was gradually shaped by men and women on the staff of these departments, as highlighted by the development of the strategy plan in 1991.*

*CIRAD's operations have been decentralized since the outset, with responsibilities delegated to operational levels (i.e. departments) for a better response to partners' requests.*

*After 12 years of operation, the unanimous conclusion is that the consolidation process is still incomplete, and divisions between departments remain issues to be resolved. One main obstacle to unity within the organization is the lack of suitable tools for joint management of both human and financial resources. The restructuring process under way should provide CIRAD with the means necessary to launch it successfully into the 21<sup>st</sup> century.*

Setting up collaborative projects will be facilitated under the new organizational structure by bringing together experts from several CIRAD departments. Joint management techniques and tools are essential for the success of these ventures.

#### *Real-time activities*

CIRAD's management strategies had to be drastically modified in response to the decision to draw up and implement the budget on a per-programme basis (which is necessary in the restructuring process). The discussions, begun in 1996, were aimed at defining the management responsibilities of each programme director, uniformizing and modernizing budgetary and accounting procedures, and drawing up new resource-allocation regulations. All of these objectives should be achieved in the 1998 budget.

All top managers will ultimately have access to management indi-



cators to facilitate real-time management of team activities.

#### *Original professional profiles*

The main resource of any research organization is obviously its staff. However, the scattered nature of the current department-based staff management organization hampers unity and curbs mobility.

Based on CNER recommendations, CIRAD thus decided to create a Human Resource Management Office within its General Administration. This new office, set up in 1997, will develop general policies on employment, assessment, and training. The challenge will be to synchronize required skills with CIRAD's present expertise. The office will also be committed to enhancing staff members' professional careers through position-rotation plans, while monitoring future changes in professional profiles at CIRAD, and promoting mobility.

The Human Resource Management Office will be responsible for drawing up joint management regulations and procedures with the aim of coordinating CIRAD management. It will also create a directory of CIRAD professions based on staff experience, to maintain and promote the unique and specific nature of these personnel profiles.

The first phase of the homogenization process began in 1996, with a hierarchical staff appraisal through standardized individual interviews. The procedure will be modified on the basis of the results of this pilot test, conducted with the agreement of labour-

### **CIRAD's agreement on objectives with the French government**

*The agreement on objectives signed by CIRAD and the French government is in line with increased environment-friendly agricultural and forest production in host countries. Three priority research orientations were set out for CIRAD in this agreement: improvement of production subsectors and product-processing techniques; sustainable and economic land and natural-resource management; and taking stakeholders' strategies into account in drawing up agricultural development policies.*

*Partnership guidelines were also defined in the agreement: renewal of cooperation with Southern countries, especially with respect to diversifying conditions for CIRAD's field research; promoting increased integration of French tropical research within the Northern scientific community; setting up projects to pool expertise from several CIRAD departments, developing budgeting and accounting management tools, and staff appraisal procedures to improve the efficiency in dealing with problems encountered in research missions.*

relations partners, before it is permanently adopted. Professional appraisals carried out by ad-hoc committees will be introduced later.

#### *Partnerships*

Setting up partnerships is crucial for the identity of all research organizations, especially at CIRAD where most research involves collaboration. The partnership dimension is therefore a keystone of the Centre's management restructuring and programming plan.

A worldwide agricultural research system is currently being formed, bringing together national institutions of Southern countries (national agricultural research systems [NARSs]), industrialized countries (advanced research institutions [ARIs]), and international centres (international agricul-



## Streamlining cooperation in the French overseas departments and territories

### The situation in Réunion

*Local governments are CIRAD's main partners in the French overseas departments and territories (DOM-TOM), with departmental, regional, provincial, and district agencies being the main donors for local development projects and research studies conducted by CIRAD.*

*CIRAD and these partners are striving to simplify cooperation procedures. In 1996, Réunion therefore set up new joint research-definition mechanisms. The related reference document is now available and supplements the memorandum of agreement signed with the Conseil général and Conseil régional of Réunion for the 1996-98 period.*

*Research in each area is scheduled on the basis of fully-defined projects involving several operations. Each project is aimed at solving a major problem that has been identified through analyses in several research areas and confirmed by joint agreement. The project coordinator is responsible for activities of the research team, keeping to schedule, drawing up research reports, and communicating results to the scientific community and extension agents.*

*Research is scheduled to meet the needs of professional agricultural and extension staff in Réunion, while remaining in line with CIRAD's overall research priorities. Two collaborative bodies were created to verify that these aims are fulfilled: upstream—scientific committees, which help in designing projects, control the quality of research work and communicate the results to the scientific community; downstream—technical commissions, which check that the adopted strategies are valid, and promote dialogues with professional organizations. Once CIRAD's research activities in Réunion are formalized, it should be easier to assess whether they fully address real development needs, analyse the results, and promote regional cooperation.*

*The organization has also been restructured in Réunion, with the role of CIRAD's representative strengthened on the basis of its aim to emphasize its unique status with the decentralization of responsibilities.*

tural research centres [IARCs]). The balance between these three pôles will have to be maintained if this new system is to be universally recognized and efficient.

Only NARSs and IARCs currently have coordinating bodies representing them at higher levels: e.g. African NARSs are under the umbrella of the Conférence des responsables de recherche agronomique 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 Co-operation in Agricultural Research (SACCAR), which are federated within the recently created Forum for Agricultural Research in Africa (FARA), and the Consultative Group on International Agricultural Research (CGIAR), which is the parent body for IARCs. ARIs are scattered widely, especially in Europe.

The first step will be to formalize the French tropical agriculture research system, comprising several experienced institutions. CIRAD will contribute to this process, on the incentive of relevant French government Ministries, i.e. Research, Cooperation, Foreign Affairs, and Agriculture.

CIRAD is actively involved in setting up a European forum on agricultural research, which could be created at the European research



institution meeting to be held in Montpellier (France) in September 1997. The European Initiative for Agricultural Research and Development (EIARD) will then liaise between European Union research institutions and policy-makers.

This forum will also be part of an agricultural research network linking institutions from industrialized countries, including those from North America, Japan, and Australia.

#### *Interactions with the private sector*

CIRAD's experience in collaborating bilaterally with Southern partners (the scientific community, political decision-makers, and the private sector), and its strategy of interaction with donors are comparative advantages offered to the worldwide agricultural research system.

CIRAD's partners are constantly evolving, e.g. the private sector is currently undergoing a complete transformation. In Africa, extension agents are being privatized at a rapid pace, while farmers and herders are setting up professional associations.

CIRAD will have to modify its modes of cooperation and partnership policies in order to remain as close as possible to partners' concerns, and meet their immediate and future demand with an appropriate supply of expertise. New types of partnerships should also be invented, especially with the private sector.

It is important to first tighten links between cooperation strategies and research strategies. External Relations staff will be responsible for ensuring that CIRAD's partners' needs are fully taken into account in the definition

of research programmes. The Centre's regional representatives, who liaise with partners worldwide, will be given a more important role in pinpointing potential demand and forecasting potential areas of cooperation.

The next step will be to promote CIRAD's expertise with partners worldwide, while planning and coordinating interactions with donors. A Coordinator responsible for relations with donors has thus been appointed within the External Relations service.

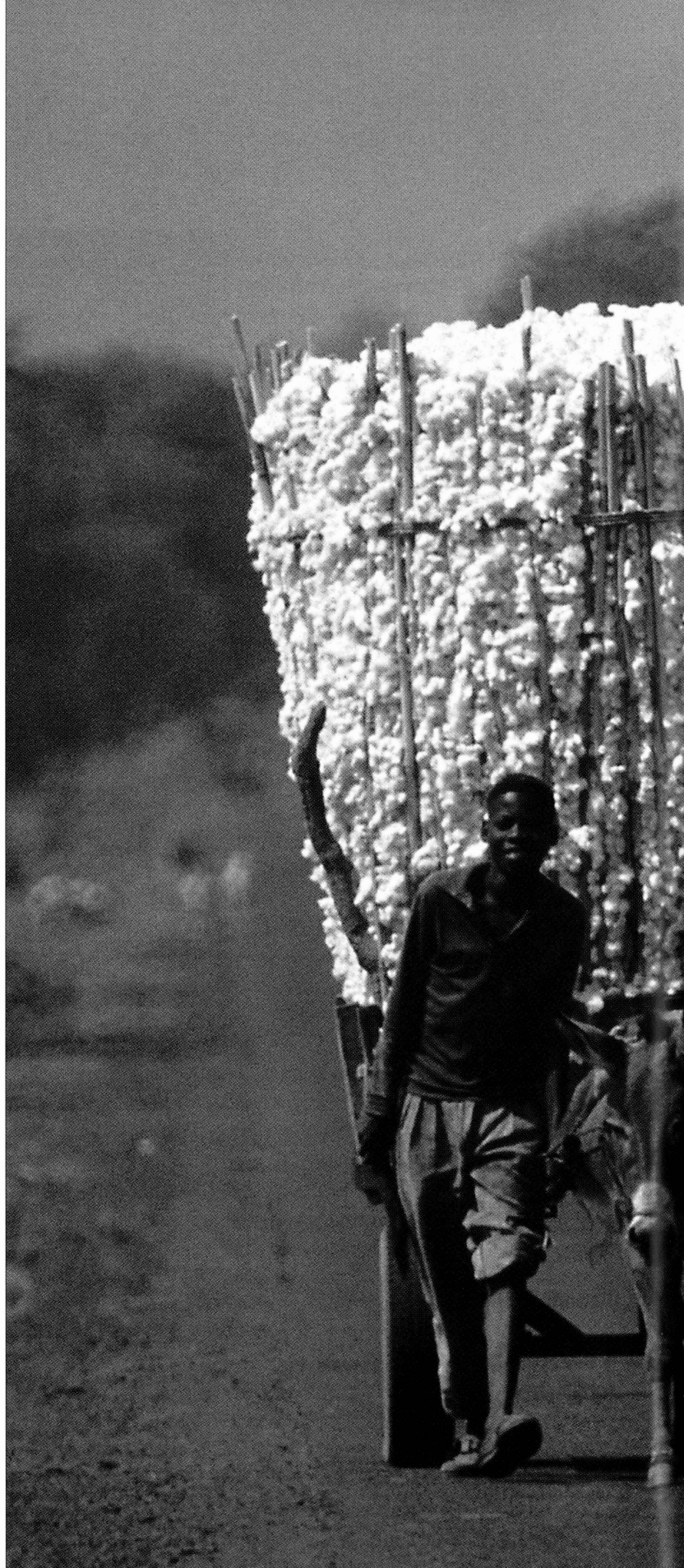
Finally, once ties are established with private companies, CIRAD will have to develop administrative and legal structures to deal with potential risks involved in conducting joint projects. Here again, new specialists have been appointed within the External Relations service who are responsible for developing partnership strategies based on analyses of partners' needs and experience offered by other public research agencies.

In terms of its scope, and through adjustments in the activities of everyone involved, CIRAD's restructuring plan is designed to have a lasting impact. It will be implemented in 1998, and the first fruits of this operation should be reaped the following year. As the success of this transition will closely depend on pertinent staff contributions, the General Administration has set up forums for individual or collective exchanges aimed at promoting staff participation. CIRAD's partners abroad are also being consulted, especially on cooperation strategies and implementing joint projects. This restructuring project reflects CIRAD's aim to become an increasingly effective agent for economic and social development in Southern countries.

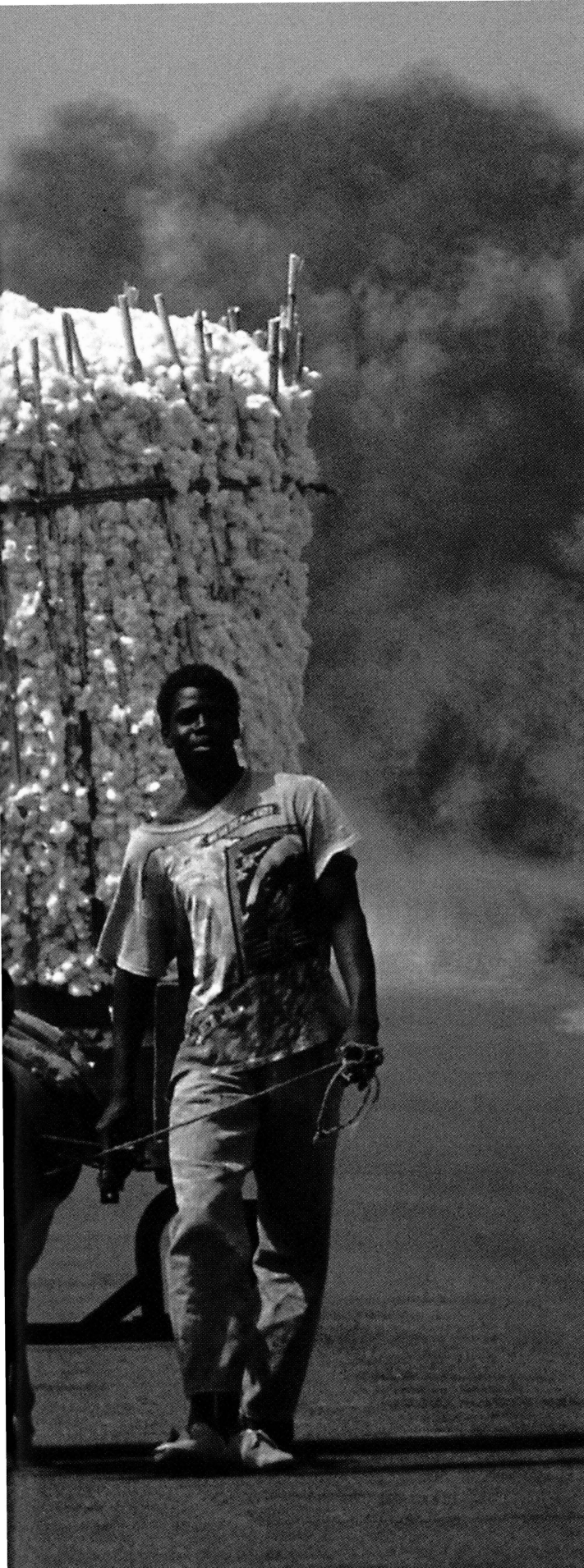
*On the basis of its experience and expertise in tropical research, especially on food crops and annual cash crops, CIRAD-CA is in a pivotal position with respect to discussions on the global development-oriented agricultural research system. Regionalization of research programmes is a priority concern. In 1996, after its involvement in setting up the Pôle régional de recherche sur les systèmes irrigués soudano-sahéliens (PSI), the Department, along with the relevant national agencies and under the aegis of the Conférence des responsables de recherche agronomique en Afrique de l'Ouest et du Centre (CORAF), helped create the Pôle régional de recherches appliquées au développement des savanes d'Afrique centrale (PRASAC), and the Pôle régional de recherche appliquée au développement des savanes d'Afrique de l'Ouest (PRASAO).*

*An analysis of the Department's current status with respect to agronomy and related sciences highlighted potential areas for its involvement in an agricultural production research programme, in terms of cropping sequences, and environment-friendly productive cropping systems. In the light of its progress in plant improvement and integrated crop protection, the Department is also in a position to contribute to research on biological aspects of crop productivity.*

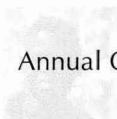
*After CIRAD's restructuring, the Department's scientists will concentrate their activities in three subsector-based programmes, i.e. cotton, sugarcane, and annual food crops, and in programmes focusing on tropical ecoregions: the semihumid savanna, the dry tropics, and the humid tropics. ■*







# Annual Crops



## Annual Crops Department CIRAD-CA

Director, *Hubert Manichon*  
Deputy Director, Cooperation and Partnerships,  
*Rolland Guis*  
Deputy Director, Scientific Coordination,  
*Hervé Saint Macary*  
Administrative and Fiscal Director, *Léandre Mas*

### Research Programmes

Smallholder farming in savanna areas, *Guy Faure*  
Smallholder farming in irrigated areas,  
*Jean-Claude Legoupil*  
Smallholder farming in highlands and  
newly cultivated areas, *Alain Leplaideur*  
Sustainability and environmental resources,  
*Francis Forest*  
Rice, *Christian Poisson*  
Other cereals, *Jean-Leu Marchand*  
Cotton, *Eric Hequet*  
Protein-oil crops, *Robert Schilling*  
Sugarcane, *Jean-Claude Boeglin*

### Research Units

Plant improvement, *Jean-Christophe Glaszmann*  
Crop physiology, *Marcel de Raïssac*  
Farming systems, *Michel Crétenet*  
Soil and land-use management, *Francis Ganry*  
Water management, *Florent Maraax*  
Plant pathology, weed management,  
*Jean-Loup Notteghem*  
Applied entomology, *Maurice Vaissayre*  
Biometrics, computer services, *Alain Joly*  
Cotton technology, *Eric Hequet*  
Cereal technology, *Jacques Faure*  
Commodity economics, *Claude Freud*

### Support Services

Technology transfer office, *Jean-Luc Khalfaoui*  
Documentation, *Marie-Thérèse Allafort*  
Publications, *Benoît Girardot*

# Smallholder farming in savanna areas

The aim of this programme is to promote sustainable development of natural resources and land management by stakeholders, with emphasis on analysis of land-use patterns, and on understanding how cropping and production systems function. It is also striving to develop new sustainable and highly efficient cropping systems, while devising ways to disseminate technological innovations to farmers.

## Madagascar: the agricultural phase of the Sud-Ouest project

CIRAD implemented the agricultural phase of the Sud-Ouest project in Madagascar, including research and extension activities focused on environmental analyses, soil fertility, productivity of the main crops (millet, sorghum, maize, and cotton), and production planning. These activities are based on the results of surveys and on-farm experiments. Moreover, the Cellule d'analyse et de localisation de l'information pour le Sud-Ouest (CALIPSO), using a geographical information system and processing remote-sensing data, provides information on land-use patterns and changes (mainly on a 1/200 000 scale map), and statistics on the area under crops.

Using organic soil-management techniques, cropping systems could be considerably improved through research conducted within the



framework of agreements signed with the Malagasy Centre national de la recherche appliquée au développement rural (FOFIFA), and NGOs, etc. Direct drilling and establishing a permanent plant cover, i.e. intercropping legumes and cereal or cotton crops, is an efficient way to increase crop yields, protect soils, and decrease labour time. Extension activities are focused on agricultural equipment, on setting up input and tool supply shops to be run by villagers, and on the seed subsector. Seed farmers produced 6 t of maize, 2 t of groundnut, and 2 t of Lima beans for seed in 1996.

## Extension of new cropping systems in Chad

In the Sudanian zone of Chad, the Terroir-Exploitation-Parcelle (TEP) project is under way at Bebedjia, in the cotton-growing region. TEP staff and the Office national de développement rural (ONDR), together with local farmers, are developing innovations adapted to a wide range of farming conditions.

Promising results have been obtained in site-specific, farm, and field experiments carried out by volunteer farmers; e.g. wood yields of 3 t/ha/year can be obtained by alley cropping *Cassia siamea*. Associating cereal crops and nitrogen-fixing legumes does not have a direct impact on cereal yields, but this strategy side-steps the need for weeding, and fodder yields of 3 t/ha can thus be obtained. In addition, planting legumes such as *Mucuna pruriens* and fodder cowpeas can lead to a 25–35% increase in cereal yields the following year, depending on the location. The results of this research have been widely disseminated by ONDR. Cropland in this region is also the focus of development projects, i.e. about 100 000 *Faidherbia albida* trees have been planted.

## Farm management group counselling

In the cotton-growing zone of Burkina, CIRAD and the Institut de l'environnement et des recherches agricoles (INERA) are developing a farm management group counselling system. This consultancy, as compared with current extension practices, is aimed at analysing problems from an economic angle, while proposing improvements adapted to a wide range of farming situations. Literate farmers are involved in this system—they meet regularly, analyse their farming situations, and then choose technological innovations that best meet their needs. This method, which has been tested by 500 farmers with the support of various extension agencies, markedly enhances food security through more efficient management of crops and income. A large area of cropland is also managed, i.e. with quick-growing hedges. Combining livestock production and cropping is on the rise, with a concomitant increase in the storage of crop residues, areas under fodder crops, manure sheds, etc. Farm management group counselling could be extended to a larger proportion of farms in the zone by focusing on critical cultivation transition phases and delegating some farmers as mediators for illiterate farmers.

### **The Garoua workshop: promoting regional cooperation**

*A workshop on farming in savanna areas of northern Cameroon was held in Garoua in November 1996. There were about 200 participants from Africa and Europe: research scientists, donors and representatives of international organizations, extension companies, and NGOs. The Garoua project was reviewed after 8 years of collaboration between Cameroonian research institutions, i.e. the Institut de la recherche agronomique (IRA) and the Institut de recherches zootechniques et vétérinaires (IRZV), the Institut français de recherche scientifique pour le développement en coopération (ORSTOM), and CIRAD. Discussions highlighted the full commitment of IRA and IRZV, along with the major achievements: support for the economic stakeholders, assistance for the development of agricultural production, and research encompassing a broader geographical area. The workshop conclusions stressed the importance of setting up collaborative projects (e.g. PRASAC) with research and development agencies from several countries.*

## Smallholder farming in irrigated areas

**R**esearch undertaken in this programme is aimed at improving the development and sustainability of water management projects. Conditions in the region and the irrigated area, and the ultimate use of irrigated fields are key considerations in planning complete (Senegal and Niger river valleys) and partial (lowlands in southern Mali) water management projects.

Over the last decade, about 450 small-scale inland valley water management projects have been completed in southern Mali. These projects are coordinated by the Compagnie malienne pour le développement des textiles (CMDT), with private agencies conducting most of the

feasibility studies and implementing the work. The fact that they have not been very successful, along with the high demand for these projects by smallholders' associations, prompted the Institut d'économie rurale (IER), CIRAD, and CMDT to collaborate in a follow-up research programme. The research results were presented at a workshop, held in Sikasso (Mali) in October 1996, on lowland management and development. One interesting product of this research is a pre-management diagnostic tool that was created to improve the efficiency of feasibility studies. This diagnostic tool can measure and evaluate physical, agronomic, and socioeconomic indicators, while analysing combinations of different value classes of these indicators. It can also be used to assess the technical and socioeconomic usefulness of potential water management projects. If they are found to be worthwhile, it determines the most suitable type and size of project, and proposes agronomic and organizational follow-up activities, according to the technical proficiency of the concerned farmers and the local socioeconomic and institutional context. It includes data collection and analysis, and potential collaborative scenarios for lowland development in projects aimed at efficient management of village hinterlands.

### **The Sépi-g software program**

*Sépi-g is a software aid for designing, planning, and assessing furrow irrigation systems. This program, developed jointly with the Institut national de recherches agronomiques du Niger (INRAN), includes a model for assessing hydraulic performance in irrigation systems, in addition to a water balance model. Sépi-g takes the diversity of the physical environment and irrigation practices into account via an original in-situ method for calibrating the hydraulic model parameters. It also includes the management of meteorological data.*

*The program calculates, by frequency analysis of the model's output variables, risks associated with a set of irrigation practices for a given situation. It is currently being used in irrigated areas in several African countries.*

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## Smallholder farming in highlands and newly cultivated areas

**H**umid tropical areas are characterized by sudden agricultural changes and high outmigration. The overall aim of this programme is to predict change processes



before they occur so as to avoid irreversibly upsetting ecological, economic, and social balances. Farmers have to be able to quickly adapt to economic changes under complex environmental conditions.

The proposed solutions address these varying constraints, while permitting sustainable resource management, e.g. innovations introduced in cotton field-cropping situations in Brazil.

In 1996, the Brazilian states of São Paulo and Goiás produced 25% of all cotton harvested in the country. Cotton yields are irregular in this highly mechanized cropping system, i.e. around 1.7 t/ha of seed cotton on average. Monocropping, cultivating with disc ploughs, and burning harvest residues cause substantial soil degradation, disease, and weed infestation.

The Maeda group, the main private cotton producer and manufacturer (producing 7% of all cotton in Brazil, on 33 000 ha of land), asked CIRAD experts to improve soil management.

This collaboration began in 1994, and the first results are already being used by Maeda, i.e. grinding up harvest residues, deep tillage at the end of the crop cycle, and land preparation with tine harrows. Yields have been increased to 2.4 t/ha, while production costs have dropped by 20%.

CIRAD and Maeda also test mixed crop rotations with cotton, maize, and soybean, direct drilling under straw mulch from millet or sorghum crops sown at the end of the rainy season, and rational herbicide treatments. With these improvements, seed cotton yields are higher than 3 t/ha, and production costs are reduced, e.g. 33% savings on motor fuel.

## Sustainability and environmental resources

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**B**ased on the know-how and techniques developed by research scientists in this programme, the overall aim is to help in developing tools and technologies that address the needs of decision-makers, farmers, and farm-product processors concerned about making optimum use of local natural resources.

### Limiting climatic risks in Brazil

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Brazilian farmers generally plant their rainfed crops when climatic risks are minimal. These farmers are given recommendations by the Centro de Pesquisa para Agricultura do Cerrado (CPAC), based on research conducted jointly with CIRAD on the cropping potential and agroclimatic risks associated with the main crops, i.e. rice, maize, soybean, and beans.

This procedure, which is now bound by a federal decree, involves indexing insurance payments on the basis of farmers' compliance with the recommended planting dates—banks and insurance companies have access to technical data on agricultural production, soils, and climate. The first operational crop season (1996-97) mainly concerns the *cerrados* region, i.e. more than 10 million ha of cropland. Applying these recommendations should reduce production costs and prompt farmers to use environment-friendly cultivation practices.

In addition, the Sarra water balance model was successfully tested and validated with rainfed maize crops. It was previously validated for simulating the effects of water availability on the growth of food crops in Sudano-Sahelian regions of Africa.

## Direct drilling under crop-residue mulch

Rainfed maize is the main crop in Mexico (7 million ha). The Instituto Nacional de Investigaciones Forestales y Agropecuarias (INIFAP), the Centro Internacional de Mejoramiento de

Maíz y Trigo (CIMMYT), and CIRAD have jointly developed cropping systems involving direct drilling under crop-residue mulch.

High maize yields were obtained with this technique in Jalisco state: with light mulching (1.5 t/ha), yields are 50% higher than those obtained with tillage. Moreover, runoff is reduced, while precipitation storage and availability are improved. A model based on physical environmental data can be used to pinpoint zones where this technique could be beneficial. Direct drilling under mulch also enhances crop mineral nutrition and biological activity in the soil.

Local associations, which consider that the technology is of considerable interest, organize field meetings to discuss the results. Farmers, however, have to decide on the ultimate use of their crop residues, i.e. for soil protection or dry-season livestock feed. A model is currently being developed that incorporates biophysical and socioeconomic data—and should thus be a useful decision-making aid for farmers.

## Rice

Strategies adopted in this programme were developed on the basis of economic imperatives in the rice subsector. The overall aim is to meet the food demand while adapting production to market requirements. For the tropics, it is focused on maintaining the diversity of rainfed, paddy, and irrigated rice cropping systems, and on genetic improvement. For Mediterranean regions, high-yielding varieties with features that meet market expectations are being developed.

## Paddy rice varieties resistant to rice yellow mottle virus

Rice yellow mottle virus (RYMV) is found throughout Africa, where it causes serious crop damage, i.e. 25–100% harvest losses in RYMV-infected paddy rice fields.

In western Africa, almost all *indica* rices imported from Asia are high-yielding varieties, fully adapted to paddy rice cropping conditions, but they are susceptible to RYMV, e.g. the

### Multimedia software packages

*Ento Doc and Adventrop Doc, two multimedia software packages available on CD-ROM, were designed and produced by CIRAD research scientists.*

*Ento Doc is a bilingual (English-French) multimedia information program on sugarcane and food-crop pests in Africa. The user has access to a wide range of information, in the form of texts and photographs, on these pests and their natural enemies.*

*Adventrop Doc is an original tool for the identification and understanding of annual crop weeds in Sudano-Sahelian Africa. Weeds are identified by graphically developing a profile of the plant, mainly based on vegetative traits.*

*Ento Doc and Adventrop Doc are user-friendly, and therefore accessible for a wide audience, e.g. extension staff, students, and research scientists, while still meeting the needs of specialists through the comprehensive range of information provided.*



widely-cropped BG 90-2 variety. In Mali, IER and CIRAD have found that Metica 1 (Sik 131), an *indica* variety of South American origin, is tolerant of this disease, and it is productive.

In field experiments, 20 days post-emergence, RYMV infection was found to cause an 85% yield loss with susceptible cv BG 90-2, and a 40% reduction for Metica 1. Immunoenzymatic analyses revealed that the virus propagates at a slower rate in Metica 1 than in BG 90-2. Unfortunately, Metica 1 does not have the resistance gene against bacterial blight, which is a considerable constraint in the Sahel—but these beneficial genes have been isolated and could be inserted in the genome of Metica 1.

## Characterization of aromatic rice varieties

Analytical procedures have been developed over the last 15 years to control the aromatic quality and conformity of fragrant rice varieties. Acetylpyrroline is essential for the olfactory and quantitative characterization of fragrant rices, but it does not distinguish between these varieties.

One of CIRAD's research objectives in this programme is to develop analytical techniques to check the trueness-to-type of commercial batches of rice. With improvements in extraction procedures and chromatographic analyses, aromatic profiles and quantitative results can now be obtained. Around 100 volatile compounds have thus been isolated from aromatic cv Azucena, and 20 of these were reproducibly quantified. Using discriminant factor analyses, three aromatic rices, i.e. basmati, Thai, and Azucena, can be differentiated by five of these compounds.

There is also a phenotype-genotype correlation for the aromatic character—two markers were identified on chromosome 8 that are linked with genes involved in acetylpyrroline synthesis. These markers were identified by processing two types of information using a software program. Aromatic analysis data for doubled haploid lines derived from the  $F_1$  hybrid between IR 64 (non-aromatic) and Azucena (aromatic) were matched with gene mapping data (obtained using molecular markers) provided by the International Rice Research Institute (IRRI).

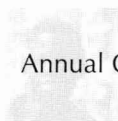
## Seminars on upland rice and cotton

*A seminar on upland rice, held in Madagascar in March 1996, reviewed European Commission-funded research under way since 1984 that is aimed at optimizing rice cropping procedures and growing this crop at increasingly higher elevations. Improved upland rice varieties can now be grown as high as 1 600 m above sea level with adapted cropping systems. These new varieties are also of considerable interest for Nepal, China, and Colombia.*

*In October 1996, the third meeting of the Interregional Cooperative Research Network on Cotton took place in Montpellier (France), under the patronage of Agropolis, the Food and Agriculture Organization of the United Nations (FAO), and the International Cotton Advisory Committee (ICAC). New working groups were set up, thus confirming the vitality of the Network. Several groups were coordinated by CIRAD experts—production modelling, economics, and technology.*

## Other cereals

In this programme, research is currently being conducted on maize and sorghum, focusing on grain quality and plant resistance to stress. Root and tuber crops are also being investigated, especially for processing purposes, as exemplified by a study



under way on sour cassava starch, which is used in making snack foods, crunchy risen biscuits, and brioche breads.

A study on cassava starch processing techniques, jointly being carried out with the Centro Internacional de Agricultura Tropical (CIAT) in Colombia and the Brazilian Centro de Raízes Tropicais (CERAT), is aimed at optimizing small- and large-scale starch production. Starch is transformed into sour starch by natural lactic fermentation, and then sun-dried. The present study demonstrated that sun-drying partially breaks down the starch, which is an important factor—otherwise food products cannot rise properly during baking. This degraded starch is more soluble, i.e. the solubilized amylopectin fraction is doubled after sun-drying, which could enable gas retention.

An analysis of photochemical mechanisms involved in starch breakdown will also be undertaken to determine how starch could be dried artificially, thus avoiding sun-drying—a cumbersome operation under large-scale processing conditions.

## Cotton

**T**his programme is following up changes in cotton subsectors under a wide range of environmental conditions, with many different systems involved in producing cotton for increasingly varied uses. Research on variability in *Bemisia tabaci*, the cotton insect pest, and the development of new products from cottonseed flour are but a few of the many projects under way.

## Molecular characterization of *Bemisia tabaci* biotypes

*Bemisia tabaci* is a serious pest that causes direct damage to cotton plants (punctured leaf blades), as well as being a virus vector, and producing honeydew that is responsible for stickiness in cotton fibres. Problems due to this insect have worsened in the last 10 years with the appearance of a more aggressive biotype that is morphologically identical to the initial strain.

The random amplified polymorphic DNA-polymerase chain reaction (RAPD-PCR) technique, which randomly amplifies parts of the genome, was used to accurately characterize *B. tabaci* populations. Analysis of results obtained with samples from Cameroon, Benin, Côte d'Ivoire, and Nicaragua confirmed the high genetic variability in this species—depending on their geographical origins and host plants.

Insects from other geographical origins should now be investigated in order to map the distribution patterns of *B. tabaci* biotypes, and determine the extent of cotton crop damage that each type could potentially cause.

## Biodegradable materials made from cottonseed flour

A process to produce biodegradable films from raw cottonseed flours was jointly developed by CIRAD and the Ecole nationale supérieure agronomique (ENSA) and Université Montpellier II (France). These films have functionally interesting features, e.g. high puncture strength and flexibility, and low water solubility. For agricultural purposes, they



could be used for packaging, mulching, or coating seeds.

These films could compete with various films already being marketed that are made with different ingredients. High quantities of cottonseed flour are produced worldwide (about 37 million t/year), and they are cheaper than flours made from other protein-oil crops. Studies are under way to improve the film manufacturing process and the functional properties of the final products in order to facilitate industrial-scale production.

## Protein-oil crops

**R**esearch carried out on annual protein-oil crops, especially groundnut and soybean, has been aimed at increasing productivity, with a specific emphasis on yield components. Studies currently under way are mainly focused on plant-health, gustatory, nutritional, and technological factors that are critical for making decisions on varieties, cropping techniques, and postharvest treatment products. A study undertaken in Indonesia on *tahu* or *tofu* (soybean curd) is an example of this research trend.

The increased demand for soybean products in Indonesia, due to increased consumption, is still being fulfilled by small-scale processing units using locally-grown crops. However, this situation could be upset with the opening of the international market and changes in

the food industry. A study was undertaken with the University of Bogor to assess the situation in terms of soybean varieties that are being cropped, supply means, manufacturing processes, and distribution channels—with the aim of increasing the competitiveness of small-scale production of *tahu*, i.e. the form in which 50% of all soybeans are consumed.

Correlations between soybean properties (determined relative to 7S and 11S protein levels) and *tahu* quality (expressed in terms of its solidity and texture) were less obvious for samples collected in the production unit than for products made in the laboratory. Manufacturers adjust their production processes (e.g. quantities of water and calcium sulphate, cooking and pressing times) according to the raw materials used. Imported soybean varieties, selected for their high oil content, could thus be suitable.

Moreover, *tahu* has only a 24-h shelf-life and its quality can vary markedly depending on the distribution channel involved, i.e. home delivery or market sales. The extent of *tahu* availability is an important factor for consumers. Hence, it would be of interest for manufacturers to modernize their equipment only if there was refrigeration in the distribution channel.

### **Licences, patents, contracts, and sales**

*In 1996, royalties were collected from seed-producing companies for four licensed cotton and rice varieties.*

*Two international patents were registered: one for an identification system (Adventrop), and another for a process to produce cottonseed flour-based films.*

*A licence to manufacture a cotton stickiness detector was handed over to a private company.*

*Thirty-two other apparatuses, including cotton technology equipment and a Rhizobium fermentor, which were initially developed by CIRAD, have already been sold worldwide.*

*Thirty contracts have been signed with private companies, and 13 of these concern experiments on crop varieties bred by CIRAD.*

*Almost 100 consultancy missions have been undertaken at the request of government ministries, international donors, and private companies.*

# Sugarcane

**I**n 1996, significant results were obtained in this programme, including successful selection of variety B 80-689 in Guadeloupe, creation of a cane residue-sawing cultivator, development of a sugarcane growth model (Mosicas), and publication of the English version of the D-cas software package for sugarcane disease identification.

## An improved sugarcane variety for Guadeloupe

### Cane residue-sawing cultivator

*The increased mechanization of sugarcane cultivation in Guadeloupe is having a negative impact on soils.*

*Mechanical harvesting of sugarcane without preliminary cane-burning is now common practice, and a thick layer of harvest residue is left behind.*

*This practice reduces the efficacy of nitrogen fertilizers.*

*No farming tools have been marketed to date that would facilitate cultivation operations on soils covered with piles of sugarcane residue. A new cane residue-sawing cultivator has been designed that can, in a single operation, cut through layers of harvest residue and break up the soil, thus enabling fertilizers to reach the root system.*

*This invention was designed and developed by a company in Guadeloupe in collaboration with CIRAD. It was awarded a silver medal at the recent Salon international de la machine agricole de Paris.*

The sugar industry in Guadeloupe has just approved the sugarcane variety B 80-689, which was selected by CIRAD from an initial cross achieved in Barbados.

This hardy clone grows uniformly, adapts well to heavy soils (Vertisols), and showed good tolerance of the drought conditions that prevailed in 1994. It is also resistant to major sugarcane diseases, especially rust and smut. This variety is well adapted for mechanical harvesting, i.e. an upright habit, resistance to lodging at harvest, and natural stripping of leaves. Sugarcane

yields with this variety are higher or equal to those obtained with the best control varieties in this zone (R 570 and B 80-08). In tests conducted in Grande-Terre, mean sugar yields were more than 20% higher than those of the control varieties through four successive harvests.

Sugarcane variety B 80-689 is being propagated in nurseries to meet growers' high demand. The Roujol micropropagation laboratory is intensively propagating this new variety, which means that cuttings can be obtained relatively quickly.

## Modelling sugarcane growth

A sugarcane growth model should be useful for all stakeholders in the subsector by forecasting yields, and should also help research scientists in understanding how sugarcane plants function.

This project was based in Réunion and Guadeloupe. In Réunion, plant cover functioning was investigated under the wide range of different climatic conditions that prevail on this island, and the data were entered in Mosicas, the sugarcane growth model.

In 1996, Mosicas was validated through experiments carried out at both locations, and data on sugarcane varieties grown in Guadeloupe were entered at this time. Mosicas simulates growth of plant cover according to solar-radiation levels. This pilot model is now being used on sugarcane plantations. A more comprehensive version of the model will be able to calculate yield potentials of the main varieties for the largest sugarcane-producing regions, thus serving as a diagnostic tool for agronomists.



Mosicas will become a useful decision-making and training aid once growth-limiting factors—water supplies, fertilization, pests, and diseases—are incorporated.

## Theses Completed in 1996

### CIRAD Scientists

**Riz local et riz importé en Afrique : les déterminants de la compétitivité. Les filières riz du Sénégal et de la Guinée face aux exportations de la Thaïlande et des Etats-Unis** [Local vs imported rice in Africa: key competitiveness factors. Impact of rice imports from Thailand and USA on rice subsectors in Senegal and Guinea] by Hélène Benz; Ecole des hautes études en sciences sociales, Paris.

**Contribution à la connaissance du fonctionnement d'un peuplement d'arachide (*Arachis hypogaea* L.) : proposition d'un schéma d'élaboration du rendement** [Contribution to the understanding of the functioning of a groundnut (*Arachis hypogaea* L.) population: proposed model representing the crop yield build-up process] by Philippe Cattan; Institut national agronomique Paris-Grignon.

**Contribution à l'étude du collage du coton au moyen de méthodes mécaniques et thermomécaniques** [Contribution to the analysis of cotton stickiness using mechanical and thermomechanical techniques] by Richard Frydrych; Université de Haute-Alsace, Mulhouse.

**Contribution à la méthodologie de l'identification des plantes assistée par ordinateur. Application aux mauvaises herbes de la rotation cotonnière** [Contribution to a computer-assisted plant identification method. Application for the identification of weeds in cotton crop rotations] by Pierre Grard; Université Montpellier II.

**Alcalinisation des sols dans la vallée du fleuve Niger (Niger). Modélisation des processus physico-chimiques et évolution des sols sous irrigation** [Alkalization of soils in the Niger river valley (Niger). Modelling of physicochemical processes and soil changes induced by irrigation] by Serge Marlet; Ecole nationale supérieure agronomique de Montpellier.

**Mise au point et étude de films biodégradables réalisés avec des farines de graines de cotonniers** [Development and studies of biodegradable films made from cottonseed flours] by Catherine Marquié; Université Montpellier II.

### CIRAD Trainees

**Les sols gris de bas de versant sur granito-gneiss en région centrale de la Côte d'Ivoire : organisation toposéquentielle et spatiale, fonctionnement hydrologique ; conséquences pour la riziculture** [Grey subsoils on granitic gneiss bedrock in central Côte d'Ivoire: the impact of their toposequence, distribution, and moisture-retention capacity on rice growing] by Sitapha Diatta (Senegal); Université Henri Poincaré, Nancy.

**Cartographie moléculaire du génome du sorgho (*Sorghum bicolor* [L.] Moench) : application en sélection variétale ; cartographie comparée chez les andropogonées** [Gene mapping of sorghum (*Sorghum bicolor* [L.] Moench): applications for varietal selection; comparative mapping of Andropogoneae grasses] by Philippe Dufour (France); Université Paris XI, Centre d'Orsay.

**Analyse du comportement hydrique de cultures : diagnostic et modélisation en vue de la gestion des irrigations. Cas des cultures de maïs et tomate sur sols alluviaux et sols andiques au Guatemala** [Analysis of moisture-related crop performance: analysis and modelling for irrigation management purposes. Case study of maize and tomato crops grown on alluvial and Andean soils in Guatemala] by Bertrand Lionel Muller (France); Institut national agronomique Paris-Grignon.

*Over the last 30 years, tropical tree crop production has been developed using largely monocultivation systems. These crops are either grown in a mosaic of small plantations or cover extensive homogenous areas.*

*As well as monocultivation systems that are under state or private management and linked with centralized marketing, there are cropping systems in which trees are intercropped with other crops. These intercropping systems, which are better adapted to smallholder production than monocultivation systems, make good overall use of the land. They contribute to local and regional food security, make more profitable use of the land, and generate regular income.*

*To improve these intercropping systems, the CIRAD-CP Department is studying their agrophysiological parameters in order to understand the way that these temporary or permanent associations function and to be able to identify the components of production.*

*The Department is also carrying out research on genetic improvement in order to develop plants that have clearly defined quality characteristics, are more productive, and have proven resistance to pests and diseases.*

*Through its basic research and fieldwork in the tropics, the Department is developing strategies for the integrated management of major pests. It has also worked this year with its Southern and Northern partners to develop new extraction methods for product processing.*

*In 1996, the Department was able to consolidate its position with international agreements and memoranda, and recognition of the quality of its research and long-standing scientific policies. ■*







# Tree Crops

## Tree Crops Department CIRAD-CP

Director, *Patrice de Vernou*

Deputy Director, *Denis Despréaux*

Administrative and Fiscal Director, *Michel Aubry*

### Research Programmes

Coffee, *Daniel Duris*

Cocoa, *Denis Despréaux*

Oil palm, *Bertrand Tailliez*

Coconut, *François Rognon*

Rubber, *Yves Banchi*

### Research Units

Agronomy, *Jean-Louis Jacob*

Breeding, *Dominique Nicolas*

Crop protection, *Dominique Mariau*

Chemistry/technology, *François Challot*

Economics, *Claude Freud*

Biometrics, *François Bonnot*

### Support Services

Information and communication,

*Christine Nouaille*

# Coffee

In Africa, the Burundi coffee programme has been progressively closed down, after 6 years of collaboration with the Institut des sciences agronomiques du Burundi (ISABU), because of the recent tragic events that have affected the country. With the improvements made in postharvest processing, Burundian coffee is now sold on the world market at prices equivalent to Kenyan coffee, which are among the highest in the world. The agronomy research unit has demonstrated the value of intercropping legumes with coffee. However, it was not possible to complete the work on chemical control of the *Antestia* bug.

In Asia, a 3-year contract for technical assistance has been signed with a private group in Indonesia. Contact has also been made with another group in Indonesia which is carrying out an ambitious 3-year programme on 4 000 ha of plantations. These two groups aim to produce high-quality coffee for the "gourmet" coffee market. In Central America, significant progress made with in-vitro multiplication indicates the potential for these techniques in the commercial development of new varieties in the medium term.

## Integrated control of arabica coffee rust

Coffee leaf rust, or coffee rust, now exists in all the arabica coffee-producing countries in Africa, Asia, and America. Coffee rust causes defoliation which reduces productivity and weakens the branches. Genetic and chemical methods were the first methods employed for controlling this fungal disease.

Genetic resistance to the disease has been identified in arabica and in arabica-canephora and arabica-liberica hybrids. Populations of the resistant hybrid lines crossed with commercial arabica varieties are now being grown commercially. However, the effectiveness of this type of resistance can decrease over time and less specific, more long-term resistance is being researched. Chemical control is based on copper-based products and the use of systemic fungicides which are metabolized by the coffee plant.

Research studies have been carried out in Honduras as part of the regional programme for the protection and modernization of coffee production (Promecafé) and in Laos, with the Ministry of Agriculture, as part of the Laos Uplands Agricultural Development Project (LUADP). These show that the development of the disease is closely linked to agronomic factors such as planting density, shading, fertilizer use, and pruning, and to environmental factors such as soil chemical content, rainfall, and altitude. Taking these factors into account should help in the development of strategies for integrated control.

## Improving arabica coffee

Traditional breeding methods for such perennial crops as coffee take 25–30 years to obtain stable improved varieties. The genetic improvement programme for arabica coffee conducted by CIRAD and the Institut français de recherche scientifique pour le développement en coopération (ORSTOM) is based on the creation of  $F_1$  hybrids between Catimor, a rust-resistant variety, and varieties of Ethiopian coffee. Vegetative propagation is the only way of identically reproducing individual plants that

have been selected from the hybrid population for their vegetative characteristics, productivity, and vigour.

Somatic embryogenesis, with temporary immersion in a liquid medium, is the most effective method of propagation. The arabica coffee improvement programme and mass propagation using somatic embryogenesis are being developed at the Centro Agronómico Tropical de Investigación y Enseñanza (CATIE), Costa Rica, as part of Promecafé. CIRAD and its partners have produced several thousand embryos over several months, developed expertise in nursery management, and have shown that it will soon be possible to apply these new techniques on a commercial scale. Field trials will be set up in different Central American countries to complete the selection process.

## Cocoa

In the context of instability in the world cocoa market, CIRAD's cocoa programme has focused its research on plant improvement and pest and disease control. Work undertaken by the Institut des forêts (IDEFOR) and CIRAD in Côte d'Ivoire has led to the distribution of plants that are characterized by their vigour, their resistance to pests and diseases, and the technological quality of the beans. In Ghana, particular attention has been given to controlling swollen shoot. The 12th International Conference on Cocoa Research, which took place in Brazil, highlighted the importance of CIRAD's role in this field.



## New varieties in Côte d'Ivoire

In Côte d'Ivoire, CIRAD is working with IDEFOR on a cocoa improvement programme based on the selection of hybrids from crosses between clones of Upper Amazon Forastero, the female parent, and Lower Amazon Forastero or Trinitario, the male parent. In 1996, seven hybrids were selected according to different criteria: production, vigour,

the correlation between production and vigour, resistance to black pod rot and mirids and the technological quality of the beans.

The average yield of these hybrids is 20% greater than yields from the best commercial hybrids currently in production. These hybrids also produce beans with good technological characteristics. Wherever possible, mixtures of hybrids with similar degrees of vigour and similar-sized beans will be distributed in order to reduce the heterogeneity found in plantations and in the cocoa market. New seed nurseries will need to be established to provide the hybrids for distribution.

### Use of cocoa germplasm

*The project for the use and conservation of cocoa germplasm, accepted by the Common Fund for Commodities (CFC) in October 1996, will last 5 years. An international network for the improvement of cocoa varieties will be established.*

*Priority will be given to disease resistance and to the recurrent selection of populations.*

*The project will be carried out in 10 producer countries, at Reading University (United Kingdom) and at CIRAD, in Montpellier.*

*The project will be managed by the International Plant Genetic Resources Institute (IPGRI) and supervised by the International Cocoa Organization (ICCO). CIRAD and IPGRI will be jointly responsible for technical coordination. CIRAD*

*will be involved in work on recurrent selection in Côte d'Ivoire and on molecular biology and phytopathology in Trinidad and Tobago. CIRAD will multiply and distribute clones, evaluate their resistance to different strains of Phytophthora and collaborate on statistical data analysis.*

## Project for the control of swollen shoot in Ghana

The cocoa swollen shoot virus disease has spread from the east to the west of Ghana and is now widespread. The "Monitoring of cocoa swollen shoot virus disease control" project has been set up by the Ghana Cocoa Board to limit its spread. The project is cofinanced by the European Commission and the World Bank, and its aim is to cut down 10 million diseased trees over 2 years in the central and eastern regions. This would create a disease-free band which should stop the further spread of the disease to the west. The felled trees are to be replaced by young, disease-tolerant plants produced in Ghana. CIRAD is responsible for the management of this control programme, which began in May 1994.

After 2 years of work, 9 million trees have been felled, which represents 90% of the target set at the start of the project. However, the number of disease hot-spots was underestimated and it will be necessary to cut down a further 20 million diseased trees in order to eliminate all the centres of infection. Furthermore, the current rate of replanting is only 15%. To compensate for being behind schedule, the Cocoa Board has decided to set up nurseries in every region, capable of producing 560 000 young cocoa plants per year for replanting in the cleared sites where the disease has been eradicated.

CIRAD's experience of replanting in other western African countries has demonstrated the importance of taking into consideration the socioeconomic conditions and the strategy adopted by local planters. In order to achieve the project objectives, the grant for felling has been increased and there are plans to improve the administration of the project and to extend it over a longer period of time.

# Coconut

The market for copra and coconut oil improved in 1996, with the price for oil exceeding US\$750/t. This upturn in the market indicates that the situation is back to normal, with the rise in market price being caused by a marked drop in supply and a sustained level of demand. This situation has regenerated interest in production in many parts of the world. CIRAD's expertise in the coconut industry allows it to respond to the different needs of the industry.

## Attractant compounds for trapping pests

CIRAD is working in association with the Institut national de la recherche agronomique (INRA) on studies into chemical substances, in particular pheromones, which affect the behaviour of certain pests. The aim of this research is to improve methods for monitoring insect populations and to develop new control methods, particularly for *Rhynchophorus* and *Oryctes*.

*Rhynchophorus* spp. larvae develop in the living tissue of coconut trees, especially in the soft parts of the plant, which causes the tree to die. With several species, such as *R. palmarum*, *R. phoenicis*, and *R. ferrugineus*, the aggregation pheromones have been identified and synthesized. They are currently being used in association with plant material, such as sugarcane or oil palm, for mass trapping of adult insects in Latin American plantations. Research is continuing into the development of a totally synthetic attractant so that it will be possible to trap *Rhynchophorus* spp. without using any plant material.

*Oryctes rhinoceros* is the most serious pest of coconut in Southeast Asia and the Pacific. Methods of control have always sought to eliminate the adult which feeds by tunnelling in the soft tissues of the plant. The identification and synthesis of the active compound ethyl 4-methyloctanoate, the principal constituent of the *Oryctes* aggregation pheromone, creates the possibility for using a powerful attractant for the mass trapping of this insect.

A number of trials still need to be carried out in order to improve the use of chemical attractants and to determine strategies for their use. Chemical attractants allow for a more rational use of insecticides, reduce the risks of pollution, conserve beneficial fauna, and offer a more environment-friendly method of pest management.

## Simulation of intercropping coconut trees with food crops

The architecture of the Laguna Tall coconut has been studied at the Philippine Coconut Authority (PCA) research centre in Davao as part of a European Commission programme. Architectural parameters, collected from pruned and unpruned trees of different ages, have been used to put together three-dimensional numerical models that represent a range of different layouts and plantation densities.

The rate of transmission of photosynthetically active radiation as a function of these factors has been simulated. The rate was highest in 5-year-old and 40-year-old coconut groves and lowest in 20-year-old groves. The rate decreases with increasing plant density regardless of plantation layout. Reducing the number of palm leaves by pruning can increase

### **Integrated pest management**

*The publication Lutte intégrée contre les ravageurs des cultures pérennes tropicales (Integrated pest management for tropical tree crops), which was published as part of the Repères series, summarizes 30 years of CIRAD research. Rational chemical control, which aims to minimize the negative effects of pesticides on the environment and beneficial fauna, can be combined with other methods of control, such as biological control.*

*This combination of different control methods is known as integrated management and uses beneficial insects, entomopathogenic organisms, cultivation techniques, olfactory and visual traps, and adapted plant material. Beneficial insects and entomopathogenic organisms often play a very important role in controlling populations of depredatory insects. They sometimes occur naturally in the same areas as the pests and they should therefore be preserved; otherwise they can be introduced where necessary. Improving these methods of management requires an excellent understanding of the ecosystems concerned.*

*The specialists must also make sure that the techniques proposed can be used by farmers.*

*This book is a contribution to the efforts being made worldwide to improve agricultural crop protection and make it more environment-friendly.*

the photosynthetically active radiation from 25 to 45%.

Increased yields are obtained from the intercrops when the density of the coconut trees is reduced. However, these increased yields depend on the age of the coconut trees and the intercrop chosen. For example, yields increase significantly for maize but not for mung bean (*Vigna mungo*).

Simulated pruning to reduce the number of leaves to 18 on coconut trees planted at standard spacing shows an increase in the rate of transmission of photosynthetically active radiation and an increase in the productivity of the intercrops. If pruning was proven to have no long-term effect on the productivity of coconut, this inexpensive technique could be used to limit competition for light between coconut and intercrops

in existing plantations without having to modify tree density. These results, which optimize the intercropping of coconut and food crops, are being evaluated in the field in order to confirm the relevance of the models.

## **Oil palm**

In 1996, palm oil was cheap and abundant again, with average prices of US\$530/t compared with US\$600/t in 1995. However, the market is still tense and prices remain unstable following the prediction of another shortfall in oil production for 1997. The market, which is still very attractive for many producer countries, favours the expansion of oil palm cultivation, particularly in Indonesia. In Africa, privatization is well under way and in Côte d'Ivoire the privatization of Palminindustrie has been completed. All these factors should act as a boost to the oil palm industry. Solicited by its partners, CIRAD will be an integral part of the development of and changes in the industry.

### **Biomolecular study of somaclonal variants**

Research on cloning using somatic embryogenesis is carried out on all the tree crop species studied by CIRAD. The aim of this technique is to identically multiply plants that are selected on the basis of their performance. However, variant plants, that is those with characters that differ from the original plant, can be observed in clones, particularly those which are mass-produced.

Vegetative multiplication of the oil palm began more than 15 years ago in Côte d'Ivoire. The experimental plantations now have tens of thousands of individuals created by somatic embryogenesis. The plants are observed individually and systematically and it is therefore possible to monitor the degree of conformity of the regenerated material. A variant characteristic that affects the structure of the flower has been



observed in all the cloned oil palm plantations. This floral abnormality, which affects on average 6% of trees, has serious implications because it can lead to plant sterility. It cannot be detected until the first flowers appear, which means at the earliest 2 years after planting out. The development of the vegetative multiplication of oil palm is impeded by this in-vitro induced floral abnormality, and neither the CIRAD/ORSTOM process nor the processes used by other research centres in different parts of the world have been able to overcome the problem.

Given the importance of this phenomenon, CIRAD and ORSTOM have launched a biomolecular study that focuses on the degree of ploidy in the regenerated plants, the organization of their genomes and the identification of specific signs in affected tissues. The long-term objective of this work is to be able to identify molecular markers that will enable variant plants to be detected long before they are planted out. In 1996 the Palm Oil Research Institute of Malaysia (PORIM) put out an international tender for projects concerning this problem. A joint project presented by CIRAD, ORSTOM, and the Centre national de la recherche scientifique (CNRS) was selected as well as six other projects from European and American teams. This fundamental research work will lead to a better understanding of the mechanisms involved in micropagation techniques. As well as the impact of this research on the oil palm industry, the results will also be useful for the other tree crops multiplied by CIRAD.

## A new oil extraction process

The fruit, or drupe, from the oil palm contains two oils: palm oil, which is extracted from the mesocarp, and palm kernel oil, extracted from the kernel. These oils, traditionally extracted separately, are different. Palm oil has many uses,

for instance as a frying oil and in margarine. Palm kernel oil, which is very similar to coconut oil, is used in soaps and cosmetic products. The Drupalm® process was developed and patented jointly by CIRAD and Flottweg, a subsidiary of the Krauss Maffei group, manufacturers of industrial equipment. With this process, most of the oil in the palm fruit can be extracted in one pass. The fruit is stripped and crushed to form a mash which is digested and then separated in a three-phase decanter. The oil obtained, which is approximately 95% palm oil and 5% palm kernel oil, is then purified. This oil is called Drupalm®, a compound of the words drupe and palm.

The trials, which were carried out at the Société camerounaise de palmeraies (SOCAPALM), were partly financed by the Agence nationale de valorisation de la recherche (ANVAR). The Drupalm® process has technical, environmental, and economic advantages over the traditional extraction process. The process is very easy to use and more oil can be extracted in a single pass than with the traditional method. The extraction is faster and carried out at a lower temperature which means that the quality of the oil is preserved and the energy requirements are reduced by nearly 30%. From an environmental point of view, the process produces less liquid waste, which is also less polluting. The solid component, once dried, provides an excellent fuel for the boilers. From the economic point of view, the cost of investment is substantially reduced and the process of crushing seeds is avoided. The labour requirements are lower. The process is also adapted to small-scale production and the investments can be made in stages.

Drupalm® oil, a registered trade mark, is a new product that should find its place on the world oils and fat market. It is already being used in producer countries to meet local demand.

# Rubber

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**T**he demand for rubber continues to increase due to growth in the market for tyres in developing countries and there are fears of a shortage in the medium term as there is still no substitute for rubber. The main aim of the rubber programme is to research ways of increasing the production of quality rubber and to propose profitable production systems for the development of the rubber industry. The main objectives of CIRAD's research are to gain a better understanding of: rubber-based farming systems; the competition for photoassimilates between the tree's latex-producing function and its other functions; and the problem of the intrinsic variability of a biological product used for industrial purposes.

## Tree growth and latex production

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The products of photosynthesis, or photoassimilates, of rubber are used for vegetative growth, latex production, and for accumulating reserves such as starch and sugars. Latex production can be increased either by more intensive tapping or by stimulating production using ethylene. The most common stimulant used is Ethrel which is painted onto the tapping cut. Researchers have observed that there is a conflict between vegetative growth and latex production: increasing the yield of latex decreases the tree's growth rate, measured in terms of the diameter of the trunk.

The aim of CIRAD's research is to understand the relationship between these two physiological phenomena. This research has shown that increasing stimulation using ethylene directly increases production and decreases the available sucrose content in the latex tissue. However, if

ethylene stimulation is too intense there can be a drop in production. For clones derived from vegetative propagation using grafted, high-yielding material, vigour is not related to productivity. However, in a population of clones derived from nongrafted material, the most vigorous trees are the most productive. The increase in productivity induced by stimulation using ethylene is less marked when the clones are naturally very productive. There is direct competition for carbohydrate assimilates between rubber production and vegetative growth, and this competition varies depending on the clones. Clones should be selected from those plants that are naturally productive without stimulation and that also have high concentrations of sucrose in the latex-producing vessels.

## Intercropping with rubber

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On smallholder rubber plantations, which represent 85% of the area covered by rubber plantations worldwide, more than half of the young plantations have food crops grown between the rows of rubber trees. These crops, such as rainfed rice, groundnut, cassava, and plantain, ensure a degree of food security for the smallholders and provide a source of income until the rubber trees start producing.

A study of these intercropping systems is currently being funded by the European Commission. CIRAD, which is supervising the project and coordinating the scientific research, is working in collaboration with Hohenheim University in Germany, the Institut national agronomique de Paris-Grignon (INA-PG), the Institut des forêts (IDEFOR) in Côte d'Ivoire, the Centre d'appui technique à l'hévéaculture (CATH) in Gabon, and the Indonesian Rubber Research Institute (IRRI). The aim of this study is to gain a better understanding of the agrophysiological functioning of the temporary associations between rubber and

annual food crops in order to identify the factors limiting the development of the intercrops. Once these factors have been identified, it will be possible to optimize the growth and productivity of these crop systems. The research is particularly concerned with quantifying and analysing competition for water, light, and minerals.

Competition, at least for water and minerals, is apparent from the second year after planting. It is therefore important to carefully manage the rows and the space between the rows so that the association of rubber and intercrops optimizes the use of available resources. The study on the rate of transmission of incident solar radiation, the leaf area index, and the yield of intercrops should make it possible to optimize the plantation layout and limit competition.

## Theses Completed in 1996

### CIRAD Scientists

**La production de latex par *Hevea brasiliensis* : relations avec la croissance ; influence de différents facteurs — origine clonale, stimulation hormonale, réserves hydrocarbonées** [Production of latex from *Hevea brasiliensis*; relationship with growth; influence of different factors: clonal origin, hormonal stimulation, carbohydrate reserves] by Eric Gohet; Université Montpellier II.

**Relations entre développement racinaire et développement aérien : modélisation de l'influence de la disponibilité en assimilats carbonés sur l'architecture d'*Hevea brasiliensis*** [Relations between root development and aerial development: modelling the effect of the availability of carbon assimilates on the architecture of *Hevea brasiliensis*] by Philippe Thaler; Université Montpellier II.

### CIRAD Trainees

**Le microbouturage du cacaoyer (*Theobroma cacao* L.) : identification et étude de quelques facteurs limitants de la réactivité des explants** [Micropropagation of cocoa (*Theobroma cacao* L.): identification and study of some of the limiting factors affecting

explant regrowth] by Maria Elena Aguilar (Costa Rica); Institut national polytechnique de Toulouse.

**Etude de la qualité des carburants dérivés des huiles végétales : approche méthodologique** [Study of the quality of fuels derived from vegetable oils: methodological approach] by Nathalie Chirat; Université Montpellier II.

**Etude de la diversité génétique des populations de *Phytophthora* pathogènes du cacaoyer (*Theobroma cacao* L.) et du cocotier (*Cocos nucifera* L.)** [Study of the genetic diversity of populations of *Phytophthora* pathogens of cocoa (*Theobroma cacao* L.) and coconut (*Cocos nucifera* L.)] by Carlos Ortiz Garcia (Mexico); Université Paul Sabatier, Toulouse.

**Etude d'un virus pathogène de *Setothosea asigna* Van Eecke (Lepidoptera Limacodidae), ravageur du palmier à huile en Indonésie : caractérisation, diagnostic et épidémiologie en plantation** [Study of a pathogenic virus of *Setothosea asigna* Van Eecke (Lepidoptera: Limacodidae), a pest of the oil palm in Indonesia: characterization, diagnosis, and epidemiology in the plantation] by Sudharto Prawirosukarto (Indonesia); Université Montpellier II.

**Mise au point de méthodes d'échantillonnage pour estimer les attaques des fruits du caféier** [Improving methods of sampling for estimating damage to coffee fruit] by Fabienne Rémond (France); Université Montpellier II.

## Quality of African rubber

*African rubber has a low rating on the world market because of its inconsistent quality. In order to remedy this situation a project to improve and control quality was launched in 1996 in the main African producer countries: Cameroon, Côte d'Ivoire, Gabon, Ghana, and Nigeria. This project, which was proposed by the International Natural Rubber Organization (INRO), is cofinanced by the CFC and the French government. The African Natural Rubber Association (ANRA) is responsible for managing the project and INRO is responsible for its supervision. This project has three parts: improving the quality of "technically specified rubber" and establishing a quality standard for African producer countries; modernizing the national laboratories of these African countries by buying equipment and training managers and technicians; and finally, launching and promoting the ANRA label. CIRAD is responsible for providing technical support for ANRA and the national laboratories at every stage of the project. CIRAD will also be in charge of training the managers in France and in England and for training the technicians and factory managers in the producer countries. Lastly, CIRAD will ensure that smallholders are made aware of the importance of quality.*



*New products, tools, and techniques were the most obvious scientific and technical spinoffs of the Department's work in 1996, with research continuously being adapted to meet development needs.*

*The overall strategies established in recent years are now yielding concrete results. Developing sustainable farming systems is the thrust of two projects—extension support in the Hauts de l'est region of Réunion, and pesticide waste management. Innovative techniques are being used to develop high-quality food products utilizing genetic resources of fruit species from the Andean zone.*

*Many new products are now encompassed within CIRAD's sphere of activities, e.g. onions and dates, which have been relatively ignored in the past but are staple foods in many countries. Other products, including indigenous fruit in Andean zones and vanilla in the Indian Ocean region, could open new avenues for economic development.*

*The Department has also been developing and distributing new tools. The EGID database was designed to meet the needs of the international scientific community for citrus genetic resource management. Techniques for indexing plant material from the Mediterranean region, and tools for the mechanization and automation of banana production in the West Indies, were developed to benefit growers.*

*New methods have also been developed to determine the main factors involved in a complex pineapple disease through systemic analyses, and to breed nematode-resistant bananas, based on the results of pathogen diversity studies. ■*





# Fruit and Horticultural Crops



## Fruit and Horticultural Crops Department CIRAD-FLHOR

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# Citrus and orchard fruit

In recent years, new studies have been under way to improve the overall understanding of yield components in woody plants, focusing on plant architecture, sap flow, and direct effects of manure, etc. The main species investigated are guava, litchi, and mango, and other studies have also begun on citrus fruit.

The Citrus and orchard fruit programme is directly supporting citrus production in the southern Mediterranean region by giving citrus growers access to the results of its research carried out in Montpellier (France), and jointly with the French Institut national de la recherche agronomique (INRA) at the San Giuliano Research Station in Corsica. In Niger, research has been finalized on phenological aspects of date palms and on how this crop has been adopted by a local enterprise, thus enhancing the possibility of its extension to intertropical zones.

## Healthy citrus trees in the Mediterranean region

In the southern Mediterranean region, an average of 20 kg of citrus fruit are consumed yearly, which is higher than any other fruit. With the current population growth, citrus production will have to be increased to meet the increased demand and maintain current consumption levels. Citrus growers require high-quality plants and new rootstock that is salt-tolerant and resistant to the tristeza virus, which is slowly but surely spreading throughout this region.





Tunisia is barely able to meet domestic and export market demand for cv Maltese half-blood oranges. Since 1993, CIRAD has been involved in a programme to promote the production and distribution of healthy plant material. This programme is funded by the French Ministère des affaires étrangères and coordinated by the Tunisian Groupement interprofessionnel des agrumes et des fruits (GIAF). The overall aim is to produce elite plants for the renewal and expansion of current orchards, based on citrus sanitation through shoot tip grafting. A local team was trained and will now take over operations to obtain disease-free plants and propagate elite plants. The GIAF nurseries have tripled their plant production since the outset of the project, with more than 200 000 plants produced to date.

CIRAD has already established cooperative ties with several Mediterranean countries for developing and testing new rootstock. Sour orange is a traditional rootstock in this region because of its tolerance of saline soils, but it is susceptible to tristeza virus. Using protoplast electrofusion, CIRAD has obtained somatic hybrids that are tolerant of tristeza virus and saline soils; these are being rapidly propagated.

These plants will be evaluated in experimental orchards at the University of Adana (Turkey) as part of a project financed by the French Ministère des affaires étrangères, which also includes training of a Turkish research scientist at CIRAD's laboratories in Montpellier.

New somatic hybrids will also be field-tested in several countries, i.e. Morocco, Israel, Tunisia, South Africa, and France, either within the terms of bilateral partnerships, or as part of a project supported by the Common Fund for Commodities (CFC) and coordinated by Morocco.

## Date palm cropping in intertropical regions

Date palm, *Phoenix dactylifera*, ranks 15th worldwide in terms of fruit production. It is traditionally grown from Arabia to the Sahara, and is also found in intertropical regions. CIRAD conducted a study in southeastern Niger, in a region inhabited by Mangas, to determine the behaviour of this species in intertropical zones and how it is adopted locally.

In a phenological analysis of date palms, two annual flowering and fruiting cycles were noted in 70% of all mature trees. This study also highlighted another cycle associated with climatic, soil, and moisture conditions in the investigated region. The summer rainy season seems to have an essential role in these cycles, whereas temperature does not have the same effects on intertropical date palms as it does in the Saharan-Mediterranean zone—where it is a critical flower induction factor.

In southeastern Niger, low-pressure weather fronts provide a renewable water supply, i.e. enough to produce two date crops yearly. Date palms were easily integrated in local farming systems, as Mangas utilize the first crop to bridge the hungry gap before the next harvest. In less than 50 years, this crop was progressively cultivated and has become an asset for farmers

### Citrus genetic diversity database

*EGID is a new CIRAD software package for the evaluation and management of citrus genetic diversity. It was initially developed in Martinique and then further perfected at the Agronomic Research Station of San Giuliano (Corsica). This program combines data, images, and text, and the user has access to information on the history of 1 140 varieties from the INRA-CIRAD San Giuliano germplasm collection, along with their phenological and pomological qualities. This citrus identification aid can, as recommended by qualified international agencies, be used by staff of large citrus repositories.*

which they tap for its products, and use for land reclamation.

Cropping techniques, e.g. propagation, maintenance, and harvesting, were developed on the basis of an overall understanding of date palm tree functions, and social and environmental constraints.

This study led to the development of a date palm functioning model, with a description of how this tree was recently adapted by man. This should facilitate the introduction of date palms in other intertropical arid and semiarid regions.

## Pineapple and fruit diversification

**I**n 1996, this programme continued providing support in the French overseas departments through the development of innovative techniques and processes applied to new crops. After initial testing, a fruit diversification operation in the Hauts de l'est region of Réunion is now in the operational development phase. The programme also maintained its support for a number of related subsectors. Moreover, the results of research under way on pineapple fruitlet core rot in Martinique can now be assessed in the field, and there is hope that this disease may soon be controlled.

## Fruit crop diversification in Réunion

In 1992, the Commissariat à l'aménagement des Hauts (CAH) and the Association pour la promotion en milieu rural (APR) in Réunion asked CIRAD to carry out a project to promote the development of new fruit crops in Hauts de l'est region. Sugarcane cropping is not cost-effective and crop diversification is quite limited in this region due to soil-climate constraints. This project, funded by the Conseil général de Réunion, the French government, and the European Union, is aimed at introducing new crops and intensifying cropping of three species that have considerable cropping potential on the island, i.e. strawberry guava (*Psidium cattleianum*), cabbage palm (*Euterpe* spp.), and passion fruit (*Passiflora edulis*). Tests were conducted, in collaboration with local farmers, on 17 field plots under different ecological conditions. The results highlighted the behaviour of these crops and their products and led to the development of fully-adapted cropping technology.

Phenological aspects of strawberry guavas were investigated for 2 years, thus clarifying the behaviour of this species under various ecological conditions. The effects of fertilization on crop yield components were determined. Nitrogen input induces growth of flower-bearing shoots that eventually yield fruit. The application of fertilizer immediately after fruit setting increases the size of the fruit produced. Three harvests/field/year are thus possible. In this project, nitrogen application-to-harvest and flowering-to-harvest times were determined, which will be useful for scheduling harvest periods.

In 1997, the project will be in the extension and development phase. A technical data sheet

that will be distributed to farmers is currently being drawn up. A concomitant subsector analysis revealed that retailers and the fruit-processing industry in Réunion are keenly interested in cultivated strawberry guavas, as they produce tasty fruit and could be useful for regulating market supplies. Strategies were proposed to enhance contacts and interactions between stakeholders, e.g. producers' organizations and promotional campaigns.

Studies on red cabbage palms (*Euterpe* spp.) highlighted important growth factors for this crop, including the critical role of soil organic matter content. Pejibaye (*Bactris gasipaes*), an Amazonian cabbage palm species, was also introduced in Réunion. It has many advantages over the local species: a shorter planting-to-harvest period (4 months rather than 20 months for 7 year-old trees), slenderer and longer palm hearts, with better taste and storage potential.

These studies are promoting the development of new processing subsectors, thus supporting farming activities in this poor region of Réunion.

## Potential control of pineapple fruitlet core rot

Pineapple fruitlet core rot is detrimental to pineapple production in Martinique, with losses as high as 30% (10% on average) affecting growers and the local canning industry (SOCOMOR). At the request of professional authorities of the Region, CIRAD began research aimed at characterizing the disease and determining soil, climate, and cropping factors that promote its development. One hundred and twenty test plots, representative of different types of plantations and

cropping practices, were monitored.

Three facies of this disease, with the same causal agent (*Penicillium funiculosum*), were detected: the black spot facies—brown and mushy; the leathery pocket facies—black and hard; and an intermediate version, combining black spot and leathery pocket features.

Different infestation levels were noted on plots located in the same zone, cropped with the same variety, and harvested on the same date. Calcium and magnesium deficiencies were detected in the most infected plots, highlighting the importance of cropping practices on disease development.

The physiological state of the fruit and its mineral content had a marked effect on the black-spot facies. The disease was found to develop rapidly when temperatures and rainfall were high during some periods of the fruiting phase.

Based on these results, new cropping practices were developed to control this disease without any direct pesticide treatments required. Rational mineral fertilization could therefore significantly reduce the impact of this disease on pineapple yields.

## Processing Andean fruit

*CIRAD, in collaboration with Del Valle University at Cali (Colombia), is investigating the domestic and export market potential for various fruit from the Andean region, e.g. lulo (Solanum quitoense), pitahaya (Hylocereus undatus), pineapple, mango, and borojo (Borojoa patinoi), and derivative processed products. This joint project is financed by the French Embassy.*

*The physicochemical and enzymatic properties of these fruits were first identified, and then new processing techniques, such as osmotic evaporation, tangential microfiltration, and vacuum frying, were assessed.*

*The results of these experiments were used to develop new products, including fruit chips and cubes, and aromatic concentrates, in conjunction with a local agro-industrial enterprise.*





# Banana and plantain

The main thrusts of this programme, i.e. stabilization of smallholder cropping and development of environment-friendly techniques to produce high-quality bananas under intensive cropping conditions, were the bases of research carried out in 1996 on controlling soil-borne pests and diseases and on the extent of pesticide pollution in runoff water from large-scale banana plantations. Many other studies focused on rational mechanization of various phases of banana cropping, which is essential for maintaining banana quality and productivity in the West Indies.

## Developing nematode resistance in bananas

Nematode resistance represents a major challenge for banana crop research. CIRAD has characterized *Radopholus similis*, the most virulent and widely distributed nematode species in intensive banana cropping systems, while investigating mechanisms of resistance to this pest in banana plants.

A study of *R. similis* populations from around the world, conducted as part of a European Commission-funded project, highlighted that its pathogenicity varies markedly, depending on its geographical origin and its propagation potential within banana plant tissues. Scientists from CIRAD, the Institut français de recherche scientifique pour le développement en coopération (ORSTOM), and Rothamsted Research

Station, detected two separate genomic groups within this species. Specialists from CIRAD and ORSTOM are carrying out further studies to characterize nematode banana pests and assess their diversity. The results will be essential for developing an integrated nematode control strategy, involving crop rotations and varietal improvement, adapted to the specific environmental conditions of each banana-growing region.

Mechanisms of resistance to *R. similis* in bananas were also analysed through a comparison of two triploid AAA cultivars, Yangambi km 5 (resistant) and Poyo (susceptible). Nematodes were able to penetrate and thus colonize susceptible plants more quickly than resistant plants, even at very early stages of development. Ultrastructural, histochemical, and biochemical studies, conducted in collaboration with ORSTOM and the Faculté de pharmacie (Montpellier, France), revealed substantial differences between cultivars. The results suggest that essential and induced phenol compounds are linked with resistance mechanisms in cv Yangambi km 5, while flavonoids and some tannins have major roles.

Research is also under way to identify resistant banana genotypes, as part of a project financed by the Common Fund for Commodities (CFC) and coordinated by the World Bank. Within the same context, the Centre régional bananiers et plantains (CRBP) in Cameroon, with scientific support from CIRAD, is screening varieties for resistance to *R. similis* and *Pratylenchus goodeyi*, the dominant species in highland areas of Africa. Nematologists are working on banana plants within the framework of the International Network for the Improvement of Banana and Plantain (INIBAP), in association with large banana breeding programmes. CIRAD also encourages and is actively involved in these dynamic network-oriented interactions.

## Pesticide pollution in runoff

As banana monocultivation is common in the French West Indies, growers use massive doses of pesticides to treat pest and disease infestations specific to each plantation. The impact of such intensive treatments on the environment, and especially on water quality, is worrisome on highly populated tourist-oriented islands such as Guadeloupe.

Nematicides and other pesticides used to treat soil-borne banana pests and diseases are the most dangerous products in terms of their high environmental toxicity. A study was undertaken to determine correlations between cropping practices and pesticide contamination of runoff.

The soil structure in banana plantations can be degraded when tillage operations are conducted with unsuitable tools and heavy machinery is used during the cropping cycle, thus seriously increasing runoff after rains. An analysis of runoff water in a small catchment confirmed the presence of three nematicide and pesticide compounds that are used in banana plantations, i.e. terbuphos, cadusaphos, and aldicarb. The extent and duration of this pollution depends on which of these active ingredients is present, and on rainfall levels.

Cadusaphos pollution of runoff is constantly high when rainfall levels are moderate or low. In contrast, high levels of aldicarb are detected in the first runoff water, followed by a sharp drop. Terbuphos pollution is relatively low at first, and then decreases quite rapidly after a few rains. This study demonstrated that considerable pollution is derived from plantations with intensive banana monocultivation, and that drinking water should be strictly monitored in banana-producing regions. The results also

indicated that the management of current cropping systems should be reconsidered, as they tend to accentuate runoff phenomena and necessitate massive systematic pesticide treatments. CIRAD, in an attempt to overcome these drawbacks, has proposed new cropping practices, involving crop rotations, the use of healthy plant material, micropropagated plants, and rational mechanization. These systems are more cost-effective, productive, and permit reductions in nematocide and pesticide treatments, thus reducing water pollution.

## Mechanization of operations in the banana subsector

*In the French West Indies, high labour costs and an overall loss of interest in farm work has considerably increased the need for the mechanization of banana cropping, harvesting, and storage operations.*

*A model storage shed was developed, in collaboration with a CIRAD farm mechanization specialist, to streamline banana packaging—an operation that generally accounts for a quarter to a third of the labour time on banana plantations. This shed enhances working conditions, while reducing sorting problems and increasing product quality. In a visit to the CIRAD research station at Rivière-Lézarde in Martinique, many socioeconomists from the banana subsector were impressed with this innovative facility.*

## Horticultural products

Feeding city dwellers, deriving income for all stakeholders of the subsector, and improving product quality are a few of the principal concerns of this programme, as addressed by the research carried out in 1996. These studies included an investigation on an onion marketing network supplying a large African city, an assessment of vanilla crop intensification techniques in Réunion, and involvement in a tomato bacterial wilt control network.

## Marketing onions in western Africa

In sub-Saharan Africa, feeding people in cities is a crucial problem because of the high urban population growth rates (7%/year). Since 1994, a deregulated marketing situation has developed as a result of the devaluation of the CFA franc and suspension of the regional agreement (CEAO), and this has had a marked effect on urban food supplies. With the overall aim of understanding this impact, especially on regional networks, CIRAD conducted a study on how Abidjan obtains its onion supplies.

Onion is one of the most highly consumed vegetables. On the Abidjan market, onion purchases represent 4–5% of household food expenses. This city of 3 million inhabitants

consumes 20 000 to 25 000 t/year of onions. During production periods, up to 70% of all marketed onions come from Niger, the main onion-producing country in this part of western Africa. When supplies are low, i.e. from October to February, some onions are also imported from The Netherlands.

Fragile onions are transported thousands of kilometres via an extensive marketing network run by Hausa merchants from Niger—but retail prices still remain competitive

relative to European imports. The economic performance of this network is based on a specific hierarchical structure involving an oligopoly of important merchants from Niger who have been controlling the market for some 20 years. This organization is built on interdependent relationships, which helps merchants overcome the inherent risks of this market, i.e. a fragile product, transported great distances along a hazardous route in unreliable vehicles.

However, with the devaluation of the CFA franc and recent onion market developments, the supremacy of this network is beginning to falter. In Abidjan, import prices for onions from The Netherlands rose sharply during the preharvest shortage period in 1994, prompting a 140% increase in consumer prices for onions from Niger. In 1995, subsequent to this price rise and a network-wide redistribution of profits (even to producers), there was a marked influx of new stakeholders in this subsector, leading to an increase in volumes of onions brought in from Niger. Wholesale prices plummeted, and the incomes of many onion exporters and transport agents from Niger dropped, thus weakening this complex network.

As these price decreases were not passed on to consumers, the oligopolistic environment of this subsector began breaking down in favour of a more individualistic approach. This trend seems to be modifying urban onion supply channels, as confirmed by the fact that large quantities of cheaper onions are now being imported from Burkina.

## New vanilla cropping practices

In response to a highly competitive world market situation, Réunion has launched a programme to rehabilitate and intensify bourbon vanilla cropping on the island. In recent years,

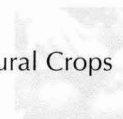
### Tomato bacterial wilt control

*Bacterial wilt caused by *Ralstonia solanacearum* (formerly *Pseudomonas solanacearum*) is the main tomato disease in humid tropical environments.*

*Tomato bacterial wilt is not yet fully controlled, despite extensive research on this topic. The Asian Vegetable Research and Development Center (AVRDC) has developed an Asian-based network aimed at controlling this disease—CIRAD is involved in two projects: an INRA scientist conducting research at CIRAD's station in Réunion is developing molecular tools to diagnose tomato bacterial wilt; and a CIRAD scientist posted at AVRDC is investigating genetic variability in strains of this bacterial agent.*

*The initial results will be reviewed at an international conference, organized by INRA, that is to be held in June 1997 in Guadeloupe.*





farmers have switched from their traditional vanilla cropping practices, i.e. no fertilization with live trees or plants used as support, to a more modern system with fertilizer inputs and staked plants grown under shaded conditions. Since 1994, CIRAD, in conjunction with local organizations, has been involved in a programme to assist vanilla growers in adapting and improving these new cropping practices.

The first phase of this project focused on soilless culture substrates. Nine different substrates were compared, and vanilla growth was found to be directly dependent on the extent of organic matter decomposition in the substrate. Vanilla creepers grow poorly on substrates with low organic matter content, regardless of the amount of fertilizer input. The environment has to be suitable for the growth of the *Rhizoctonia* fungus, which interacts symbiotically with the vanilla plant and promotes creeper extension. It was found that vanilla plant stems grew longer, with more branching, flowers, and harvested pods when compost substrates made from town refuse or bagasse were used, along with a slow-release fertilizer supplement.

Further studies are under way to determine the conditions that induce high vanillin levels. It should then be possible to propose fully adapted cropping procedures that will ensure suitably high vanillin levels in pods.

## Theses Completed in 1996

### CIRAD Scientists

**Organization of the Brazzavillian vegetable market** by Paule Moustier; University of London (UK).

### CIRAD Trainees

**Phénologie d'un arbre méditerranéen acclimaté en région tropicale : le dattier au sud du Niger et son appro-**

**priation par la société manga** [Phenology of a Mediterranean tree adapted to a tropical climate: growing date-palms in southern Niger and their adoption by Manga inhabitants] by Michel Jahiel (France); Institut de botanique de Montpellier.

**Les relations sémiocchimiques chez le charançon du bananier *Cosmopolites sordidus* Germar et la résistance de sa plante-hôte** [Semiochemical interactions in the banana borer *Cosmopolites sordidus* Germar and host-plant resistance] by Laurence Lemaire (France); Université Montpellier II.

**Etude de la ramification de deux cultivars d'ananas (*Ananas comosus* [L.] Merr.), Cayenne Lisse et Queen Victoria, en relation avec leur développement sous diverses conditions climatiques de l'île de la Réunion** [A study of shoot growth in two pineapple (*Ananas comosus* [L.] Merr.) cultivars, Cayenne Lisse and Queen Victoria, relative to their development under different climatic conditions in Réunion] by Amon Maerere (Tanzania); Université Henri Poincaré, Nancy.

**Contribution à l'étude des troubles et de la désamérisation des jus d'oranges** [Contribution to the study of overcoming cloudiness and bitterness in orange juice] by Agnès Rotheval (France); Institut polytechnique de Lorraine, Nancy.

**Etude de la variabilité des interactions bananier-nématode : approche des facteurs de la résistance du bananier à *Radopholus similis*** [Study on variability in banana-nematode interactions: an analysis of factors involved in banana resistance to *Radopholus similis*] by Catherine Valette (France); Université Paris VI.

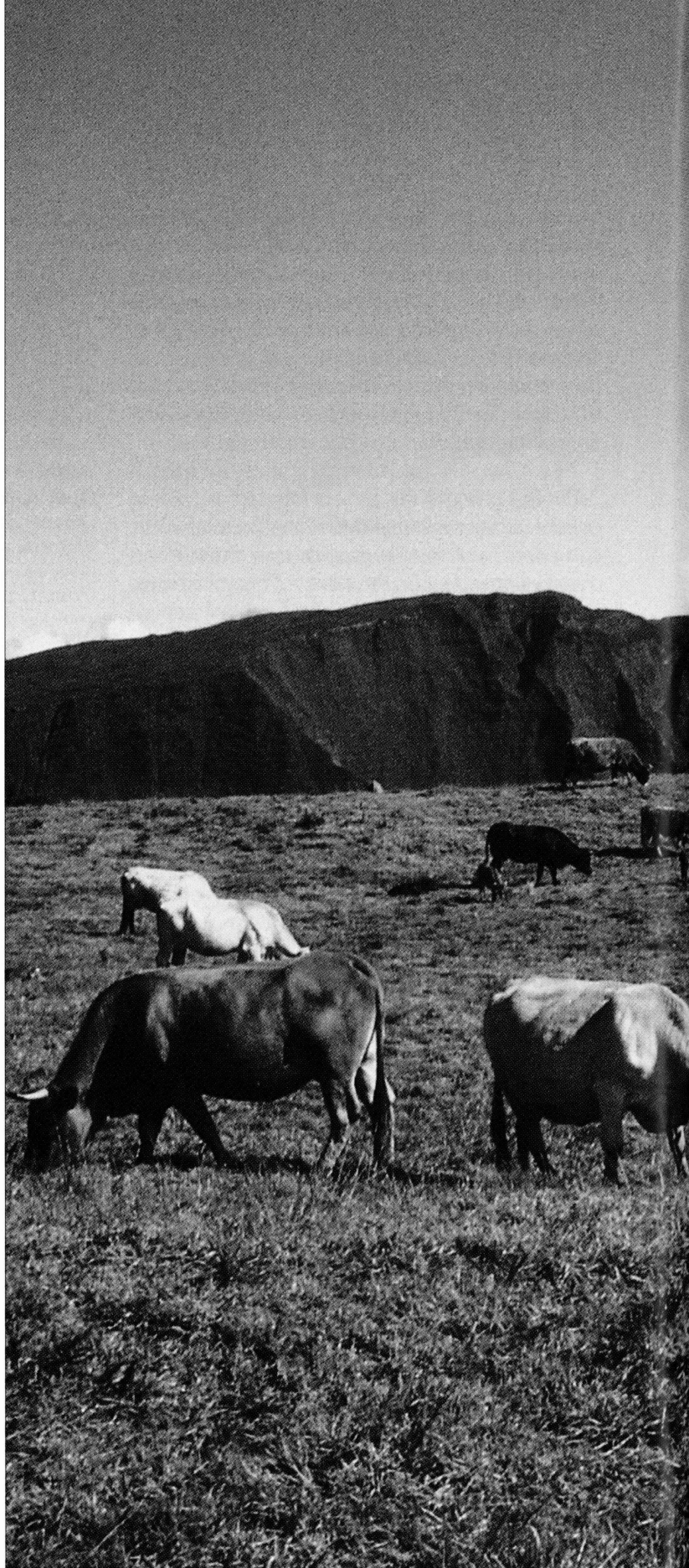
*The Department was reorganized in 1996, with the creation of four new research units and three new programmes. These programmes provide a solid operational framework for activities that address partners' needs—meet challenges, assist them in drawing up strategies and development-oriented policies, and pinpoint their requirements. Multidisciplinary research conducted within the programmes complies with CIRAD's overall scientific priorities.*

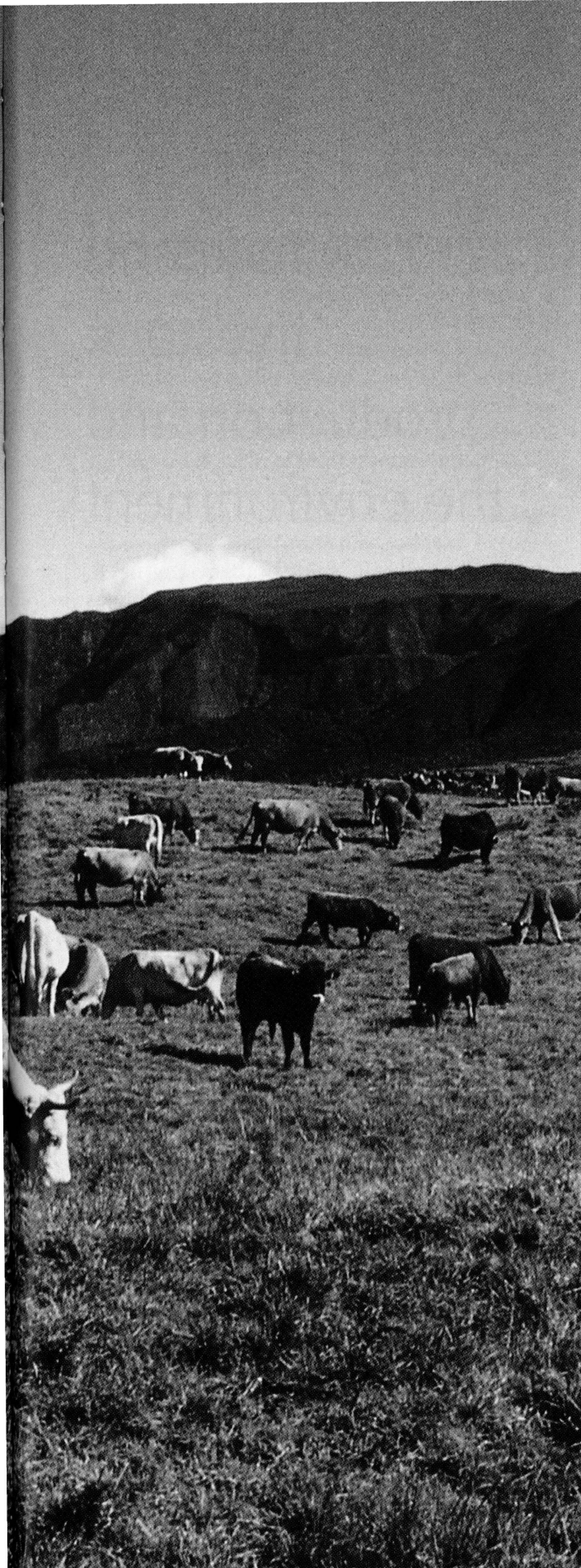
*Two production-based programmes target operations in specific regional areas.*

*The Rangeland livestock production and the environment programme focuses on low labour and input livestock production on rangelands. Environmental management is a major thrust of this programme with respect to natural resource use by livestock.*

*Another programme combines livestock and crop production through projects that investigate animal and fodder components of such systems, in addition to some agricultural aspects, such as manure and animal-draught cultivation. The main objective beyond livestock production is to promote higher overall farming-system sustainability.*

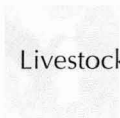
*The Subsectors and diversification programme is striving to enhance people's diets by diversifying protein resources through wildlife use and the production of nontraditional livestock species. Flourishing animal-related production subsectors are also being developed, e.g. production of milk, poultry, pigs, and aquatic animal species. ■*





# Livestock Production and Veterinary Medicine





Livestock Production and  
Veterinary Medicine Department  
CIRAD-EMVT

Director, *Joseph Domenech*

Deputy Director, Programme Director, *André Martin*

Research Director, *Didier Richard*

Development Coordinator, *Léon Letenneur*

Administrative and Fiscal Director,  
*Jean-Vital Decloquement*

**Research Programmes**

Rangeland livestock production and  
the environment, *Dominique Dulieu*

Livestock and crop production, *Philippe Lhoste*

Subsectors and diversification, *Philippe Chardonnet*

**Research Units**

Feed resources, *Bernard Toutain*

Livestock production and herding, *Bernard Faye*

Aquaculture, *Jérôme Lazard*

Tropical livestock diseases, *Jean-Jacques Tulasne*

**Support Services**

Education and training, *Gérard Duvallet*

Documentation, *Annie Marti*

Cartography, *Isolde de Zborowski*

Publications, *Dominique Lasserre*

# Rangeland livestock production and the environment

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**R**angeland livestock production systems thrive in dry, savanna, and forest zones that are generally unsuitable for crops or other production activities. Natural rangelands are thus utilized and minimally maintained with low inputs.

CIRAD research conducted within this programme—analysis of livestock production systems, rangeland dynamics and management, biodiversity and livestock management, epidemiology and control of epizootic diseases—is aimed at enhancing livestock production while conserving the ecosystems that are being tapped.

## Rangeland water management in Chad

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A project to set up about 100 livestock watering sites in Chad, as part of a rangeland water development programme, was assigned to a private agency (Burgeap) by the Caisse française de développement (CFD). CIRAD was called upon to assist project staff with livestock production issues, i.e. provide technical advice and consultancy on rangeland mapping, etc.

This water management project, which began in 1995, covers a large region (700 km north/

south, 300 km east/west) along the Sudanese border. The climate differs markedly between the north, a desert zone, and the south, a Sudanian zone where the Salamat floodplain is located. Herding is the main activity, with an estimated 1.5 million head of cattle, in addition to camels, sheep, and goats. Most of this livestock is herded, sometimes over long distances, to take advantage of seasonal grazing areas.

The first step of the project was to assess the water needs of different categories of herders. A survey method with questionnaires was developed to determine current types of herding systems and herders' needs. After analysing the survey results, plans were made to dig several ponds. This differed from the initial goal of only digging wells, which would be suitable for some small-scale settled and transhumant herders but useless for farmers with large sedentary or transhumant herds, since each cow requires a water supply of 30 L/day. In addition, vegetation and rangeland resources on 12 million ha of land in this region were mapped at 1/200 000 and 1/500 000 scale, using Landsat remote-sensing imagery and ground-survey data.

The Sahelian part of the zone was the focus of the initial phase of the programme. Potential pond and well sites were planned on the basis of the survey results and a geographical resource analysis.

Forty-five wells have already been rehabilitated—the first wells of the initial phase are to be dug in April 1997, and the ponds will be set up after the rainy season. Two follow-up studies are now under way: one concerning the effects of these new water installations on the functioning of traditional herding systems; the other an environmental impact study.

Before allowing users to access these new livestock watering places, it was considered

essential to draw up (jointly with all concerned people) a management plan to ensure that they will be used for livestock supply purposes only. The problem is that water prices could skyrocket, and farmers requiring water for their crops could be denied access to these sites. A joint management scheme involving all stakeholders, i.e. sedentary and transhumant herders, farmers' representatives, and local authorities, was thus implemented on the basis of between-user discussions that were coordinated by a sociologist.

The project will now take other socioeconomic herding constraints, land management, and herders' organizations into account. There is also a complementary project under way to privatize the veterinary component and provide support for cattle marketing. The whole livestock production subsector in Chad will eventually benefit from this programme.

## PCR and gene sequencing: new diagnostic tools

The polymerase chain reaction (PCR) analysis technique has revolutionized investigations aimed at identifying and characterizing causal agents of infectious and parasitic diseases of livestock. By this technique, high quantities of nucleic acid fragments can be very quickly obtained *in vitro* and then analysed. The degree of gene-amplification specificity depends on the primers used. Hence, it is now possible to detect pathogens, even in very low quantities or inactive forms, in test samples.

The advent of automated gene-sequencing widened the horizons for PCR applications. Amplified DNA fragments can therefore now be directly identified from their nucleotide sequences, whereas identifications were previously

### Livestock Atlas of the Lake Chad Basin

*The Livestock Atlas of the Lake Chad Basin is a bilingual (French-English) publication funded by the Technical Centre for Agricultural and Rural Cooperation (CTA). It has a modern reader-friendly layout, with supplementary photographs and explanatory text to enhance the maps, tables, and graphs that form the main body of the document. It covers the physical environment (geography, hydrology, geology, climate, and remote-sensing data) and biodiversity (fauna and flora) in this very large region (more than 2 million km<sup>2</sup>). This atlas focuses on herding, grazing, and cropping activities within their respective socioeconomic and environmental contexts: domestic animals, rangelands, transhumance, infectious diseases, fish farming, fishing, wildlife, and termites. It is an essential reference tool that should be useful in developing the natural potential of this region.*

made according to molecular weights, or restriction-enzyme maps. This means that the pathogen species, group, and individual can be accurately determined on the basis of variability noted on the amplified gene fragment. This promising technique was used to study three very important tropical livestock diseases: cowdriosis, peste des petits ruminants, and contagious caprine pleuropneumonia. Each European Commission-funded study was carried out in close collaboration with European, African, and Asian countries.

Fragments of genes specific to each available *Cowdria ruminantium* isolate have already been detected by this technique. DNA typing is an essential step towards developing an efficient cowdriosis vaccine. The infection treatment method, which has many drawbacks, is currently the only medical means of dealing with this disease.

After PCR analysis, viruses that cause peste des petits ruminants were classified into four separate groups, three of which originate from Africa, the Middle East, and India. In addition, the pathogen strain infecting livestock in northern India differs from that found in the south.

Finally, in mycoplasma of the "mycoid group", it is now possible to distinguish between *Mycoplasma*

*plasma capricolum* strains and those of *capripneumoniae* subspecies, which are responsible for contagious caprine pleuropneumonia.

## Livestock and crop production

Countries in the South can benefit considerably from combined livestock and crop production systems, as improvements in either system can lead to concomitant progress. Combined production also enhances the sustainability of low-input systems. Joint multidisciplinary projects are under way in this CIRAD programme to improve combined production systems; these include: integration of livestock and crop production, as part of CIRAD's ecoregional research strategy, with studies on draught animals, animal-product chains, and feed systems; rangeland management, with projects in Burkina, Brazil, and the French overseas departments and territories; animal genetics, with activities in Côte d'Ivoire, Guadeloupe, and Senegal; control of vector-transmitted diseases, involving analysis of immune-response mechanisms, and the development of improved vaccines.

### Livestock genetics

For several years, CIRAD has been conducting molecular and quantitative genetic analyses on livestock. In 1996, significant results were obtained in two of these studies, i.e. on the phylogenesis of Creole cattle in Guadeloupe,



and on the heredity of reproductive traits in Senegalese sheep and goats.

The phylogenetic study was conducted in collaboration with the French Institut national de la recherche agronomique (INRA) in Guadeloupe, the Centre international de recherche-développement sur l'élevage en zone subhumide (CIRDES) in Burkina, and Trinity College in Dublin, Ireland. The aim of this investigation was to check whether the Creole cattle population in Guadeloupe is the result of many crosses between a wide range of animals introduced since the beginning of colonization, originating from the Iberian Peninsula, western Africa and, to a lesser extent, France and India. Traditional cattle from the French West Indies have high resistance to many diseases, especially tick-borne diseases, and are very hardy—a feature that could be derived from their African ancestors, e.g. N'Dama-type cattle.

Several biochemical, immunogenetic, and biomolecular markers were used to analyse diversity in the Creole cattle population of Guadeloupe. The results highlighted phylogenetic relationships between this population and other breeds for which previous polymorphic-marker analysis data were available. A sample of 190 unrelated animals from 82 different livestock farms in Guadeloupe was investigated. Twenty-one relatively polymorphic markers were used in the analysis, including the most common markers used in previously published studies: four blood proteins, two milk proteins, 11 erythrocyte blood group systems, and three class-1 Bola microsatellites and antigens. The gene frequencies obtained in these different polymorphic systems were compared with those noted in 20 breeds from different groups: European and African cattle breeds, Indian zebu, African zebu, and zebu x cattle crossbreeds. A phylogenetic classification was drawn up for all of these breeds from the above

comparisons—based on principal component analysis of gene frequencies, and on genetic-map distances calculated using four different mathematical models.

The results of this study demonstrated the uniqueness of the Creole cattle population in Guadeloupe, whose characters seem to be a blend of Iberian cattle, African N'Dama cattle, and western African Gobra-type zebu. The initial hypothesis was confirmed, i.e. the Creole cattle breed that is common in the French West Indies is a *Bos taurus* x *Bos indicus* cross, and its hardiness originates from its African ancestors' genes. In addition, after molecular characterization of these genes, and as part of an integrated livestock disease and pest control strategy, it should now be possible to breed animals resistant to some parasitic diseases of tropical livestock, e.g. trypanosomosis, tick-borne diseases, and internal parasites. A programme is also still under way to genetically validate bovine dermatophilus dermatitis resistance markers identified in Brahman zebu in Martinique.

The aim of the second study is to investigate the heritability of reproductive performance and how this feature varies in sheep and goats under traditional herding conditions in Senegal. Baseline data for the study were obtained from a follow-up study of individual animals, as part of a programme on the pathology and productivity of small ruminants, which was jointly set up by CIRAD and the Institut sénégalais de recherches agricoles (ISRA). Sheep and goats were thus monitored under environmental conditions that varied markedly, i.e. climate, vegetation, and farming system. Reproductive characters of these animals were measured: prolificacy, parturition interval, and age at the first parturition.

In the first phase, specific environmental factors affecting reproductive performance were identified and tested using variance analysis models.

### **Win-mod: simulation of livestock herd dynamics**

*Population analysis is an essential tool for livestock development projects in the tropics. Livestock productivity forecasting and studies on the cost-effectiveness of management plans also rely on such analyses. To address the increasing demand for livestock-management studies, CIRAD developed Win-mod, a user-friendly software program that can simulate variations in one or several livestock herds.*

*From an initial pyramid menu of ages (number of animals/age class), and biological and economic parameters of the study population (fertility, mortality, utilization rate/age class, and animal weight and value/age class), Win-mod can predict temporal changes in the population, i.e. numbers, and market weight and value. Moreover, various initial modelling parameters can be modified, while assessing the effects of these modifications on productivity. Win-mod is a simple and efficient decision-making tool which is especially useful for comparing different herd management strategies relative to specific economic objectives.*

Of these factors, the village of origin of animals, and the parturition season and year were found to be highly significant for the first two characters, while the birth season and year were significant factors for the age at the first parturition. For prolificacy, the parturition rank and interval had significant effects, i.e. litter size increased with the parturition rank and with the length of the parturition interval.

Estimated heritability and repeatability values were relatively low for all characters studied as compared with previously published data. This could be explained by the fact that reproductive performances were affected by un-

controlled environmental factors, even when the data were adjusted for specific significant factors. Production of many offspring could also have been out of line with animals' capacity to withstand the harsh environmental conditions that prevail in Senegal.

## **High-altitude rangelands in Réunion**

Cattle grazing systems provide a basis for farming activities in highland areas of Réunion.

The economy of the livestock production subsector on this island is closely dependent on the sustainability of these systems. However, grass production (quantity and quality) is very irregular during the year, which upsets the balance between feed supply and herd demand. Moreover, sown grasslands, and plant communities in general, deteriorate substantially on account of the steep slopes in these areas.

A study was conducted to determine exactly how these grasslands should be managed in order to improve feed supplies for livestock, while conserving the rangeland environment. The design of this study, developed jointly by CIRAD, INRA, and the Union des associations foncières pastorales (AFP) of Réunion, is based on a systems analysis, whereby grasslands are considered as ecosystems controlled by livestock farmers. These systems were investigated at three levels, i.e. ecological sites, farms and field plots. This involved assessing the effects of livestock farmers' practices and environmental factors on short-term control of grassy biomass and on long-term changes in the composition of plant communities on rangelands. The analyses were based on three indicators—botanical composition, mineral nutrition, and grass height—and the results were used to develop diagnostic tools useful for management decision-making: grassland sustainability, fertilization, and rotational-grazing.

With the combined use of these three diagnostic tools, grassland areas can be rationally managed, thus improving the balance between forage production and livestock consumption. This means that grass supplies can be steady throughout the year, and of higher quality, while reducing losses due to senescence in the rainy season and overgrazing in the dry season. By this approach, fertilization is adapted to the soil nutrient status and the ground is permanently protected by a thick grass cover.

Field studies were also carried out on the physiology of forage crops under various fertilization conditions.

This approach provides a dynamic view of grassland systems based on correlations between vegetation components and livestock farming practices that affect this plant cover. In addition, the experimental methods, patterns, and tools previously tested by INRA research teams in France were checked under tropical conditions. Practical operational applications were developed on the basis of the results of this study, and successively implemented by local institutions. One operation, which involves validating agronomic and botanical diagnostic analyses potentially useful for making grassland-management decisions, is currently under way on about 30 suckler and dairy cattle farms in the highlands of Réunion. In 1996, AFP, the main partner in this operation, created a new operational grassland management consultancy service, with CIRAD providing scientific support.

## Subsectors and diversification

In this programme, projects are under way on fish-farming systems, short-cycle livestock production (pigs, poultry), rearing non-traditional animal species (deer), and animal-product subsectors, e.g. dairy production. Other prime objectives are to increase wildlife meat production, investigate the domestication of new species, and promote the production of non-traditional animal species.

## Biodiversity conservation in Zimbabwe

The use of natural resources, especially big game, in the middle Zambezi valley of northern Zimbabwe, is highly controversial. Farmers often take advantage of areas that become available after tsetse-fly eradication, and quickly cultivate these savanna lands, especially to crop highly profitable cotton. The local government has the right to manage big game in the region and finances much of its budget through Campfire, a local natural resource management programme. It is, however, unable to deal with negative impacts on the fauna. The Ministry of the Environment of Zimbabwe is attempting to boost its income by increasing its control of landscape and wildlife.

CIRAD has set up a biodiversity conservation project in this context. Six thousand rural families thus earn more than FF 15 million by growing cotton, and receive almost FF 1 million for sport-hunting fees, in an area of less than 4 000 km<sup>2</sup> that contains more than 1 000 elephants and 4 000 water buffaloes. The aim of the project is to determine suitable ways of managing this mosaic of wildlife species and farming zones, and develop techniques for utilizing undomesticated biota. Following a joint assessment of the situation conducted with the Zimbabwe scientific community, the project focuses on specific means of developing and managing areas that are relatively unaffected by man's socioeconomic activities. The French-Zimbabwe research team, which is under the authority of the local government and a national steering committee, is currently working in the Zambezi valley. This project was initiated in July 1996 and will be funded for 3 years by the Fonds français pour l'environnement mondial (FFEM) and the French Ministère des affaires étrangères.



## Tropical deer production

1996 marked the 10th anniversary of the tropical deer production programme which was initially set up with the technical, scientific, and commercial support of CIRAD. The result is that deer, i.e. mainly Rusa deer (*Cervus timorensis*), are now being produced throughout Asia and the Pacific region.

In Asia, the programme is involved with the Deer Cooperative of Thailand, supervising the Thai deer subsector and providing technical support in Bangkok for handling breeding deer imported from New Caledonia. A research and training programme was also developed with Kasetsart University. Regional promotion of this programme led to the signing of a cooperative agreement on deer production with Guangxi University in southern China, and a turnkey contract with a commercial producer in the region to set up a deer-production farm.

Rusa deer are also being reared for meat in the Indian Ocean region. CIRAD is still providing technical and scientific support for a development group on deer in Réunion, and for a deer production cooperative in Mauritius.

## Theses Completed in 1996

### CIRAD Scientists

**Agroécologie des pâturages d'altitude à l'île de la Réunion : pratiques d'éleveurs et durabilité des ressources herbagères dans un milieu à fortes contraintes** [Agroecology of high-altitude rangelands in Réunion: livestock farming practices and sustainability of grassland resources in a harsh environment] by Vincent Blanfort; Université Paris XI.

### CIRAD Trainees

**Etude de la viabilité d'une pisciculture rurale à faible niveau d'intrants dans le centre-ouest de la Côte d'Ivoire : approche de réseau trophique** [Study on the viability of low-input rural fish farming in central-western Côte d'Ivoire: analysis of pond dynamics] by Lionel Dabbadie (France); Université Paris VI.

**Etude des pathologies de la crevette d'élevage *Penaeus stylirostris* en Nouvelle-Calédonie** [Study of diseases in farm-reared shrimp (*Penaeus stylirostris*)

### Three-way exchanges on fish farming

*Professionalism and technical skills, integration in farming production systems, an enterprising approach and efficient farm management, and professional organization—these are a few of the key elements that have permitted successful development of fish farming in Africa.*

*A decentralized cooperative operation, coordinated by CIRAD, is under way to promote this trend in two African countries through direct collaboration with professional NGOs, i.e. the Association des aquaculteurs (ADA) in Niger, and the Association pisciculture et développement rural en Afrique tropicale humide (APDRACI) in Côte d'Ivoire. This project was developed and assessed by CIRAD, and is receiving funding and operational support from the Centre region of France. The project provides direct support for fish-farming associations and their members, and represents a forum for three-way exchanges between fish farmers from Côte d'Ivoire, Niger, and the Centre region.*

*This 5-year project, which was initiated in October 1996, will focus on some specific themes—e.g. farm management support (Niger), professional organization (Côte d'Ivoire)—coordinated by specialized agencies from the Centre region. The Association française des volontaires du progrès (AFVP) is providing field support.*

In New Caledonia, this programme supervises production at the Etablissement des éleveurs de cerfs de Nouvelle-Calédonie, and provides technical support at the Office de commercialisation et d'entreposage frigorifique (for exporting meat), and at Sodexport (for exporting breeding animals). Deer to be exported are prequarantined by CIRAD's Port-Laguerre research station. Studies were carried out this year on quality control of meat produced for export, on agroforestry development (especially with *Calliandra* sp.) of marginal lands for rearing deer, and on promoting the introduction of wild deer in open areas along the western coast.

in New Caledonia] by Isabelle Mermoud (France); Université Montpellier II.

**Etude des relations parasites-hôtes dans l'épidémiologie moléculaire des trypanosomoses bovines au Burkina Faso** [Study of host-parasite relations in the molecular epidemiology of bovine trypanosomosis in Burkina Faso] by Jean-Marc Reifenberg (France); Université Montpellier II.

**La croissance différentielle liée au sexe chez le tilapia (Pisces : Cichlidae) *Oreochromis niloticus* (Linnaeus, 1758) : contribution des facteurs génétiques, nutritionnels, comportementaux et recherche d'un relais endocrinien** [Sex-related differential growth in tilapia (Pisces: Cichlidae) *Oreochromis niloticus* (Linnaeus, 1758): involvement of genetic, nutritional, and behavioural factors, and assessment of an endocrine relay] by Aboubacar Toguyeni (Burkina); Ecole nationale supérieure agronomique de Rennes.

**Capacité de travail, comportement à l'effort et réponses physiologiques du zébu, de l'âne et du cheval au Nord-Cameroun** [Labour capacity and behaviour, and physiological responses of zebras, donkeys, and horses in northern Cameroon] by Eric Vall (France); Université Montpellier II.

*Forestry management prospects have improved with the involvement of local authorities in natural resource development and conservation. In arid zones, the government of Niger, with which the Forestry Department has been collaborating for several years, has adopted a widely applauded hands-on strategy in its organization of rural fuelwood markets. Based on this experience, Mali also decided to get actively involved in forestry management in 1997, as part of a World Bank-funded joint project with the Department. In the humid tropics, an integrated forestry management pilot project for Dimako, Cameroon, also concluded with recommendations promoting the participation of local authorities.*

*CIRAD-Forêt is also involved in development-oriented scientific and technological research with, for instance, the Center for International Forestry Research (CIFOR) in a project to assess sustainable forest management criteria and parameters. In addition, the Department is collaborating in the FORAFRI project for the development of tropical rain forests in Africa, and in the STREK project on timber forest regeneration in Indonesia. The latter project ended with a seminar that was held in 1996—the proceedings will be published in 1997.*

*This wish to share its knowledge prompted the Department to publish a state-of-the-art report on silviculture in dry African zones. More specifically, research conducted this year in northern Cameroon and Côte d'Ivoire investigated whether planting quick-growing species could upgrade soil fertility in fallows.*

*A joint approach to management of forest areas and training is being developed through collaborations with the Ecole nationale du génie rural, des eaux et des forêts (ENGREF), the French Office national des forêts (ONF), and other CIRAD departments.*

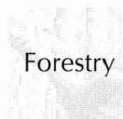
*As appears in the pages that follow, the Department is constantly striving to combine research and development activities, including partnerships and training—through management of natural forests, creation of plantations, agroforestry enhancement, and development of forestry products. ■*





Forestry





## Forestry Department CIRAD-Forêt

Director, *Jacques Valeix*  
Research Director, *Jean-Claude Bergonzini*  
Administrative and Fiscal Director,  
*Yves Danglehant*

### Research Programmes

Natural forests, *Jean-Guy Bertault*  
Forest plantations, *Philippe Vigneron*  
Agroforestry, *Bernard Mallet*  
Forest product development, *Christian Sales*

### Research Units

Silviculture and forest management,  
*Henri-Félix Maître, Jean-Pierre Bouillet*  
Biodiversity and genetic improvement, *Hélène Joly*  
Soil classification and land use, *Yves Prin*  
Wood quality and technology, *Bernard Thibaut*  
Energy and the environment, *Philippe Girard*  
Economics, *Didier Babin*  
Biometrics, *Louis Houde*

### Support Services

Scientific and technical information,  
training and communication, *Mireille Chiaverini*

### Joint CIRAD-ORSTOM-INRA Unit

Laboratory of tropical and Mediterranean  
forest symbioses, *Bernard Dreyfus*

# Natural forests

**D**iscussions on the shortcomings of initial development policies laid the foundations for an integrated forestry development concept. Forestry resources have to be rationally managed so that environmental balances will not be upset, despite considerable climatic and socioeconomic constraints. Understanding man's functional impact on one of the most complex ecosystems on our planet is a major challenge at the close of this century. This programme therefore aims at developing tools and methods for combined management and enhancement of forestry development areas.

## Protected areas in Madagascar

Studies were carried out, within the context of the first environmental plan for Madagascar, to investigate setting up new protected areas in ecologically-rich but fragile locations. Two test sites were chosen: a tropical mountain rain forest zone at Midongy-du-Sud, on the east coast, and a complex coastal zone, which includes a dry closed forest, near Belo-sur-Mer on the west coast. The work was done in collaboration with Orgasys, a local research office.

About 450 000 ha of tropical rain forest will be developed on the basis of the research results, with 70% of it conserved.

These initial studies were conducted just as the strategies and objectives of the second environmental plan were being finalized. A review of already protected areas revealed some problems in applying the plan, and the

marked imbalance between conservation and development. Preliminary discussions with local inhabitants are clearly essential, i.e. management with active involvement of local communities. The legislation was drafted, providing for a possible contractual transfer of natural resource management to traditional structures.

At Belo-sur-Mer, traditional authorities and local inhabitants were also interviewed in order to rationalize the initial research results. The survey highlighted that they were generally able to define long-term objectives for resource use in their area. For their own benefit, local communities obviously prefer to limit free access to contractual management, which means that negotiable protected areas could be set up. Belo-sur-Mer could therefore become a pilot forest conservation area.

## Management of forest ecosystems in central Africa

December 1996 marked the end of the first phase of a regional European Commission-funded project on sustainable forestry management and conservation in seven central African countries, i.e. Cameroon, Central African Republic, Congo, Equatorial Guinea, Gabon, São Tomé and Príncipe, and Zaire. This phase involved setting up a regional network of protected areas to assess the sustainability of forest ecosystems when their resources are tapped by local people. The second phase focused on wildlife conservation and development. One important thrust of the programme was to involve these communities in project activities. The Central African Republic was an original case as it had planned to develop a large forest, partly for timber production—it was therefore important that the corresponding

management strategy include regular discussions with the logging company that had been awarded this contract.

The overall area considered in this project, i.e. 825 000 ha (90% closed forest), was divided into three sectors with different specific purposes—conservation, rural development, and sustained timber production. The first sector (75 000 ha) is monitored by a team of ecoguards who enforce special protection laws. For the second sector, which is largest (565 000 ha), a programme of activities prenegotiated with local communities has been planned. The last sector includes

185 000 ha of closed forest with a broad range of tree species of high market value, e.g. sapele (*Entandrophragma cylindricum*), utile (*Entandrophragma utile*), gedu-nohor (*Entandrophragma angolense*), African walnut (*Lovoa trichilioides*) and omu (*Entandrophragma candollei*). Annual timber yields, set at 100 000 m<sup>3</sup> of standing timber, correspond to the predicted input potential of a local sawmill. This latter sector, which is divided into 10 three-plot groups, will be logged progressively over the next 30 years. Logging rotations were calculated on the basis of research results obtained at the Mbaiki site, in the Central African Republic, and in the integrated forestry management pilot project at Dimako, Cameroon.

### Management of natural forests in dry tropical zones

*Aménagements des forêts naturelles en zones tropicales sèches, published by FAO and with the participation of CIRAD-EMVT, reviews research findings and development projects that have been carried out, mainly in Africa, over the last 15 years. Possible means of reorienting activities are also presented, while specifying the initiatives that should be undertaken immediately to promote long-term management of natural forests and grazed woodland areas.*

*International interventions are discussed, along with descriptions and distributions of the main plant communities, followed by a definition of the concepts, principles, and technical imperatives for sustainable management of these natural forests. There is a state-of-the-art review of various disciplines involved. The main criteria and parameters used are then presented, in addition to the operational options and guidelines relative to the very recent international dry tropical forest initiative.*

## Forest plantations

**I**t is crucial to preserve and rationally-manage forest ecosystems in the light of the increased demand for plantation wood. The overall aim of this programme is to maintain or stimulate productivity in man-made forests. Studies have thus been conducted on plant growth potentials and improvement techniques, while assessing cropping practices, and defining analytical, production forecasting, and management procedures. Research activities are thematically focused on three structural components, i.e. the tree, the stand, and the forest.

### Stabilizing production in Congolese eucalyptus plantations

Clones used in the industrial eucalyptus plantations established in coastal savanna areas of the Congo are well adapted and productive when relatively intensive maintenance and

fertilization techniques are used. Eucalyptus trees are grown in high forests and thereafter in coppices on a 43 000 ha area. Up to 120 t/ha of dry matter is exported after each rotation of about 7 years. Eucalyptus nutrient uptake mechanisms have not yet been fully defined, but the substantial productivity obtained on these poor soils highlights a question of their potential medium- and long-term fertility.

Fertility maintenance is a prime research objective of the Congolese Industrial Plantation Production Research Unit to which CIRAD belongs. In one approach, a model is being designed to simulate the biomass production potential, based on climatic factors such as radiant energy and rainfall; the results are then compared with yields obtained using different cropping sequences. Another goal is to characterize mineral element cycles and the water balance.

Initial biomass and mineral mass in aerial and underground plant parts and changes in these levels at the end of rotations, along with physical, chemical, and biological soil features are thus being defined. In addition, flows occurring within the ecosystem are investigated, e.g. atmospheric inputs, drainage, and the dynamics of plant mineral uptake from the litter layer. The impacts of cultivation practices on plant establishment dynamics and root storage mechanisms are also assessed.

The results of these studies will be useful for adapting management strategies to soil potentials and promote sustainable forestry development.

### Rattan silviculture in Southeast Asia

Rattans are climbing palms with very long stems that yield one of the most important non-ligneous forest products of Southeast Asia. Rattan canes are used especially for making furniture and handicrafts. The fact that the international market for this product is growing, whereas the resource is faltering, prompted several Malaysian enterprises to set up large-scale rattan plantations.

Since 1989, CIRAD has been trying to overcome the lack of technical skills in these initiatives. This

#### **Singapore: a highly productive collaboration**

*The joint CIRAD-ORSTOM laboratory of tropical and Mediterranean forest symbioses has been conducting collaborative research in Singapore since 1989. In this context, a series of five French development volunteers have been involved in related research topics, utilizing symbiosis to improve the growth of Acacia mangium, which is found in commercial plantations throughout Southeast Asia. A project agreement was signed between Nanyang Technology University and CIRAD to propagate plants by cuttings, and to use aeroponic culture for the production of plants inoculated with nitrogen-fixing bacteria and mycorrhizal fungi.*

has involved the selection of plant material and development of silvicultural techniques—in partnership with Innoprise Corporation Sdn. Bhd. (ICSB), a forestry company in Sabah, Malaysia. *Calamus* species seem to be the most promising rattans. Parent and progeny tests are conducted as part of a rattan genetic improvement project.

The initial focus was on nursery techniques, e.g. germination, transplanting, shading, and fertilization. ICSB now produces 2 million plants/year. Forest experiments revealed that forest cover density is a determining factor for rattan growth. Recently-logged and still relatively clear Dipterocarpaceae forests are very suitable for planting rattans. They are enrichment-planted along forest trails, where they have the physical support and moderate shading conditions required for growth. These techniques were used in replanting about 10 000 ha of logged forest. The rattan cane produced will be processed by a company that was bought by ICSB.

Studies currently under way focus specifically on the effects of controlling lighting by thinning out unmarketable species, of soil type, topography, and stand structure.

## Agroforestry and soil conservation

A major thrust of this programme is to promote sustainable management and integrated development of agrosylvo-pastoral areas through a better understanding and optimization of interactions between

farmers, trees, crops, and livestock production. There are currently three general projects: improved forest fallows and soil fertility maintenance; optimization of overall production with agroforestry tree-and-crop associations; and management of trees and tree stands in rural areas.

In 1996, the programme was evaluated by an external review panel that included members from the International Centre for Research in Agroforestry (ICRAF), the Cameroon Institut de recherche agricole pour le développement (IRAD), the French Institut national de la recherche agronomique (INRA), and CIRAD. The recommendations highlighted the need to increase the number of staff involved in the programme so as to strengthen the projects under way and improve its national and international status.

### Improved forest fallows in Côte d'Ivoire

In Côte d'Ivoire, studies are being conducted, in collaboration with the Institut des forêts (IDFOR), to clarify and then reinforce the functions of short-duration forest fallows, i.e. boost the cropping capability of soils, and enable farmers to profit by collecting and utilizing the wood grown in these forest fallows. This is in line with agronomic strategies.

In forest and savanna regions, tests were carried out under controlled conditions in research stations to compare wood and litter production, growth and regeneration modes, and the efficiency of symbiotic systems in about 20 shrub legume species. The most promising species were then assessed in terms of their effects on the fertility and cropping capabilities of poor soils, and on the behaviour and productivity of food crops planted in cleared and recultivated fallow fields.





### ***Faidherbia* stands**

**Les parcs à *Faidherbia*, coedited by CIRAD, ORSTOM, and the Conférence des responsables de recherche agronomique en Afrique de l'Ouest et du Centre (CORAF), and published in the Cahiers scientifiques series, is a multidisciplinary review of research conducted over the last 10 years in several Sudano-Sahelian countries in Africa. These studies covered *Faidherbia albida* regeneration, growth, production, ecophysiology, impact on soils and crops, introduction into farming systems, and planting and management procedures. The results of research studies, conducted by specialists in agroforestry, genetics, agronomy, geography, anthropology, and socioeconomics, were enriched with empirical information obtained through surveys of farmers and observations on various farming systems. This pluralistic approach provides development organizations with backup information that will be useful for the management of Sudanian and Sahelian agroforestry areas.**

In forest regions, shrub legumes can produce almost 100 t/ha of dry wood in 6 years, and 5–7 t/ha/year of dry litter, i.e. 100–200 kg/ha of nitrogen. The effect on food crops seems to be similar to that of traditional slash-and-burn farming systems on natural-regeneration fallows. Soil fertility in cropping systems can be improved by integrating trees, which helps in recycling leached minerals and fixing atmospheric nitrogen.

Food crops and charcoal, produced after quick-growing legume species were experimentally introduced in fallows near Abidjan,

could provide an interesting source of income for local periurban farmers. In the central region, farmers grow shrub legumes to help regenerate their cocoa trees. Other studies, focusing on land tenure, the structure of fuelwood subsectors, and the institutional and legislative situation, were aimed at developing a suitable agroforestry management strategy for rural areas through modifications in farmers' cropping practices.

## **Tree management in savanna regions of Cameroon**

Agroforestry studies carried out by IRAD, in collaboration with CIRAD as part of the Garoua

project in northern Cameroon, are aimed at sustainable management of natural resources and farming systems in rural areas. These investigations, which have been under way for about 15 years, have touched on various functions of natural-regeneration and planted trees growing in cropped fields or in relatively unmodified shrub savanna ecosystems.

Interesting conditions for the production of wood and forage were delineated in grazed woodland experiments conducted at Laf (Cameroon). A woody plant layer, producing off-season wood and forage, can develop over a grazeable grass layer when rainy-season burning and grazing, selective fuelwood cutting, and planting potential tree stands are carefully managed.

Many performance trials with woody plants were carried out in different soil-climate zones within the northern Cameroonian cotton belt. A wide range of shrub and tree species proved of interest for various potential uses, such as: production of construction wood and fuelwood, tree-and-crop associations, refertilization of degraded soils, rehabilitation of sterile land with degraded soil, establishment of quick-growing hedges, and stabilization of antierosion structures. Further in-depth studies were focused on introducing improved fallows in cotton and cereal crop rotations—to reduce mineral depletion in ferruginous soils, and subsequent clearing of virgin tree savanna zones.

These studies revealed a promising development outlook. Acacias could be used to refertilize ferruginous soils, but the saplings would have to be protected from browsing livestock, and an alternative to tree felling, which is a more restrictive means of tapping this resource, should be used. Undoubtedly, the most cost-effective sequence for farmers would involve marketing the gum

arabic, felling the trees, then replanting. Planting *Eucalyptus camaldulensis* and *Cassia siamea* trees for fuelwood and poles could also be beneficial.

## Forest product development

For the efficient use of wood, i.e. as construction material or raw material to generate energy for domestic or industrial purposes, it is essential to have an overall understanding of its properties and behaviour, to create products that are fully adapted to market needs, to develop well-adapted processes, and to transfer this know-how to Southern countries. The aim of this programme is to meet the increasing wood requirements of developing countries—for housing, communication infrastructures, and domestic and industrial energy. Another challenge is to help develop village communities and local administrations by promoting their forest products on regional, national, and international markets.

### Natural durability of torrefied wood

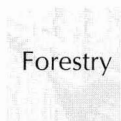
Using plantation woods for industrial-scale manufacturing of joinery has two major advantages: preserving natural forest resources; and easy-access to a uniform and cost-effective raw material.

While pretreating wood can protect it from external modifications and improve some physical features, the chemicals used (e.g. polychlorophenols) are generally toxic and polluting when discarded. Moreover, restrictive legislation will soon be passed to control the use of these products. CIRAD, in collaboration with the French Centre technique du bois et de l'ameublement (CTBA), the Finnish Valtion Teknillinen Tutkimuskeskus (VTT), CIDEMCO (a Spanish technological research centre), and commercial manufacturers, have developed a more ecologically-acceptable alternative involving thermal treatment of wood at higher than 200°C.

Thermal treatment (torrefaction) can improve the natural resistance of plantation woods that are relatively fragile or difficult to chemically-impregnate, e.g. limba (*Terminalia superba*), curupixa (*Micropholis* spp.), poplar (*Populus* spp.), and spruce (*Picea abies*), thus protecting them from insect pests, fungi, and harsh environmental conditions (high humidity, temperature fluctuations, etc.). This process also improves the dimensional stability of wood, which means that joinery or garden-furniture manufacturers have ready access to material that meets all of their performance requirements, and at relatively low cost.

A European Commission-funded project, jointly coordinated by CIRAD, CTBA, and VTT, is already under way. The biological, physical, and mechanical properties of curupixa, spruce, and poplar, have been investigated to establish optimal thermal processing parameters.

This environment-friendly process could be extended to other tropical plantation species such as eucalyptus. Many research organizations are interested, including the Indonesian Forest Products Research and Development Center (FPRDC).



## Decorative wood panelling from French Guiana

Barely more than 100 tree species grow in France, whereas the rich flora of French Guiana includes more than 1 000 different tree species. There are very low supplies (volume/ha) of each species, despite the impressively high diversity, but many forest woods from this French overseas department, e.g. purpleheart (*Peltogyne* spp.), letterwood (*Brosimum guianense*), and satinwood (*Brosimum rubescens*), have the

advantage of being high added-value niche products. These very decorative woods are used by craftspeople, sculptors, and cabinet makers. Two different strategies were adopted to make optimum use of this material.

First, technical procedures for making veneers (ranging from one-tenth to a few millimetres in thickness) were studied in laboratory conditions. Ten common species that produce tropical woods representative of the very wide range of woods available in French Guiana (from structurally very light to very dense) were investigated. After the green timber is steamed or boiled, the uncoiled veneers should not be damaged or deformed.

This process will now be simulated in the laboratory to determine optimal processing parameters for each separate species.

Secondly, around 100 species were preselected on the basis of their esthetic qualities. A practical handbook is being published to help investigators in identifying these species. A data/image bank and a veneer catalogue will also be available. These tools will be useful for decision-making, in collaboration with manufacturers. Chosen species are to be tested in a veneer cutting and uncoiling laboratory that was set up at Kourou by CIRAD, in collaboration with the French Centre national de la recherche scientifique (CNRS), the Université Montpellier II (France), and the Ecole nationale supérieure des arts et métiers (ENSAM) of Cluny (France).

There are also plans to build a veneer manufacturing plant in French Guiana. These technological advances could be further utilized to process tropical woods from Amazonian forests and Africa.

### Wood research and industrial processing

*The 4th Wood Science and Industrial Processing Colloquium was held in Nancy (France) from 11 to 13 September 1996, and attended by about 100 francophone research scientists, along with manufacturers, and foreign scientists. Five topics were on the agenda: wood formation and quality, and characterization; industrial woodworking, conditioning and improvement processes; processing and production optimization techniques; wood construction innovations and developments; and woodworking industries and the environment.*

*Papers presented by CIRAD research scientists stressed the characteristics of 'abnormal' wood, and the mechanical performance of wood. These discussions focused on: the characterization of immature wood; correlations between growth stresses and reaction wood properties; the effects of temperature on the mechanical performance of green wood; and classification of construction timber from French Guiana.*

## Theses Completed in 1996

### CIRAD Scientists

**Evolution du comportement mécanique du bois vert avec la température : application à l'étude du tranchage et du déroulage de quelques bois guyanais** [Temperature-dependent variations in the mechanical performance of green wood: applications for the study of cutting and uncoiling of veneers made from some French Guiana timbers] by Jacques Beauchêne; Ecole nationale du génie rural, des eaux et des forêts (Kourou, French Guiana).

**Structure dynamique et fonctionnement des parcs à *Faidherbia albida* (Del.) A. Chev. : caractérisation et incidence des facteurs biophysiques et anthropiques sur l'aménagement et le devenir des parcs de Dossi et de Watinoma, Burkina Faso** [Dynamic

structure and functioning of stands of *Faidherbia albida* (Del.) A. Chev. Characterization and effects of biophysical and socioeconomic factors on the management and ultimate uses of Dossi and Watinoma parks, Burkina Faso] by Denis Depommier; Université Paris VII.

**Prédiction des valeurs génétiques, cartographie génétique et recherche de Qtl dans un croisement interspécifique *Eucalyptus urophylla* x *Eucalyptus grandis*** [Genetic value prediction, genetic mapping and QTL analysis in a *Eucalyptus urophylla* x *Eucalyptus grandis* interspecific cross] by Daniel Verhaegen; Université Paris XI.

CIRAD Trainees

**Variabilité de la qualité des bois d'une essence guyanaise : l'angélique** [Variations in the quality of wood from a French Guiana forest species: basralocus] by Isabelle Bonjour (France); Ecole nationale du génie rural, des eaux et des forêts (Montpellier, France).

**Estimation de l'intensité locale d'un processus ponctuel de Cox : application à l'analyse spatiale d'un inventaire forestier** [Evaluation of the local intensity of a punctual Cox process: application in digital mapping for a forest inventory] by Hélène Dessard (France); Université Montpellier II.

**Evolution de la diversité génétique intrapopulation et de sa structure : étude d'un modèle de simulation spatialisé en vue de la gestion des ressources génétiques forestières tropicales** [Intra-population genetic diversity and structure variations: study of a simulation-mapping model designed for the management of tropical forest genetic resources] by Agnès Doligez (France); Institut national agronomique de Paris-Grignon.

**Distribution spatiale des espèces forestières de Kalimantan Est en relation avec la topographie et la nature des sols** [Spatial distributions of forest species from East Kalimantan relative to the topography and soil type] by Sumaryono Moeljo Soeparto (Indonesia); Université Paris VI.

**Hétérogénéité spatiale des structures en forêt naturelle de basse altitude à Sumatra, Indonésie** [Spatial heterogeneity of lowland natural forest structures in Sumatra, Indonesia] by Valérie Trichon (France); Université Toulouse III.

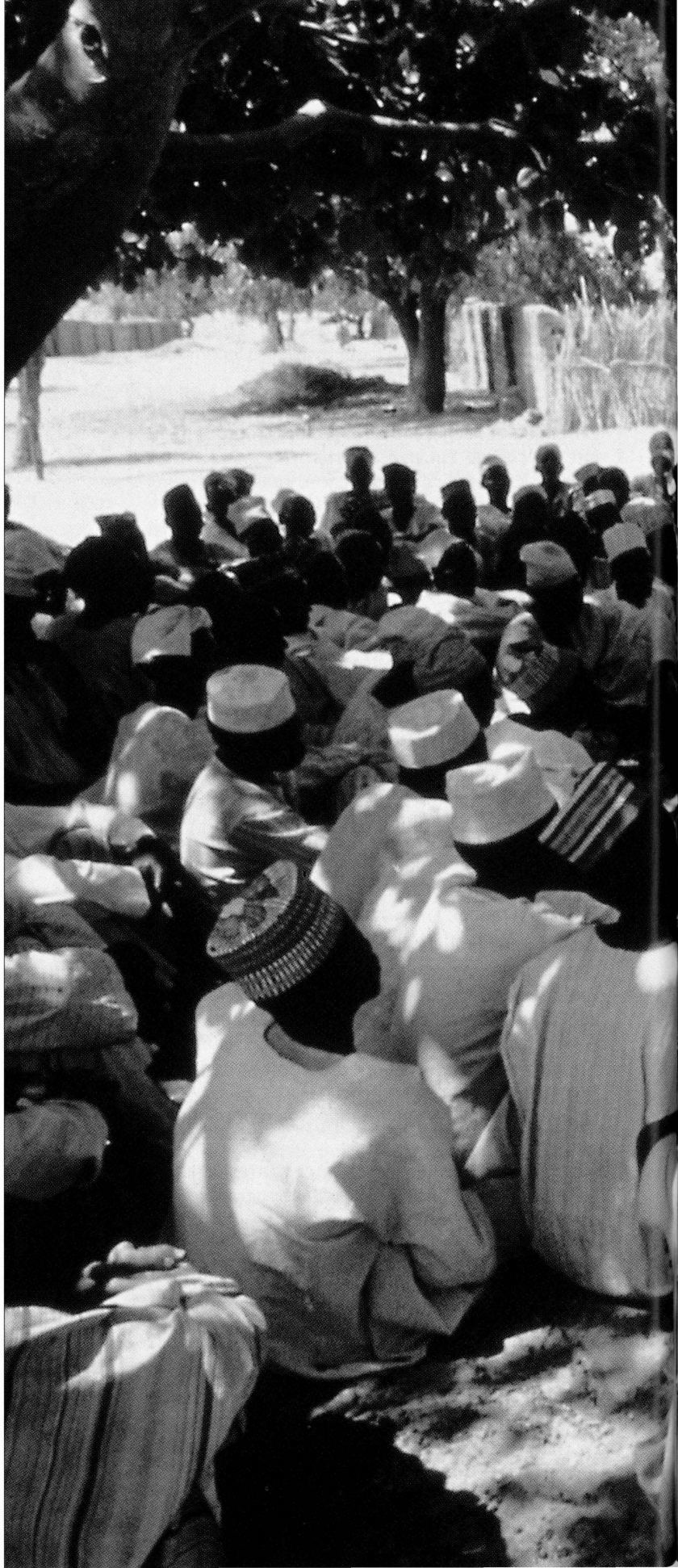


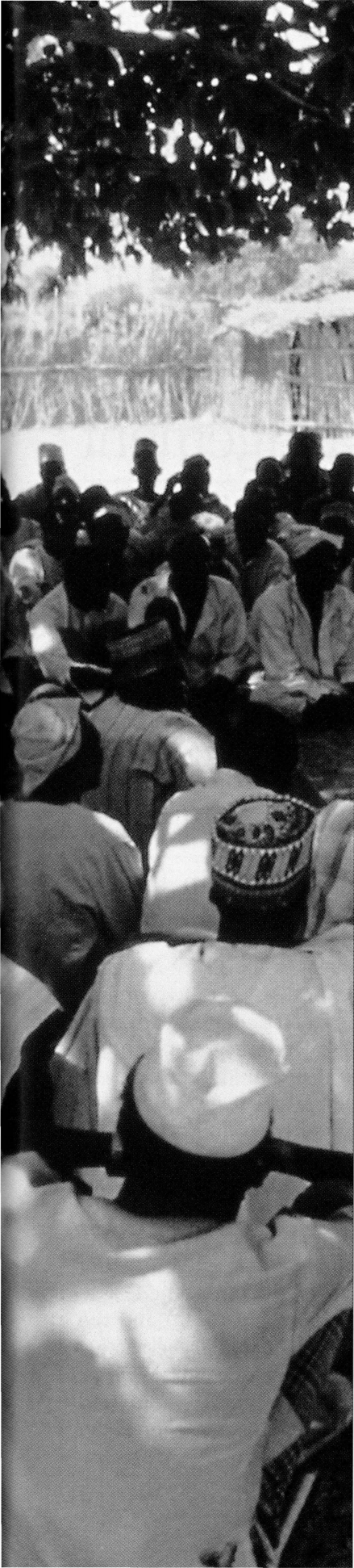
*In a context of strong competition, population growth, and increasing pressure on natural resources, producers and food processors have to use their resources effectively and adapt their production methods to the risks posed by the vagaries of climate, economics, and marginalization.*

*The CIRAD-SAR Department and its partners are carrying out research to analyse the changing environment of smallholder farms and farmer organizations in order to be able to identify their constraints and provide innovative solutions. These innovations focus particularly on processing farm produce, improving food conservation, and marketing in order to maximize the value added to the products from farms or family businesses.*

*In order to reduce risks and adapt to changes, information needs to be well managed and made available at the right time. The Department is involved in developing information management systems and decision-making aids that will be useful for decision-makers and development workers. It is contributing to the establishment of technical and socioeconomic databases for development and farmer organizations. Through its economic research on agricultural extension services, it is also involved in developing management methods for farms and food-processing units.*

*The role of national agronomic research is changing fast: state intervention is being reduced, and development organizations need to adapt to work with the new rural development structures. The Department is contributing to this evolution with its research on different methods of providing institutional support for rural development. ■*





# Food Technology and Rural Systems

## Food Technology and Rural Systems Department CIRAD-SAR

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Deputy Director, *Vincent Dollé*  
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*Jean-Philippe Tonneau*  
Food technology, industries, and markets,  
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*Anne-Lucie Wack*  
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*Pierre-Yves Le Gal*  
Economics of rural systems, *Philippe Bonnal*  
Socioeconomics of innovations in rural systems and  
food technology, *Jean-Michel Yung*

### Support Services

Documentation, *Marie-Dominique Lafond*  
Publications, *Monique Pellecuer*  
Computer services and biometrics, *Michel Passouant*  
Training and communication, *Jean-Luc Mazot*

# Farming and rural land management

The aim of agricultural development is no longer solely to produce higher yields but now also includes improving quality, optimizing production costs, and conserving renewable resources. A new approach to management, especially for decision-making, is required. The programme focuses on individual and group decision-making on a plot, farm, area or regional level.

## Local development in Tunisia

Integrated rural development projects have existed in marginal areas of Tunisia for 20 years. These projects generally have two major objectives: to set up infrastructure (roads, irrigation, water and soil conservation) and to increase agricultural production. However, where the infrastructure has been well developed, it is often underused and returns on investment are low. These problems stem from poor project design, inadequate farmer participation, and inappropriate technology.

At the request of the Tunisian Ministry of Agriculture and with funding from the Caisse française de développement (CFD) and the International Fund for Agricultural Development (IFAD), research and development units were set up in the provinces of Kef, Sidi-Bouzyd, and Siliana. The aim of these units is to change the

way that projects are organized. The programme includes monitoring and evaluation, studies of agrarian systems, technical follow-up research, and participatory trials. The Groupe de recherche et d'échanges technologiques (GRET) and French and Tunisian non-governmental organizations are also involved in the programme.

The long-term aim is for the units that manage these projects to act as regional development agencies. They will act as observers, provide support for the design and carrying out of projects, and participate in the organization of farmers by creating regional interprofessional planning structures.

To help launch these activities, a training course in Languedoc-Roussillon was organized in which project representatives learned about the principles and organization of research and development.

## Smallholdings in Brazil

In some areas of Brazil, developing small-scale agriculture is the only way to provide rural populations with an economic role, to reduce migration, increase food supply, and improve social justice. Ninety per cent of farmers are smallholders and, until now, public organizations have largely failed to take them into account.

In 1993, the Empresa Brasileira de Pesquisa Agropecuária (EMBRAPA) created a programme for small-scale agriculture. CIRAD, with the support of the French Ministère des affaires étrangères, is coordinating the scientific aspects of this programme. This work is an extension of the research and development work that

began in the 1980s in the Nordeste region. The programme has developed progressively and now covers a wider area, involving research on new technical themes and collaboration with other partners. For example, in the Nordeste region, the study of milk production, processing, and marketing in the state of Sergipe led, in 1996, to the development of agricultural policy measures, the creation of extension services, and quality improvement with a network of small-scale cheese producers.

In the *cerrados*, the agricultural extension services for farmers and farmer organizations, which focus particularly on management advice, now cover a wide area in the form of pilot projects set up by the Brazilian Ministry of Agriculture. The experience gained from this project has contributed to discussions concerning the organization of public and private agricultural extension services.

In Amazonas, in collaboration with EMBRAPA and the Universidade Federal do Pará, trials were conducted on processing the pulp and beans of cupuaçu (*Theobroma grandiflorum*). New forms of technical organization and human resource management were tested in the production units.

Lastly, in southern Brazil, CIRAD is collaborating with the Empresa de Assistência

## African agriculture and animal traction

*Agriculture africaine et traction animale (African agriculture and animal traction), published with funding from the French Ministère de la coopération and the Centre technique de coopération agricole et rurale (CTA), is a guide for development workers in intertropical Africa. It puts the mechanical aspects of animal traction in the context of production systems, distinguishing it from other publications that concentrate on technical aspects. It deals with the factors involved in developing animal traction, draught animals and their management, types of harness, cropping practices, equipment and its maintenance. This publication is designed to advise and train farmers and takes into account their needs and constraints.*



Técnica e Extensão Rural (EMATER) in the state of Rio Grande do Sul on a research project on intervention methods in areas undergoing agrarian reform.

## Food technology, industries, and markets

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Consumer patterns, particularly in fast-growing urban areas, are changing and there is now a demand for a wider range of food products. The food technology, industries, and markets programme aims to diversify the food use of local produce as a way of adding value, creating jobs, and providing income. It is also developing methods of advice and management aids for small- and medium-sized food-processing enterprises.

### Promoting tropical starch products

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In developing countries, food security is based on the production of food crops such as roots, tubers, and plantain. CIRAD, the Institut national de la recherche agronomique (INRA), and the Institut français de recherche scientifique pour le développement en coopération (ORSTOM) have expertise in this field and the PROAMYL programme has brought them together to form an interorganizational network. The aim of this

network is to orient research and development work to the demands of the market for human and animal consumption, and industrial use. A unit was created in 1996 to identify the demand for research and development, to locate the expertise able to respond to that demand, and to set up projects. The unit promotes the PROAMYL programme among partners in developing countries, donors, and research and development organizations.

In addition to its role as coordinator and in developing international contacts, PROAMYL has carried out a number of other activities. It conducted a market and sector study of arrowroot (*Maranta arundinacea*), with the aim of boosting arrowroot production in Saint-Vincent-et-les Grenadines. It was involved in organizing a project to transfer sour starch technology from Colombia to Benin, in collaboration with the faculty of agronomy at the Université nationale in Benin, and to Côte d'Ivoire, in collaboration with the Ecole nationale supérieure des industries agricoles et alimentaires (ENSIA), and a private company from the Côte d'Ivoire. It took part in the organization of a congress on roots and tubers with the Centro de Raízes Tropicais (CERAT) and the Universidade Nacional do Estado de São Paulo (UNESP) in Brazil. A number of other research and development projects are being planned, including a project on adding value to cassava which will be conducted jointly with IFAD and the Common Fund for Commodities (CFC).

### Disseminating food-processing expertise

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Offering a diverse range of products to urban consumers is a way of adding value to local food resources. This diversification can come

from the adoption of know-how from neighbouring countries. In West Africa, a project was developed by the Université nationale of Benin, the Centre national de la recherche scientifique et technologique (CNRST) in Burkina, and the Senegalese branch of Environnement, développement, action dans le tiers-monde, groupes de recherche action formation (ENDA-GRAF), an international non-governmental agency, to exchange culinary practices between these three countries.

Food-tasting sessions were conducted in restaurants to test the acceptability of different products. Twenty potential products (based on maize in Benin, fruit in Senegal, and West African locust beans in Burkina) were selected. The country with the know-how trains a woman from a neighbouring country, and she, in turn, teaches other women in her own country. In 1996, the first women trainers passed on their knowledge to 242 other women, who are, in turn, training more women. These new restaurateurs are now recognized and are starting to set up associations. Twenty different organizations are working on the project and there are already 560 members. The products, which are of a higher hygiene standard, are selling well and the main area that needs improvement is the packaging. A database has been installed on the CIRAD website server so that the network partners can exchange information. Mali will join the network in 1997.

In Burkina, CNRST is providing technological support to small-scale food-processing businesses, with methodological backup being provided by CIRAD. A federation of organizations that support these small-scale establishments was created in 1996 to encourage exchanges between its members. Surveys were conducted to identify the constraints and the needs of 120 businesses in Ouagadougou, and

inventories of equipment and procedures were carried out in 50 establishments. The activities were adapted to individual businesses: identifying the business project, improving quality or reducing costs. In 1997, further surveys will be carried out to examine the quality of the products sold in towns and to identify the marketing strategies used by innovative businesses.

### **Salting, drying, and smoking fish**

*Salting and drying fish with the dehydration-impregnation process, which involves immersion in a salt and sugar solution and electrostatic smoking, is significantly faster than traditional methods (3.5 hours for salmon instead of 15 hours) and can be carried out continuously.*

*In 1996, the bath immersion equipment was replaced by a "shower", that is easier to use continuously and requires less chemical solution. In 1996, CIRAD applied for a patent on this original technique.*

*An industrial prototype was developed with funding from the Agence nationale de valorisation de la recherche (ANVAR) and tested in industrial conditions. The equipment manufacturer Arbor Technologie has acquired a production licence.*

*The process is being studied in Réunion and New Caledonia for salting, drying, and smoking local fish in small-scale production units.*

## **Institutional support**

**T**he role of rural development organizations is undergoing major changes due to the decline in state intervention. It is important to encourage private and public rural development organizations to provide more appropriate support that meets farmers' needs. The programme, in partnership with public research institutes and agricultural extension services from six Central American countries

and four West African countries, is working on redefining the roles and functioning of these development organizations.

## Research, extension, and farmer organizations

In West Africa, systems for consulting with farmer organizations are being set up to transform the public services and to ensure that research and extension services serve farmers' interests effectively. Major institutional changes

are required in order to achieve this.

### Transferring expertise in India

*For 2 years, CIRAD has been exchanging expertise in computer-assisted design (CAD) and field metrology with the Central Institute of Agricultural Engineering (CIAE) in Bhopal, which is the agricultural machinery department of the Indian Council of Agricultural Research (ICAR). This work has been funded by the French Embassy in India.*

*The initial exchange of researchers enabled an analysis of CAD software to be carried out and for two Indian scientists to be trained in the use of three-dimensional imaging software used by CIRAD. Following these contacts, CIAE created a team in 1996 to coordinate equipment design activities and to work with this software. CIRAD's equipment design method is now being applied to develop new equipment.*

*In the field of metrology, two Indian scientists were trained in Montpellier to use the electronic measuring system developed by CIRAD for collecting data on animal-drawn or power-driven equipment. In 1997, the collaboration will focus on creating a second team to test equipment.*

CIRAD is taking part in the design of new procedures and methods of organization for agricultural development programmes. This work is financed by the World Bank, Caisse française de développement (CFD), and the French Ministère de la coopération. The objective is to ensure that the farmers' voices are heard and that representatives of farmers' organizations participate in the decision-making of the organizations that are there to help them. CIRAD is collaborating in the development of a consultation procedure and the setting up of a partnership between research,

extension, and farmers' organizations. This will encourage exchanges between countries at similar stages of development, evaluate the different experiences of coordination between rural organizations, and assess the impact of these partnerships on the performance of research and extension services.

This programme is being set up with research and extension services in Mali, Senegal, Burkina, and Guinea.

## Land reform in the French overseas territories

CIRAD has been asked to undertake a study on land reform in the French overseas territories by the Centre national pour l'aménagement des structures des exploitations agricoles (CNASEA), a public institution that is part of the French Ministère de l'agriculture, in the context of an international seminar on land reform that will take place in Réunion in 1997.

The aim of the land reform process, which began in 1961, was to replace the large plantations of the "sugar islands", which were often farmed by sharecropping, with smallholder farms. The objectives were twofold: to achieve social development and to regenerate agricultural production. The process gathered momentum in the 1970s with the establishment of Sociétés d'aménagement foncier et d'établissement rural (SAFER), which carried out most of the transfers. Each transfer involved three stages: purchase, development, and then redistribution of lots with priority given to the former plantation workers and sharecroppers.

The study was carried out in Réunion and Guadeloupe. Réunion is the best example as it is both the oldest and largest of the land reform

programmes with more than 40% of the island's cultivable land redistributed. In Guadeloupe a smaller but nonetheless significant area of land has been transferred (20–25% of cultivable land) that demonstrates a range of different land reform methods in a Caribbean context. A comparative analysis of the effects of land reform will identify the conditions necessary for success and the potential for extending or reorienting land reform in the future.

## Theses Completed in 1996

CIRAD Scientists

**Les évolutions dans l'occupation de l'espace et l'utilisation des ressources en zone agropastorale sahélienne : le cas de la province du Soum, au nord du Burkina Faso** [Changes in the use of land and resources in a cropping and grazing area in the Sahel: the case of Soum Province in the north of Burkina Faso] by Patrick d'Aquino; Université de Provence Aix-Marseille I.

**Proposition d'une démarche de conception posant les bases de la trajectoire technologique d'un futur équipement dans les pays du Sud** [Forward-planning in new conceptions of design for equipment in developing countries] by Stéphane Degres; Ecole nationale des arts et métiers, Paris.

**Régulation d'une production en situation d'incertitudes et de fortes contraintes : exemples des systèmes rizicoles du lac Alaotra (Madagascar)** [Stabilizing production in conditions of uncertainty and severe constraints: examples from the rice-growing systems of Lake Alaotra (Madagascar)] by Raphaële Ducrot; Institut national agronomique de Paris-Grignon.

**Vers un nouveau rôle pour l'Etat et les institutions privées dans le développement du système financier rural indonésien** [Towards a new role for the State

and the private sector in the development of the rural financial system in Indonesia] by Cécile Lapenu; Ecole nationale supérieure agronomique de Montpellier.

**Organisations et stratégies des petites entreprises agroalimentaires à Maroua (Nord Cameroun)** [Organizations and strategies in small-scale food-processing businesses in Maroua (northern Cameroon)] by Elisabeth Lopez; Université Paris X.

**L'organisation alimentaire et urbaine au Bénin : l'approvisionnement de Cotonou en produits vivriers** [Food and urban organizations in Benin: the supply of food products to Cotonou] by Claire Thuillier-Cerdan; Université Paris X.

CIRAD Trainees

**Etude des trajectoires d'activités agroalimentaires du sud et de l'ouest du Cameroun** [Study of future developments in food processing in south and west Cameroon] by Paul-Charles Bom Kondé (Cameroon); Université Lyon II.

**Mise en forme et caractérisation de biomatériaux à base de protéines myofibrillaires** [Formation and characterization of biomaterial based on myofibrillar proteins] by Bernard Cuq (France); Université Montpellier II.

**Bactéries lactiques isolées de l'amidon de manioc : physiologie de la croissance en milieu solide et liquide, analyse de la diversité génétique et production de polysaccharides exocellulaires** [Lactic bacteria isolated from cassava starch: physiology of growth in a solid and liquid medium, analysis of the genetic diversity and production of exocellular polysaccharides] by Carlos Figueroa (Mexico); Institut national agronomique de Paris-Grignon.

**Transitions thermiques de l'amidon de manioc en milieux peu hydratés** [Thermal transition of cassava starch in a slightly hydrated medium] by Véronique Garcia (France); Institut national agronomique de Paris-Grignon.

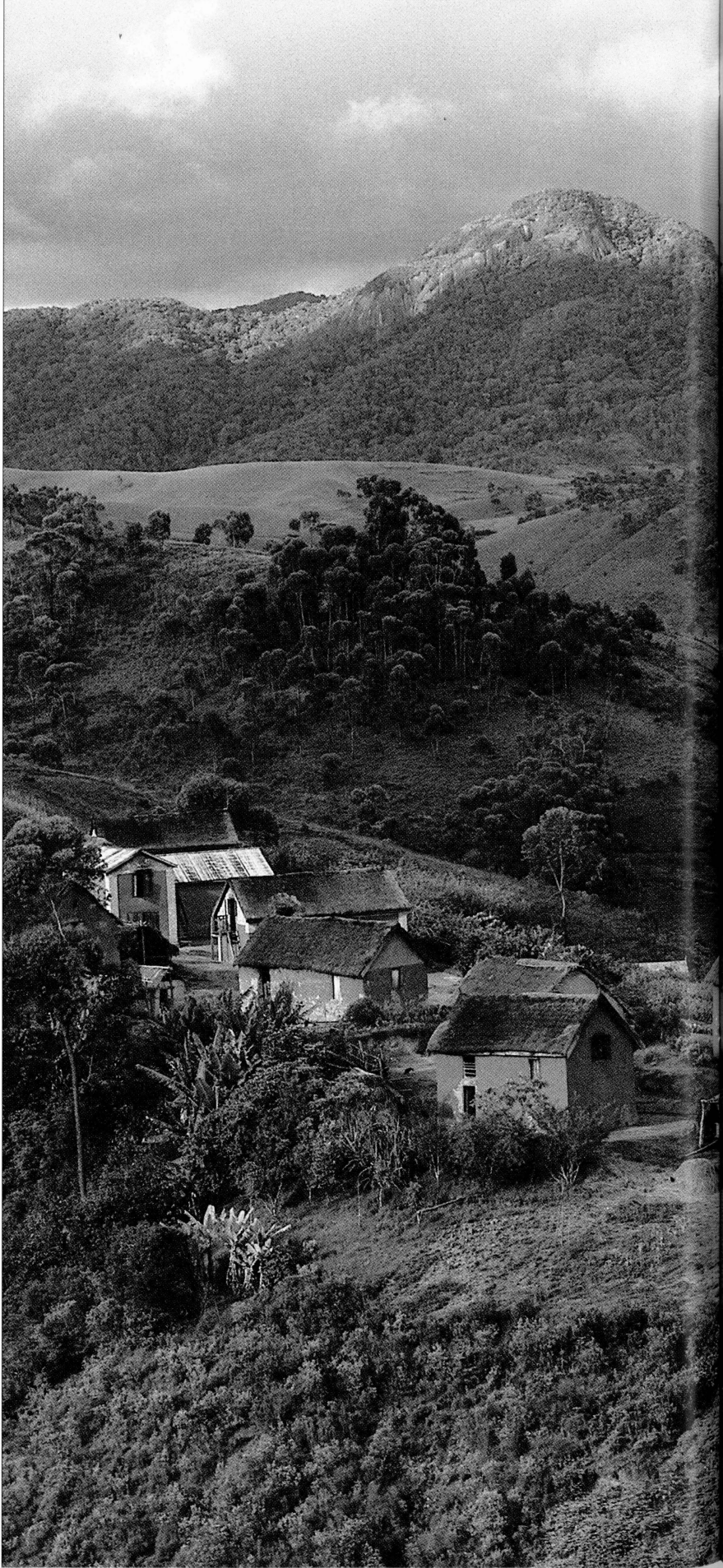


*The CIRAD-GERDAT Department brings together research programmes and units that aim to develop expertise and new methods to support the scientific projects carried out by other CIRAD departments and its partners. In 1996, the Biotechnology for tropical crop improvement unit developed a method for identifying new genes encoding insecticide toxins in *Bacillus thuringiensis*. Progress made in genome mapping has led to more precise marker-assisted selection techniques. The Plant modelling unit is studying new methods of breeding perennial species using architecture models. The Renewable resources management unit and the Soil and plant analysis unit have been studying the functioning of irrigation systems, the former by simulating farming systems taking into account farmer behaviour, and the latter by studying the evolution of irrigation water in these systems. The research units are also involved in practical research that can be applied directly in the field. For example, the Locust research programme is working on control of the Mato Grosso locust and the Plant modelling unit has produced a software package for predicting wood quality.*

*The Department's units and laboratories also provide training for scientists, particularly those from developing countries.*

*This work is an integral part of CIRAD's mandate and has been enhanced by the creation of a European Master's degree (graduate university level) in Operational Acridology.*

*One of the highlights of the year was the World Food Summit organized by FAO. The Agricultural policies and outlook studies unit was involved in developing the French position at the summit, and in organizing discussions on the role of research in solving the problems of world food security and poverty. ■*





# Management, Common Services and Laboratories, and Documentation

Management, Common Services and  
Laboratories, and Documentation  
Department  
CIRAD-GERDAT

Director, *Jacques Meunier*  
Research Director, *Philippe de Reffye*  
Administrative and Fiscal Director,  
*Vincent Fabre-Rousseau*

#### **Research Programmes and Units**

Locust research, information, and training,  
*Michel Launois*  
Biotechnology for tropical crop improvement,  
*Jacques Schwendiman*  
Plant modelling, *Philippe de Reffye*  
Agricultural policies and outlook studies,  
*Michel Griffon*  
Renewable resources and environment management,  
*Jacques Weber*  
Soil and plant analysis, *Paul Fallavier*

#### **Support Services**

Training, *Marc Roesch*  
Scientific and technical information,  
*Jean-François Giovannetti*  
Computer services, *Joël Sor*  
Physical plant and maintenance, *Didier Servat*

## Locust research, information, and training programme (Prifas)

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**T**he aim of this programme is to find effective methods of control for locust and grasshopper pests in tropical regions. Its activities are based on a sound knowledge of field conditions and insect bioecology. In 1996, significant results were achieved in managing outbreaks of a Brazilian locust and in the preventive control of desert locusts. One of the programme's main priorities is training and 1996 saw the creation of a European Master's degree in Operational Acridology.

### Control of the Mato Grosso locust

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The Mato Grosso locust *Rhammatocerus schistocercoides* is rife in Brazil, causing most damage to agriculture in the states of Mato Grosso and Rondônia, and is also a problem in Colombia and Venezuela. For 4 years, Prifas has been carrying out research on this locust in collaboration with the Empresa Brasileira de Pesquisa Agropecuária (EMBRAPA) with funding from the European Commission. The research has involved a series of bioecological investigations that have led to a better understanding

of the ecology and life cycle of this pest. A number of techniques, including satellite imaging, have been used to map the extent of outbreaks of *R. schistocercoides* in Mato Grosso in order to be able to identify the correlations between cropping and grazing land use and locust outbreaks. The phenologic state of the vegetation, estimated from satellite data, will provide the basis for a new index for evaluating the quality of the environment for the locust. This index, combined with estimates of the probability of locust outbreaks and knowledge of the species' life cycle, will be used for medium- and long-term forecasting. A new strategy for controlling locusts is being proposed which consists of destroying hopper bands found close to cropland instead of destroying swarms. There are also a number of other methods, notably biological control, that could be developed to control this pest.

### Trials with a new acridicide

In 1996, Prifas published the results of a series of trials carried out in Mauritania, Niger, and Russia to test the efficacy of fipronil, a pesticide from the phenylpyrazol family. The trials were carried out at different dose rates and under near-field conditions. Dose rates as low as 0.5 g/ha eliminated many different grasshopper species. Fipronil remained active for 8–30 days depending on the dose rate (from 1–13 g/ha of active ingredient). As a result of these properties, it was decided to test the efficacy of fipronil using the barrier treatment. Bands of desert locust hoppers were destroyed using drift spraying by helicopter with passes every 2 000 m on thousands of hectares. With an average dose rate of no more than 1 g/ha, this treatment is cost-effective and has limited environmental impact. The results of the

work done by Prifas on the effect of fipronil on nontarget fauna has led to recommended dose rates of 1–2 g of active ingredient/ha. Hymenoptera and Coleoptera populations have at least as much chance of recovering from a fipronil treatment as from the non-persistent organophosphate and pyrethroid insecticides that are currently being used to control locusts.

### **Natura Master's degree in Operational Acridology**

*A new European Master's degree in Operational Acridology has been created by Prifas in collaboration with the Centre national d'études agronomiques des régions chaudes (CNEARC) and the Interstate Committee for Drought Control in the Sahel (CILSS), under the aegis of Agropolis and the European university network, Natura (European ecological network of "special areas of protection"). This Master's degree is aimed at training high-level professionals in locust and grasshopper management and is made up of eight modules on locusts and crop protection and a 5-month practical training period. There is also a professional project that exists to put the theory into practice. The course will draw on the expertise of a number of French and international organizations and is scheduled to start in 1998.*

## Biotechnology for tropical crop improvement

**T**his unit (Biotrop) specializes in the micropropagation of tropical species, genetic transformation, research on useful genes, and genome mapping. In 1996, significant progress was made in all of these areas. This is illustrated below with examples from rubber and rice.



## Mapping the rubber genome

CIRAD has been carrying out studies on the natural rubber genome for several years in order to evaluate the potential of marker-assisted selection. This method of selection could be particularly useful for the programme for improving cultivated clones that are being bred for long-term resistance to *Microcyclus ulei*, a fungal parasite of leaves, which is a problem for rubber production in South America. The first stage is to construct a gene map for rubber, which has a haploid genome made up of 18 chromosomes. Two incomplete maps based on restriction fragment length polymorphism (RFLP) markers have been constructed from two

lines created in collaboration with the Institut des forêts (IDEFOR) in Côte d'Ivoire.

The first line, which is made up of 73 individuals, is the result of the self-pollination of a high-yielding clone, PB 260. Linkage analysis was carried out on 210 molecular markers of this line and 23 linkage groups were identified. Agronomic data on latex production and tree growth will be collected for this line and compared with the genetic map in order to identify the quantitative trait loci (QTL), the areas of the genome that relate to quantitative characters.

The second line is the result of a cross between PB 260 and a clone resistant to *M. ulei*, found on an expedition to the Amazon forest. Half of the 200 individuals that make up this line have been analysed using 270 molecular markers. The map that was constructed from this information is concordant with the map for the first line, even though it contains only 20 linkage groups. In Guyana, resistance measurements have been taken from young plants from this line that had been artificially inoculated with two isolated colonies of fungi. Comparison of genetic data with resistance measurements for the same individuals has revealed the presence of QTL involved in resistance to *M. ulei*. These are the first QTL to be identified in rubber.

These studies on the rubber genome show that rubber behaves like a diploid and that few loci are duplicated. They have also led to the development of 30 microsatellites, which is the first time that this has been achieved with rubber. These markers are well-adapted for large-scale use because the protocols and equipment are less complex than with the RFLP markers.

## Genetic transformation of rice

CIRAD has adopted a new technique for the genetic transformation of rice. This technique, which involves bombarding the embryogenic callus with microprojectiles, was developed by the International Laboratory for Tropical Agriculture Biotechnology (ILTAB), that was established by the Institut français de recherche scientifique pour le développement en coopération (ORSTOM) and the San Diego Scripps Institute in the United States, and is now fully operational. All the plants that have been

### New toxin genes discovered by using polymerase chain reaction (PCR)

*PCR is a method for rapidly detecting the presence of known nucleotide sequences (for which there are specific primers) that, for example, encode insecticide toxins present in colonies of B. thuringiensis. However, it is unable to detect new, potentially useful genes. In 1996,*

*CIRAD developed a technique that will make it possible to detect new toxin genes. This new technique was tried on cloned genes and on known colonies of B. thuringiensis and then tested successfully on a collection of 250 colonies of B. thuringiensis. A new gene that resembles Cry1B was detected using this technique. Most of the sequence of this gene has now been identified and the specificity of the toxin that it encodes will soon be tested on insects.*

obtained using this technique are fertile, which was not the case with protoplast transformation, the previous technique used. The new technique has been successfully used on cultivars of Mediterranean and tropical rainfed rice to transfer genes resistant to herbicides (ammonium glufosinate) or *B. thuringiensis* endotoxins. It is now in routine use and more than 1 000 transgenic plants have been created.

The second aspect of research on the genetic transformation of rice concerns the study of the action and specificity of promoters (sequences that regulate the expression of a specific gene) when they are inserted into the rice plant. This work is part of an interorganization thematic research project on cloning promoters that have a spatio-temporal role. The first promoter, that of maize streak virus, specific to vascular tissues, was identified and cloned in 1995. This year, three new promoters have been studied. The promoter for the maize protease inhibitor (MPI) gene has been successfully transferred in work carried out in collaboration with the Consejo Superior de Investigaciones Científicas (CSIC) in Barcelona. When the plant is damaged, this promoter is induced at the site of the lesion as well as in the rest of the plant. This promoter could be associated with genes that are resistant to borer and leaf-eating insects. The promoter for the gene that encodes a lipid transfer protein (LTP) in rice was successfully inserted into rice, in work carried out in collaboration with the Centre national de la recherche scientifique (CNRS), Perpignan. This promoter is specific to the epidermis and is induced by fungal attack. After fusion with genes that defend the plant against pathogenic fungi, this promoter should lead to the expression of resistance in the epidermis. The third promoter, for the bread wheat puroindoline gene, was identified as part of a programme to analyse the genes expressed in cereal grains carried out with the Institut national de la recherche agronomique (INRA),

Montpellier. This promoter demonstrated a specificity for the albumen and aleuron layers in the grain and could be used to increase the nutritional value of wheat or to modify reserve proteins. Studies are also being carried out on promoter dissection (functional dissection) in order to identify the sequence that determines the specificity and the induction capacity of each promoter.

## Plant modelling

The objective of this unit is to develop our understanding of plant architecture and to apply this knowledge to agronomy and other fields, such as computer-generated images. In 1996, the unit completed work on a system for simulating the architecture and growth of plantation trees, which enables the internal structure and potential timber-producing capacity of trees to be visualized. The unit also began an interorganization thematic research project on the applications of plant modelling to tree crops improvement. Lastly, the unit is adapting its computer image software for commercial use in more diverse fields.

### Predicting wood quality

CIRAD has developed a number of software packages to simulate the architecture and growth of plantation trees, which make it possible to predict the external appearance of trees. CIRAD has also just developed a new software package for predicting the internal characteristics of trees

### Restoring former landscapes

*Computer image software developed by CIRAD makes it possible to simulate future landscapes, but it can also be used to reconstruct former landscapes. It is therefore being used increasingly to reconstruct lost archaeological sites. In Tahiti, at the request of the Direction territoriale de l'équipement and in collaboration with the Centre des sciences humaines de Polynésie française, CIRAD has adapted its simulation software to the vegetation of a sacred archaeological site that existed on the island before the arrival of Europeans. The necessary parameters have been collected in order to model some 30 indigenous plant species. This work could provide the basis for the restoration of the site. It will be followed by the reconstruction of horticultural landscapes associated with the human colonization of the Marquesas Islands.*

(trunk and branch structures) and, therefore, wood quality.

Based on silvicultural parameters (plantation density, pruning, tree size, fertilizer use, etc.), environmental constraints (climate, competition between trees), and tree type (clone, hybrid), this software simulates the development of growth rings. Using a virtual sawmill, it is then possible to visualize the rings and knots on the planks or veneer that would be produced.

This software was developed with a grant from the European

Commission and is one of the first achievements of the CIRAD-INRA forestry partnership, that was formalized in 1995. Although still at the experimental stage, a number of timber research centres have already shown an interest, and it is planned to develop this software further.

### Tree crops improvement using model-assisted selection

The improvement of tree crops requires large areas of land for conducting trials, involves long production cycles, and is therefore expensive. In order to offset these problems, CIRAD plans to use the systems developed by the Plant modelling unit for analysing and simulating tree growth and production.

This innovative approach should enable the early identification of the architectural parameters that predict the tree's potential yield or its vulnerability to external factors. It is based on establishing correlations between growth strategies and the expression of characters of economic interest. Sophisticated procedures will be used in the trials for observation, taking measurements, and to estimate the heritability of parameters for architectural development. Architecture modelling could become an integral part of conventional improvement programmes for tropical tree crops.

A related interorganization thematic research project is planned using plant architecture modelling. It involves botanists, biometricians, mathematicians, and geneticists and will focus on rubber, coffee, and eucalyptus. The methodology that will be developed could be applied to other tree crops of economic importance in the future.

## Agricultural policies and outlook studies

**T**his unit has two principal areas of research: agricultural policy and food security. In 1996, tools and methods for agricultural policy decision-making were developed: MATA (Multi-level analysis tool for the agricultural sector), a model for assessing the impact of economic policies on different

agricultural sectors; and CADIAC (Cadenas y diálogo para la acción), a method for planning agricultural policies by sector, developed as part of a cooperation programme in Latin America.

The unit has played an important role in the debate on food security with international organizations. These discussions are based on the results of outlook studies, most of which predict that there will be an alarming food shortage in certain areas of Africa and Asia at the beginning of the next century despite a sufficient global food supply. These predictions coincide with a period of instability on world markets, which is sometimes interpreted as being the first sign of a coming shortage.

CIRAD was involved in the preparation for the World Food Summit, organized by FAO in Rome in November 1996, and took part in developing the position that France was to adopt at the summit. In September 1996, a conference was organized in Montpellier entitled "Feed the world, reduce poverty", where the issues to be discussed at the FAO summit were presented to French scientists, nongovernment organizations, and the press.

CIRAD also participated with the association Solidarités agricoles et alimentaires (SOLA-GRAL) in the organization of a European Commission seminar on "Policies for food security: long-term prospects". In December 1995, the European Commission completed a major reform of its policy on food aid. Since then, European aid has been used for development and is integrated into the food security policies of beneficiary countries. Following this reform, the Commission organized a seminar in April 1996 to bring together the officials responsible for food aid from the European Union Member States, international organizations, and the main development agencies. The

participants identified the similarities and differences of the forecasts made by the food security studies and considered different plans of action. There were discussions on how to coordinate the food aid policies of the various aid agencies and on a European strategy that will take into account the existing policies for the different sectors and the Commission's own development policies.

#### **Towards a doubly-green revolution: seminar proceedings**

*The seminar on the doubly-green revolution was a highlight of the year 1995. It was organized by CIRAD and the Fondation innovation et perspective at Futuroscope in Poitiers and brought together scientists and decision-makers from developed and developing countries to debate food security and the management of the world's natural resources. The seminar proceedings, which include the papers presented and details of the ensuing debates, have recently been published.*

## Renewable resources and environment management

**I**n 1996, this unit (Green) consolidated the achievements of its first 2 years of work. Two examples illustrate the progress that has been made: in Madagascar, where Green was involved in local resource management; and in Senegal, where it focused on the simulation of an irrigation system.



## Legislation for local resource management in Madagascar

The law that was passed on 11 September 1996 provides Madagascar with a legal framework for the local management of renewable resources. It is hoped that this will put an end to the situation of free access that prevails on the main island, which is the cause of the decline in plant and animal biodiversity. This law is the outcome of action that mobilized the entire Madagascan community and also involved CIRAD.

In 1994, CIRAD was asked by the Office national de l'environnement de Madagascar to look into the problem of the human occupation of

protected areas and to coordinate a national symposium on the issue. There was consensus on the need to manage the problem by negotiating with local communities in order to draw up a contract between these communities and the State. This approach, which is considered appropriate for the whole of the main island, was the origin of the project for the law on local management of renewable resources. This project made provision for transferring control of access and management of most of government land (more than 90% of all land) to local communities. In order for this local manage-

ment to work, the concessions granted to the communities had to offer exclusive rights of use, which meant that the property laws needed changing. The local communities also needed to have the legal right to sign contracts. A tax on extraction was required in order to finance the infrastructure necessary for local management. It was vital that professional mediators help local communities to negotiate and draw up management contracts. The 1996 law meets all these criteria.

CIRAD also participated in the assessment of Madagascar's second environmental plan, which begins in January 1997. Establishing a system of local management is a major part of this plan. Green helped develop a long-term management plan for the Mananara UNESCO biosphere reserve on the northeast coast. Green is involved in the analysis of the dynamics of bush fires and in the contract management of protected areas and forests. This work has enabled Madagascan and French students to be trained and has led to the establishment of firm partnerships with the Université d'Antananarivo and the Centre national de la recherche appliquée au développement rural (FOFIFA). The second environmental plan, and the local management of resources in particular, represent a major step forward for environmental management in Madagascar.

## Simulation of an irrigation system in Senegal

Following the construction of a number of large dams on the Senegal river, irrigation systems have been developed. In collaboration with the Institut sénégalais de recherches agricoles (ISRA), the Ecole supérieure polytechnique de Dakar, and the Pôle systèmes irrigués (a regional research centre for Sudano-Sahelian irrigation systems),

### Indicators of sustainable development

*There are many definitions for sustainable development and trying to establish the criteria and indicators for what constitutes sustainable development is a controversial subject.*

*In order to establish a strict set of criteria, CIRAD took part in a mission organized by the Center for International Forestry Research (CIFOR) to test the relevance of these indicators in Cameroon.*

*CIRAD also supervised a course at the Ecole polytechnique on the indicators for the interactions between people and the environment.*

*Lastly, CIRAD is coordinating a team research project involving 30 research scientists on forest cover, forest dynamics, and deforestation.*

*One of the main themes of this project is indicators.*

*This research aims to provide indicators for evaluating the interactions between the natural and the human environment, which are not catered for by the current indicators of sustainable development.*

CIRAD carried out a simulation of an irrigated farming system using artificial intelligence.

This simulation focused on the flow and distribution of water as a function of the current local rules governing water use. The exchange of information and services between farmers was then taken into account. These exchanges of services alter the perception of the importance of water and demonstrate the importance of the circulation of money in the dynamic of the system. The smallholders' financial situation (their debts to organizations, shopkeepers, family members, or other farmers) was therefore taken into consideration. The simulation shows that the flux of debts is at least as important as the flow of water for the future viability of irrigated farming systems.

This work will lead to the creation of a standard model that can be applied to all types of irrigated farming systems. The work has enabled CIRAD to develop fruitful partnerships with the Université de Dakar and ISRA that have resulted in the development of courses for Senegalese students, and future collaborative projects are planned. These partnerships will ensure that the simulation tools and methods are adopted by the local people.

## Soil and plant analysis

**T**his unit has three complementary objectives: to carry out physicochemical analyses, to undertake research to improve the quality of these analyses, and to train

scientists from developing countries to use these techniques. The tools and the expertise developed by the unit are used in the thematic research programmes carried out in collaboration with teams from CIRAD, ORSTOM, and INRA.

The unit carries out physicochemical analyses on a wide range of substances: soils, plants, animal feed, water, fertilizers, culture substrates. The demand for carrying out analyses rose by almost 10% in 1996, with nearly 20 000 samples tested. This sector is undergoing considerable changes as regulations now require laboratories to formalize their systems for guaranteeing service quality. The unit has established new procedures to conform with these quality standards.

### Aluminium toxicity in tropical acid soils

The results of the European Commission-funded project on the adaptation of maize to tropical acid soils were published in 1996. Another programme on the adaptation of maize to cropping systems on tropical acid soils, which is also funded by the European Commission, began at the end of the year. The collation of laboratory and field results led to the ranking of maize varieties according to their susceptibility to aluminium toxicity, which will be extremely useful to plant breeders. The European partners for this research are INRA in France, Hannover University in Germany, and the Universidad Autònoma de Barcelona in Spain, and the partners in the tropics are the national agricultural research institutes: INRA in Guadeloupe, EMBRAPA in Brazil, the Institut de la recherche agronomique (IRA) in Cameroon, and CORPOICA in Colombia. ORSTOM is also now involved in research on this subject.

## Degradation of irrigated soils in arid regions

The risks of soil degradation in arid and semi-arid regions is closely linked to the composition of irrigation water and the changes in water composition when water collects. CIRAD and the Institut d'économie rurale (IER) are conducting field studies on this subject in Mali. The unit is providing expertise to determine how the water changes (becoming more alkaline, neutral, or acid) using chemical analysis and thermodynamic models. More laboratory research is

required in order to identify the thermodynamic constants that form the basis of these models, in particular the constants for precipitation and mineral-dissolving kinetics. A review of the current knowledge in this field has been carried out in collaboration with INRA and ORSTOM in preparation for a 3-year programme that will be one of the sections of an interorganization

thematic research programme on the association of geochemical and hydrological models.

### Training in analytical techniques

*CIRAD and ORSTOM are focusing their research on methods for characterizing the surface properties of acid soils and soil solution analysis. In 1996, joint training activities were organized and several trainees were taken on.*

*Two chemistry scientists from the Bangkok soils department in Thailand were trained in techniques for soil solution analysis (extraction, analysis, speciation). A scientist from Nankin Institute of Soil Science, in China, undertook research on correcting the acidity of red soils.*

**modèle** [The action of roots in aluminium mobilization: analysis of the functioning of a model system] by Henri Calba; Ecole nationale supérieure agromique de Montpellier.

CIRAD Trainees

**Etude des relations structure-fonction chez les endotoxines de *Bacillus thuringiensis*** [Study of the relation between structure and function of *Bacillus thuringiensis* endotoxins] by Cécile Rang (France); Université Montpellier II.

\* The Department's research units also supported many thesis studies listed with other CIRAD departments.

## Theses Completed in 1996\*

CIRAD Scientists

**Action des racines sur la mobilisation de l'aluminium : analyse du fonctionnement d'un système**

# CIRAD at a Glance

Organization chart

Committees

Research coordination

Regional representatives

CIRAD worldwide

Budget and personnel

CIRAD training



# Organization Chart



**Board  
of Trustees**  
President  
*Guy Paillotin*



**Director  
General**  
*Bernard Bachelier*



**Scientific  
Advisory  
Committee**  
Chairman  
*Alain Pavé*



**Secretary General**  
*Michel Eddi*

## Department Directors



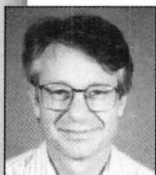
**Director, Research**  
*Michel Dron*



**CIRAD-CA**  
*Hubert Manichon*



**CIRAD-CP**  
*Patrice de Vernou*



**Director,  
External Relations**  
*Henri Rouillé  
d'Orfeuill*



**CIRAD-FLHOR**  
*Jean-Pierre Gaillard*



**CIRAD-EMVT**  
*Joseph Domenech*



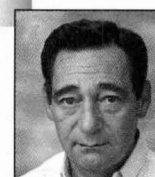
**CIRAD-Forêt**  
*Jacques Valeix*



**Director, Montpellier  
Research Centre**  
*Gérard Matheron*



**CIRAD-SAR**  
*Jean Pichot*



**CIRAD-GERDAT**  
*Jacques Meunier*

# of CIRAD in 1997

## General Administration

French Overseas Departments  
and Territories

*François Pointereau*

Internal auditor

*Antoine Bourgeois*

French Overseas Department  
and Territories

Centre

Representatives

(see page 91)

## General Secretariat

Accounts and finance  
*Marc Gélis*

Business and  
social relations  
*Danielle Bonneau*

Legal affairs  
*Hervé de Font-Réaulx*

Computer services  
*Joël Sor*

Physical plant and  
maintenance  
*Didier Servat*

## Scientific and Technical Information

Head  
*Jean-François Giovannetti*

Publications  
*Martine Séguier-Guis*

Library  
*Marie-Gabrielle Bodart*

Automatic information  
systems  
*Jean-François Foucher*

## Research Administration

Deputy Director  
*Jacques Meunier*

## Research Coordination

Crop and environment  
management  
*Eric Malézieux*

Plant improvement  
*Dominique Nicolas*

Plant protection  
*Jean-Loup Notteghem*

Animal production  
*Philippe Lhoste*

Technology  
*François Challot*

Economics and sociology  
*Michel Griffon*

Biometrics  
*Xavier Perrier*

## Forward and Strategic Studies Unit

*Marie de Lattre*

## Training Service

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Caribbean  
*André de Courville*

Asia, South Pacific  
*Patrick Safran*

International organizations,  
North Africa,  
Middle East

*Pierre-Luc Puglièse*

Overseas representatives  
(see page 91)

Relations with  
the private sector  
*Christian Brunin*

Relations with donors  
*Alain Guyot*

Communication:  
Publicity  
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 French Polynesia, **Jean-Jacques Baraer**, *Representative*  
 Guadeloupe, **Emmanuel Camus**, *Representative*  
 Martinique, **Philippe Melin**, *Representative*  
 Mayotte, **Bernard Leduc**, *Correspondent*  
 New Caledonia, **Daniel Bourzat**, *Centre Director*  
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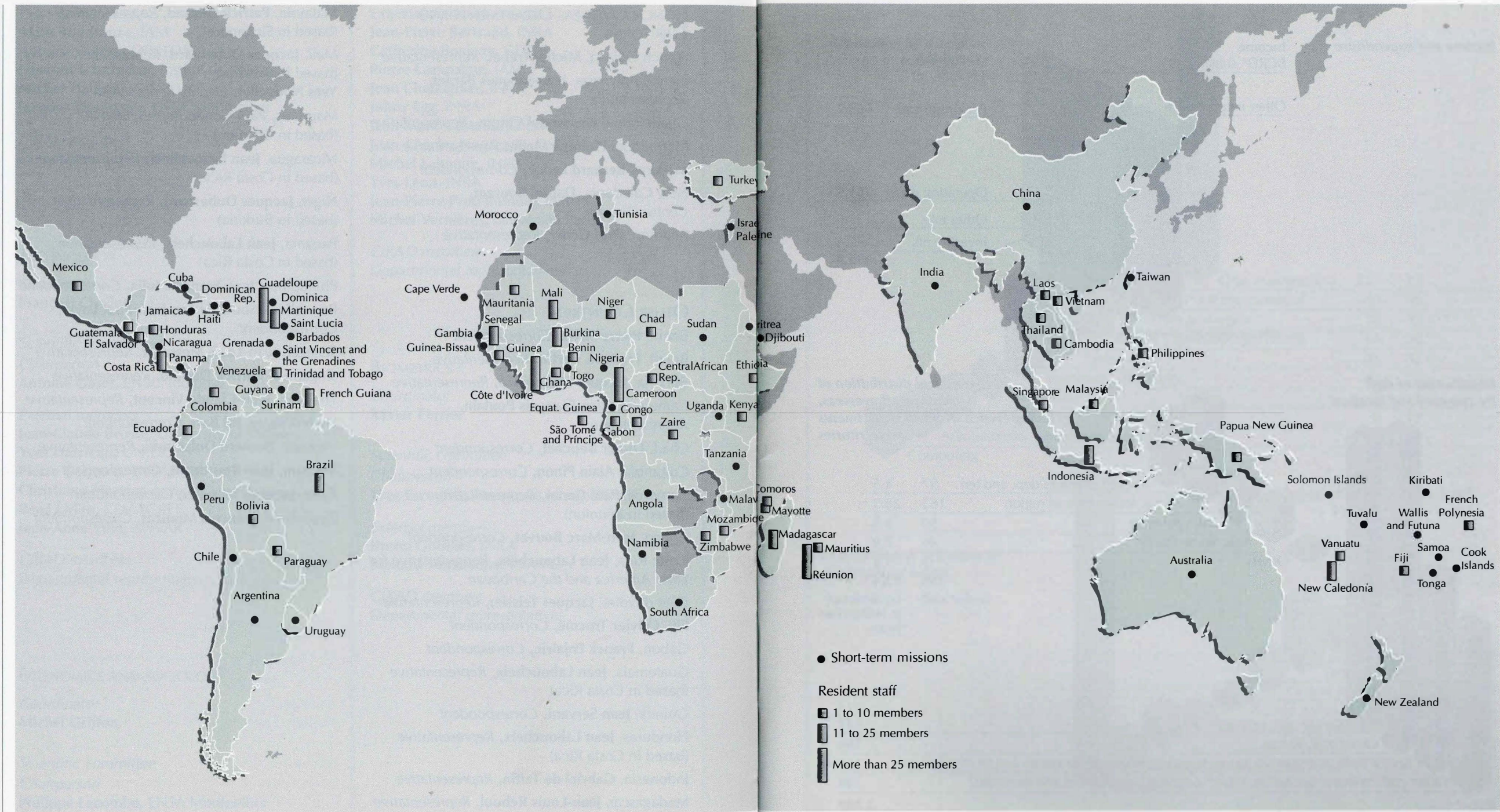
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 Gabon, **Franck Enjalric**, *Correspondent*  
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**Yves Nouvellet**, *Deputy Representative*  
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 Vietnam, **Jean Bourdeaut**, *Correspondent*  
 Zaire, **Jacques Monnier**, *Correspondent*  
 Zimbabwe, **François Monicat**, *Correspondent*



CIRAD Worldwide





## 1996 Budget and Personnel

### Income and expenditure

#### Income

BCRD\* subsidy 69%

Other income 31%

#### Expenditure (FFr million)

Personnel exp. 663.7

Operating exp. 261.9

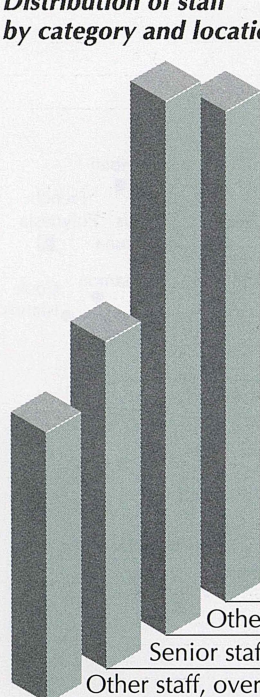
Other exp. 33.6

Investments 37.6

**996.8**

\* Civil research and development budget.

### Distribution of staff by category and location



Senior staff, France 541

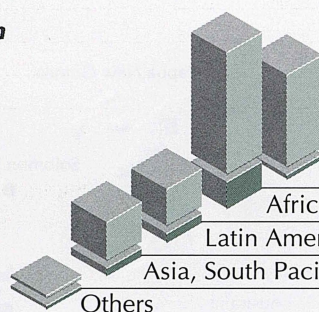
Other staff, France 589

Senior staff, overseas (including French overseas departments and territories) 359

Other staff, overseas (including French overseas departments and territories) 298

**1 787**

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



French overseas dep. and terr. 97 4.5

Africa, Indian Ocean region 163 28.3

Latin America 50 9.3

Asia, South Pacific 46 7.9

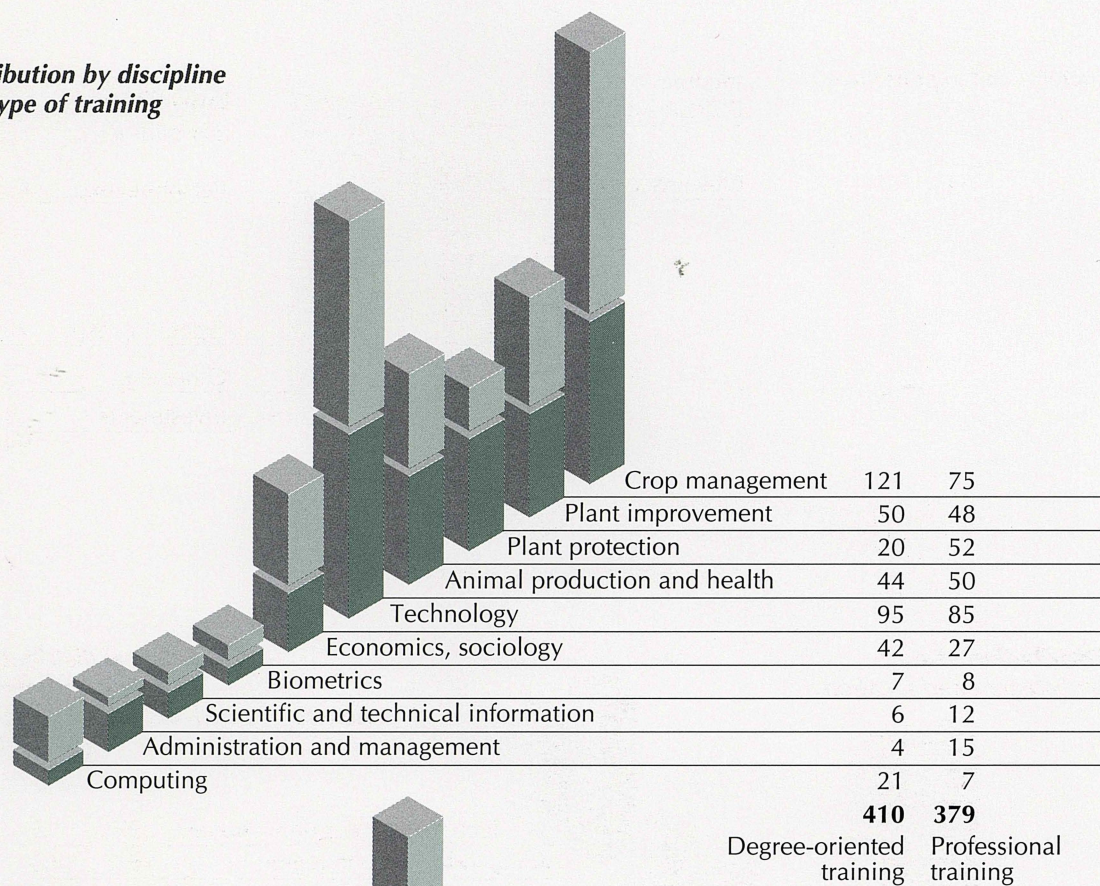
Others 3 3.4

**359 53.4**Senior staff Equivalence  
in researcher  
years

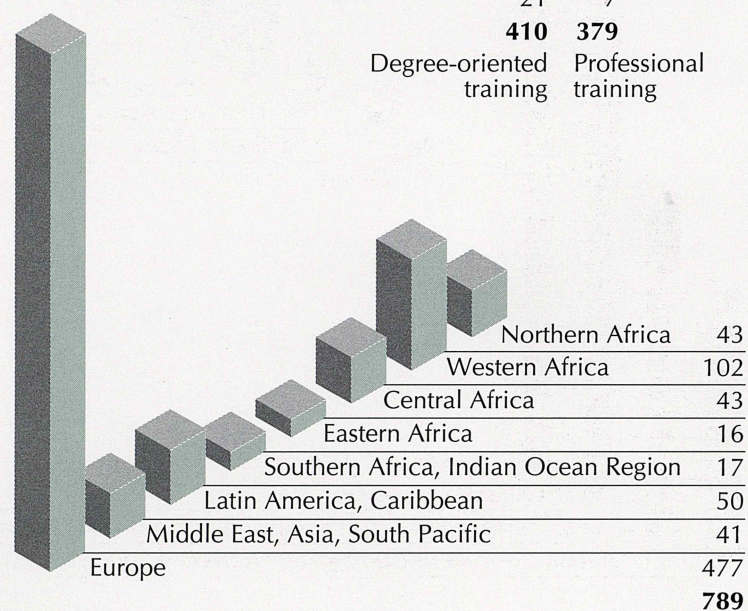


# CIRAD Training in 1996

*Distribution by discipline  
and type of training*



*Distribution of scientists by  
geographical origin*



# Annexes

CIRAD addresses

List of acronyms



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## List of Acronyms

AB-DLO, Research Institute for Agrobiology and Soil Fertility, The Netherlands

ADA, Association des aquaculteurs, Niger

AFDI, Agriculteurs français et développement international, France

AFP, Association foncière pastorale, France

AFVP, Association française des volontaires du progrès, France

ANRA, African Natural Rubber Association, Côte d'Ivoire

ANVAR, Agence nationale de valorisation de la recherche, France

APDRACI, Association pisciculture et développement rural en Afrique tropicale humide, Côte d'Ivoire

APR, Association pour la promotion en milieu rural, France

ARI, Advanced Research Institution

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

AVRDC, Asian Vegetable Research and Development Center, Taiwan

BURGEAP, Bureau d'études de géologie appliquée et d'hydrologie souterraine, France

CAH, Commissariat à l'aménagement des Hauts, France

CATH, Centre d'appui technique à l'hévéaculture, Gabon

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

CEAO, Communauté économique de l'Afrique de l'Ouest, Burkina

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

CERAT, Centro de Raízes Tropicais, Brazil

CERDI, Centre d'études et de recherches sur le développement international, France

CFC, Common Fund for Commodities, The Netherlands

CFD, Caisse française de développement, France

CFDT, Compagnie française pour le développement des fibres textiles, France

CIAT, Centro Internacional de Agricultura Tropical, Colombia

CIFOR, Center for International Forestry Research, Indonesia

CILSS, Permanent Interstate Committee for Drought Control in the Sahel, Burkina

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

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

CMDT, Compagnie malienne pour le développement des textiles, Mali

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

CNER, Comité national d'évaluation de la recherche, 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

CORPOICA, Corporación Colombiana de Investigación Agropecuaria, Colombia

CPAC, Centro de Pesquisa para Agricultura do Cerrado, Brazil

CRBP, Centre régional bananiers et plantains, Cameroon

CSIC, Consejo Superior de Investigaciones Científicas, Spain

CTA, Technical Centre for Agricultural and Rural Cooperation, The Netherlands

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

EIARD, European Initiative for Agricultural Research and Development

EMBRAPA, Empresa Brasileira de Pesquisa Agropecuária, Brazil

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

ENSA, Ecole nationale supérieure agronomique, France	INRAN, Institut national de recherches agronomiques du Niger, Niger
ENSAIA, Ecole nationale supérieure d'agronomie et des industries alimentaires, France	INRO, International Natural Rubber Organization, Malaysia
ENSAM, Ecole nationale supérieure des arts et métiers, France	IRA, Institut de la recherche agronomique, Cameroon
ENSC, Ecole nationale supérieure de chimie, France	IRAD, Institut de recherche agricole pour le développement, Cameroon
ENSIA, Ecole nationale supérieure des industries agricoles et alimentaires, France	IRRI, Indonesian Rubber Research Institute, Indonesia
FAO, Food and Agriculture Organization of the United Nations, Italy	IRRI, International Rice Research Institute, Philippines
FARA, Forum of Agricultural Research in Africa	IRZV, Institut de recherches zootechniques et vétérinaires, Cameroon
FFEM, Fonds français pour l'environnement mondial, France	ISABU, Institut des sciences agronomiques du Burundi, Burundi
FOFIFA, Centre national de la recherche appliquée au développement rural, Madagascar	ISRA, Institut sénégalais de recherches agricoles, Senegal
FPRDC, Forest Products Research and Development Center, Indonesia	LUADP, Lao Upland Agriculture Development Project, Laos
GEVES, Groupement d'étude et de contrôle des variétés et des semences, France	NARS, National Agricultural Research System
GIAF, Groupement interprofessionnel des agrumes et des fruits, Tunisia	NRI, Natural Resources Institute, UK
IAM, Institut agronomique méditerranéen, France	ONDR, Office national de développement rural, Chad
IARC, International Agricultural Research Centre	ONF, Office national des forêts, France
ICAC, International Cotton Advisory Committee, USA	ORSTOM, Institut français de recherche scientifique pour le développement en coopération, France
ICAR, Indian Council of Agricultural Research, India	PCA, Philippine Coconut Authority, Philippines
ICCO, International Cocoa Organization, UK	PORIM, Palm Oil Research Institute of Malaysia, Malaysia
IDEFOR, Institut des forêts, Côte d'Ivoire	PROMECAFÉ, Programa Cooperativo Regional para la Protección y Modernización de la Caficultura, Costa Rica
IER, Institut d'économie rurale, Mali	SACCAR, Southern African Centre for Cooperation in Agricultural and Natural Resources Research and Training, Botswana
IFAD, International Fund for Agricultural Development, Italy	SOLAGRAL, Solidarités agricoles et alimentaires, France
ILTAB, International Laboratory for Tropical Agriculture Biotechnology, USA	UNIDO, United Nations Industrial Development Organization, France
INA-PG, Institut national agronomique Paris-Grignon, France	VTT, Valtion Teknillinen Tutkimuskeskus, Finland
INERA, Institut de l'environnement et des recherches agricoles, Burkina	WARDA, West Africa Rice Development Association, Côte d'Ivoire
INIFAP, Instituto Nacional de Investigaciones Forestales y Agropecuarias, Mexico	
INRA, Institut national de la recherche agronomique, France	

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