CIRAD
1992

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The Centre de coopération internationale en recherche agronomique pour le développement (CIRAD) is a French research organization that specializes on agriculture in 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 about 50 countries. Its budget amounts to approximately FFr1 billion, more than half of which is derived from public funds.

CIRAD is made up 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, documentation). CIRAD operates through its own research centres, national agricultural research systems, or development projects.

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Research and Cooperation

It is only a few months that I have taken over as President of CIRAD's Board of Trustees from Jacques Poly and it is impressive to see the work that was accomplished during his term of office since the creation of the Centre.

In CIRAD, I found a united and harmonious enterprise for cooperative research that is integrated in the French and international scientific communities. CIRAD's belief in its goal and mission motivate it to face current problems.

Budget constraints are aggravated by difficulties in host countries. Abolishing poverty seems to be an even more difficult task today. My thoughts turn to the expatriate scientists who are acutely conscious of this issue. But they are also aware of the potential latent in the rural societies of these countries, their dynamism and ability to change.

The greatest asset of our expatriate scientists is their in-depth and first-hand knowledge of these societies. They have the task of communicating this knowledge to their colleagues in France. In this way both can commit their force and talents to the real problems of socioeconomic development in our host countries.

Such cohesion and solidarity are needed so that CIRAD can fulfil its mission. The strategy plan that was adopted in 1991 and implemented in 1992 has already given a fresh impetus. I am certain that it will make CIRAD's input even more effective.

Guy Paillotin
President of CIRAD

IMPLEMENTATION OF THE STRATEGY PLAN

A New Image for CIRAD

Renewing our Cooperation in a Changing World—
the title of CIRAD's strategy plan is a statement of the Centre's ambition and will. It confirms CIRAD's identity as an agricultural research enterprise that promotes economic and social development in the tropics and subtropics. And it reiterates CIRAD's research and cooperation functions. The research strategy and cooperation policy are aligned with global issues and supported by a restructured internal organization. 1992 was the first year of the implementation of the new strategy

Research Strategy

CIRAD's research strategy was fashioned by the actual needs of rural societies in the south. To formulate an effective response, we analyze critical issues in their historical context, giving due recognition to those arising from adaptation of knowledge to local conditions and those related to adoption of innovations. The skills needed for this task are strengthened and broadened in a variety of ways.

Internal Reform

The primary objective is to enhance the effectiveness of our research programmes in the field and the scientific quality of our work. We took the first step in this direction by improving the research structure as prescribed by the recommendations of the strategy plan, which are based on observations made during the external reviews of the departments.

When CIRAD was created in 1984 it was made up of 11 departments. We inherited a structure of cohesive communities that gravitated around a meritorious institutional past. But a serious drawback was that resources for cooperative programmes were necessarily fragmented among the departments. Moreover, our partners in multiple-commodity projects would need to deal with several departments simultaneously.

We had to pool our resources for further cooperative activities. Between the two rounds of external reviews of the departments, we had the opportunity of reflecting on the coherence of CIRAD's structure . At this time we took the decision to form large units by merging departments with complementary activities.

The annual crops department, CIRAD-CA, was formed by merging IRCT (cotton), IRAT (annual food crops), and the annual oil crops division of IRHO. The new department is organized into programmes based on cropping systems and degree of crop intensification. In this

way CIRAD-CA is better able to address current issues in agricultural research for development: How to manage cropped areas efficiently? How to use natural resources sustainably? How to make crop production a gainful activity?

The perennial crops department, CIRAD-CP, combines CIRAD's expertise on those crops that were formerly divided between IRHO (oil palm and coconut), IRCA (natural rubber), and IRCC (coffee and cocoa). The new department with its reinforced research base can now organize its outreach in the tropics more rationally. It can also respond more effectively to the apparently conflicting issues of earning profits from crop enterprises and protecting the environment.

The food technology and rural systems department, CIRAD-SAR, was created by merging CEEMAT (agricultural engineering, energy, and food technology) and DSA (agrarian and farming systems). Agricultural production, food processing, and rural socioeconomics can now be studied together. This possibility takes on an added significance because of the transformation of these systems due to changes in economic and government policies.

These changes also led to the expansion of the mandate of the fruits department. CIRAD-FLHOR, the new department, covers the entire horticultural sector (fruits, vegetables, flowers), with special emphasis on fresh products, particularly for export.

The other departments are: CIRAD-Forêt (forestry), CIRAD-EMVT (livestock production and veterinary medicine), and CIRAD-GERDAT (technical support, special research programmes). In addition to management, CIRAD-GERDAT is responsible for common services and laboratories.

In 1992 each new department drew up its long-term plan based on an analysis of its sector's current situation and prospects. The departments established the general framework of their respective research and cooperation polices for the next 5 years. They then planned their structure and operations according to their capacity and that of their partners.

Reorganization of the Centre was accompanied by the constitution of common research units to pool capacity existing in France and overseas for a given sector; the objective was to increase efficiency. An ad-hoc steering committee ensures that research carried out by the units fulfils the needs of the departments. In 1992 Biotrop, the biotechnology for tropical crop improvement unit (managed by CIRAD-GERDAT), was expanded through the addition of genetic engineering and molecular pathology laboratories. A research unit was created for economics of commodities; it is managed by CIRAD-CP. Other common units are planned, including those linked to the construction of the new technology building at the Montpellier Research Centre. The units concern: physics and chemistry of products (CIRAD-CP), food technology processes (CIRAD-SAR), and stabilization of fresh products and aromas (CIRAD-FLHOR).

CIRAD at the end of 1992 has fewer—but stronger—departments with renewed mandates and a larger number of common units. These developments do not signify a break. They are in keeping with the logic behind the creation of the enterprise in 1984: to pool research resources and capacity, and to achieve greater efficiency and economy. The upcoming move to Montpellier of CIRAD-Forêt and CIRAD-EMVT following the decentralization measures decided by the government in 1992 is a step in the same direction.

Partnerships in the Scientific Community

A key factor of CIRAD's research strategy consists in forming alliances with other centres of excellence and thus provide an adequate response to the vast research needs for development. The Centre collaborates with organizations worldwide to underpin efforts of southern countries and their institutions.

Some of our common research units work with other French research organizations. This involves setting up of common laboratories that benefit from the pooling of research talent and equipment, even if the other organizations focus on regions other than the tropics. Examples of such units are the joint laboratories with the Institut

français de recherche scientifique pour le développement en coopération (ORSTOM) for plant virology and biotechnology of tropical forest symbioses. Other joint units are planned in the short term for nematology, integrated pest management, ecophysiology, and modelling. The partner for the last three units will be the Institut national de la recherche agronomique (INRA). The Maison de la technologie, which will be opened at the Montpellier Research Centre in early 1994, will also involve the tropical food technology section of the Ecole nationale supérieure des industries agricoles et alimentaires (ENSIA).

Collaboration between organizations takes the form of formal or informal arrangements. These are usually managed through our *missions* for research coordination. We have eight such *missions*, which cover the major fields of activity of the Centre. Their task is to coordinate research activities of the departments, to organize in-service training, and to propose new, common projects in response to external invitations to tender.

Each *mission* has a scientific committee of external experts and representatives from each department. The experts—about 60 eminent scientists—form an efficient network that links CIRAD to their respective organizations (European and French universities, CNRS, INRA, ORSTOM, and others). Their opinions and advice are extremely valuable because they are based on a sound knowledge of the Centre's objectives and strengths. In this way, the committees support the work of the Scientific Advisory Committee.

Field visits to host countries are undertaken to support CIRAD staff and partners. For example, the visit to Réunion and Mauritius in 1992 accelerated work on the establishment of a regional cooperative research pole in Réunion for crop protection. An INRA scientist and an American university student have already been posted at the base.

The *mission* for crop and environment management is organizing a seminar in northern Cameroon. It will be held in 1993; African and CIRAD scientists in the region will attend the meeting to exchange

ideas on analysis of the diversity of agricultural situations and implications for research planning.

Mutual understanding is promoted through reciprocal participation in scientific committees, institutional reviews, and staff appraisals.

An important initiative was taken in 1992 with the Natural Resources Institute (NRI), United Kingdom; the Koninklijk Instituut voor de Tropen (KIT), The Netherlands; and the Instituto de Investigação Científica Tropical (IICT), Portugal. These organizations joined CIRAD to create the European Consortium for Agricultural Research in the Tropics (ECART) to support the southern countries. The four organizations have a combined strength of more than 2000 scientists working in farmers' fields and on station. Environment and natural resource management, and advisory services for research planning and management are the main thrusts of ECART. The consortium is formed by autonomous institutions with similar mandates and it is open to cooperation with partners in the south and north. The creation of ECART demonstrates the commitment of European countries to solidarity with the south through efficient coordination of their activities.

We strengthened our links with the international scientific community, including the centres of the Consultative Group on International Agricultural Research (CGIAR). CIRAD is cosignatory with ORSTOM and INRA of memoranda of agreement with most of the centres. In 1992 new agreements were signed with the International Network for the Improvement of Banana and Plantain (INIBAP) in March; the West African Rice Development Association (WARDA) and the International Fertilizer Development Center (IFDC) in June; and the International Laboratory for Research on Animal Diseases (ILRAD) in October. Four meetings took place to evaluate results of joint activities and to plan new projects. At the meetings CIRAD, INRA, and ORSTOM met partners from the Centro Internacional de Mejoramiento de Maíz y Trigo (CIMMYT) in Mexico in February; the International Rice Research Institute (IRRI) in the Philippines in March, the Centro Internacional de la Papa (CIP) in France in April;

and the Centro Internacional de Agricultura Tropical (CIAT) in Colombia in November. Almost 30 researchers from the three French organizations are seconded to the international centres; about 15 of them are from CIRAD. Discussions with the International Institute of Tropical Agriculture (IITA) were held in Nigeria in June.

High Recruitment Standards and More In-Service Training

We recruit young doctorate researchers and stress internal training in our policy for strengthening research capacity.

Distribution of senior scientists according to work area shows a high percentage for crop and environment management (36%), followed by plant improvement (14%) and plant protection (11%). But the proportions are low for economics and sociology (6%), animal production (9%), and technology (10%); these sectors need to be strengthened because of their increasing importance in our strategy. Our recruitment policy therefore favours the last three disciplines.

Training of research fellows—some of whom will be recruited on completion of their training—will be aligned with the needs of the establishment. In 1992 we received 8 trainees who were sponsored directly by us, 67 with scholarships from the French Ministry of Research and Space, and about 20 from other organizations. In addition, 40 doctorate students carry out part of their research work in our laboratories .

Cooperation Strategy

Enhancement of our research capacity has only one aim: to improve the contribution of our scientists towards economic development in the tropics and subtropics. At CIRAD, it is our tradition and mandate to collaborate with many partners. They include national agricultural research systems, regional organizations, development agencies, nongovernmental organizations, private enterprises, and farmers.

Close association with the producers is the best way to understand farming and rural dynamics and to identify research needs.

Diverse Partners

By late 1992, 365 CIRAD scientists were working in 51 countries of the south. Many of them participate in development projects, which explains our presence in so many countries. Altogether, CIRAD has over 100 partners worldwide.

However, for our long-term cooperative activities we concentrate on a limited number of countries. More than 70% of our expatriate scientists are concentrated in 12 countries.

Our presence is strongest in Africa and the Indian Ocean region; 9 of the 27 countries with resident programmes have more than 10 scientists each.

Our scientists are also posted in 13 Latin American and Caribbean countries, and 11 Asian and South Pacific countries. Among these countries those with the highest number of CIRAD scientists are Brazil, Indonesia, and Vanuatu.

Our geographic spread remained relatively stable in 1992, compared with 1991. The only exceptions were Côte d'Ivoire and, to a lesser extent, Togo, where we terminated direct management of national research organizations and withdrew a significant number of our staff.

In 1992 we signed memoranda of agreement for long-term programmes with the Institut de recherche agronomique et zootechnique (IRAZ), Burundi; the Agency for Forestry Research and Development (AFRD), Indonesia; Innoprise Corporation Sdn. Bhd. (ICSB), Malaysia; and the Institut d'économie rurale (IER), Mali.

From Regular Consultation to Collaborative Research Contracts

With our partners, we are regularly engaged in the identification of common objectives and their translation into research projects.

The exercise is familiar to our new partners such as EMBRAPA, Brazil, who started working with us in the past decade. But this is not the case with our traditional partners with whom we have historical ties.

Annual meetings are a useful instrument for concertation. In 1992, six meetings were held with our main partners including: Centre national de la recherche appliquée au développement rural (FOFIFA), in Madagascar; the Cameroonian Ministry of Scientific and Technical Research, in Cameroon; Institut sénégalais de recherches agricoles (ISRA), in Senegal; Centre national de la recherche scientifique et technique (CNRST), in Burkina Faso; Empresa Brasileira de Pesquisa Agropecuária (EMBRAPA), in Brazil; and Institut des savanes (IDESSA), in Côte d'Ivoire.

Themes of common interest were identified and long-term projects for cooperative research were often planned. We still need to sign specific agreements. In certain cases, joint teams were formed to facilitate shared management of the regional cooperative research poles. This is the case of Garoua for crop diversification in cotton-growing areas and that of Nyombé for plantain banana, both in Cameroon.

The projects are financed through CIRAD contributions, French foreign aid, or European Community funding (eg, projects of the programme on Life Sciences and Technology for Development). They involve European and southern organizations and are sometimes regional efforts.

The geographic spread of our research is gradually being established, initially through about 20 collaborative research contracts, which should be signed by 1993.

Our withdrawal—as decided in late 1991—from the management of research organizations in southern Côte d'Ivoire was not followed by a renewal of cooperation, in spite of our efforts and the discussions in Abidjan in February.

We still maintain a minimum staff to ensure continuation of strategic research on genetic improvement of coconut, natural rubber, and

oil palm. The rest were repatriated because of the uncertain situation. Out of 46 scientists in late 1991, only 26 remained by end 1992. They work at the recently created Institut des forêts (IDEFOR), which has taken up the activities of the institutes formerly managed by CIRAD.

Cooperation with IDESSA, which is located in Bouaké, Côte d'Ivoire, is progressing satisfactorily.

Support for Regional Organizations

The Conférence des responsables de la recherche agronomique africains (CORAF) received political recognition at the meeting, in Dakar in March, of 20 African ministers for agricultural research. Gambia, Burundi, and Rwanda joined CORAF, bringing its membership to 21.

CIRAD is an associate member of CORAF, along with ORSTOM and INRA. Several of our scientists participate actively in its research networks (maize, rice, groundnut, cotton, drought resistance). The *bases-centres* of these networks have not yet all been established, but CORAF continues to serve as a powerful medium of collaboration between the national agricultural research systems. It has succeeded in forming a solid scientific community in Africa over the past few years and we were also involved in this effort.

The Special Program for African Agricultural Research (SPAAR), which had defined its action plan for the Sahel in 1991, began work on a plan for the African humid zones. Some of our scientists were invited to attend the meetings in Abidjan and Abuja. In March we hosted a SPAAR workshop in Montpellier on the establishment of a database on agricultural research projects.

Role of the French Overseas Departments and Territories

Almost 370 CIRAD staff, including 88 senior scientists, work in the French overseas departments and territories (DOM-TOM). They

hold a special position between expatriates working overseas on cooperative projects and scientists working in France.

They are members of a French public research establishment and their research is determined by the agricultural needs of these regions. The objectives, operational methods, and resources are determined after detailed discussions with the administrative and political authorities, and local professional organizations that together fund the projects. The concertation process will be revised in 1993.

Research organizations working in the DOM-TOM (CIRAD, INRA, ORSTOM, CEMAGREF) also need to harmonize their activities for greater efficiency.

The first task of our scientists in the DOM-TOM is to understand and respond to the needs of these tropical agricultural systems. In 1992 we undertook research on agricultural prospects in Réunion. It mobilizes all the scientists in Réunion and receives methodological support from several organizations in France. The conclusions of this work are expected to orient research activities towards a more effective response to the development needs of this overseas department.

Our scientists in the DOM-TOM also have the task of conducting work related to their respective departmental research programmes. In fields such as crop protection, the regional cooperative research poles in the tropics are irreplaceable. They are useful for training young scientists and extending research within the region.
The two tasks should develop simultaneously in the future, along with a strengthening of our local laboratories.

Operational Flexibility and Adaptability

The strategy plan determines our options and activities, without, however, being an abstract document whose implementation would have a paralyzing effect. The same applies to the multiannual plans of the departments. The world continues to change, sometimes

dramatically. This requires strategic thinking combined with clear rules of operation that are accepted by all. The two conditions are prerequisites for a rapid response to new situations.

Principles of Organization

The implementation of ideas adopted in the strategy plan has highlighted simple principles of organization, based on devolution of operational responsibilities. The Office of the Director General guarantees unity of the establishment and sets major orientations of the Centre and objectives of the departments; it allocates resources and oversees the execution of its directives.

The departments are operational units that have the authority to define research programmes and to commit the human and financial resources necessary for their execution. A devolved management structure allows the departments to respond effectively to changes in their environment. Based on these principles, the departments fashion their internal organization according to their respective 5-year plans.

Calibre of Human Resources

The human resources of a research organization are its main asset. Calibre is vital for an organization like CIRAD with a wide geographic spread. Recruitment of highly competent staff and training contribute to this requirement. Our human resources policy also looks beyond these prerequisites. It focuses on future needs and potentials, staff appraisal, career development, staff mobility, and internal communication.

Strategic Thinking

The strategy plan highlighted the need for regular analysis of long-term prospects. In late 1992 we launched such an exercise in recognition of the changes taking place in our working environment in the south and north, and of their impact on our strategy. The working group was given the task of proposing strategy guidelines for the next decade.

The group is made up of 15 CIRAD scientists who will consult experts from the Centre or other organizations for specific questions. It will submit its report in early 1994.

Public Awareness

Public awareness is a significant activity in a research organization that has to rely on its reputation for donor support. Promotion of a corporate image is also a powerful means of motivating and unifying staff. Our communication policy was defined in late 1991 and implemented through a detailed action plan.

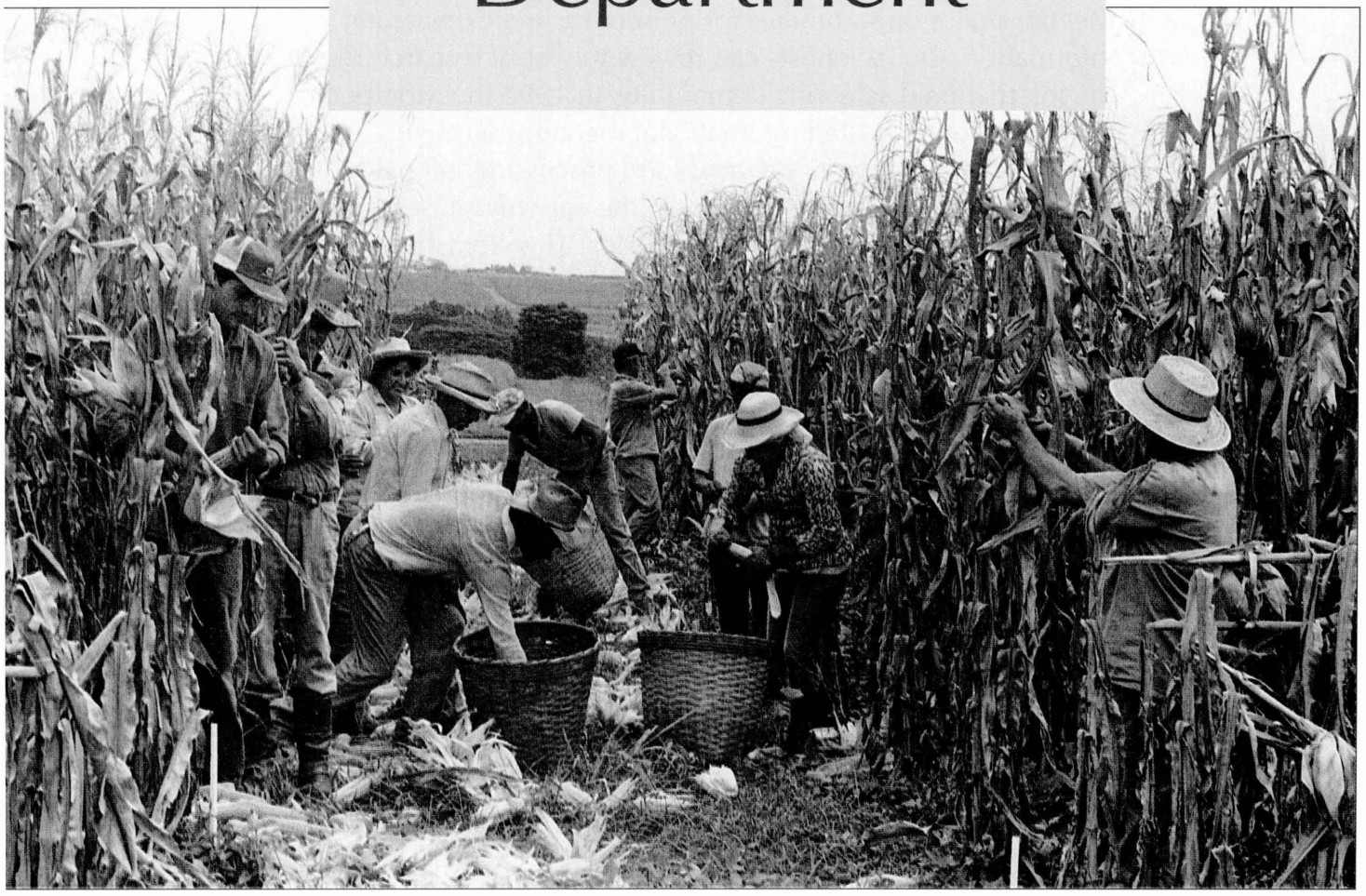
CIRAD was given a new "look". We now have a new logo and a style guide to harmonize the presentation of our products. Information on our work is disseminated through press releases and conferences; information bulletins (*CIRAD Information* and *Horizons Sud* for internal distribution; *CIRAD Echos* and its English version *CIRAD News* for external distribution); visitors' days in France and our overseas centres; and participation in trade fairs and exhibitions.

In 1992 we participated in many events. Major events included the agricultural machinery fair SIMA, the wood fair Expobois, Forum Agro, and Forum Bio in France; the United Nations Conference on Environment and Development and the Environmental Technology Exhibition, in Brazil; the Franco-Kampuchean agriculture week, in Kampuchea; the Miami Conference on Investment, Trade, and Development for the Caribbean Region, in the United States.

The communication plan also concerns our research products. We decided to transform our scientific publications completely. We encourage publication of original research work in international journals that are authorities in their field. Our own departmental journals were further adapted to meet the needs of professionals and development specialists. We also launched several new publication series.

Meetings offer opportunities for presenting and exchanging information. Our scientists can review the latest research results with the international scientific community. In 1992 the Montpellier Research Centre hosted international meetings on topics as varied as genetic improvement of banana, food processing, oil palm breeding, and the economics of institutions in the agricultural sector. We also coorganized meetings in other countries. The workshops concerned various topics: *Phytomonas* (in Colombia); *Phytophthora* diseases of coconut (in Indonesia); tropical veterinary medicine institutions (in Côte d'Ivoire); livestock farming systems (in Spain); and monitoring deforestation in Southeast Asia (in the Philippines).

Annual Crops Department



Sustainable development of annual food and cash crops depends on proper management of natural resources. Cropping systems studies should therefore focus on rotations of cereals, legumes, tubers, and, in favourable locations, cotton. Crop intensification—the response to population growth—is the other aspect of agricultural progress in the south. These are the challenges that are addressed by CIRAD's new department of annual crops

The Département des cultures annuelles or CIRAD-CA, the annual crops department, was created in 1992. It combines research activities on food crops and natural resources (IRAT), cotton (IRCT), and oil crops (division of IRHO). CIRAD-CA will continue to fulfil the mandates of the former departments.

This reorganization is favourable for farming systems work. Rotations and intercrops of food and cash crops can now be studied together. Sustainable improvement of the systems and environment management—the main concerns in tropical agriculture—can now be addressed globally. Specifically, the studies pertain to long-term evolution of soil fertility, water management, erosion control, and weed and insect pest management.

CIRAD-CA has five programmes that deal with the main issues raised by the development of different types of agriculture in the tropics.

The problems confronting smallholders who grow food crops are mostly related to low input use. Lack of vital inputs can affect crop production and protection, soil fertility conservation, and economic sustainability. Existing systems are characterized by the need to obtain stable yields despite erratic climatic conditions. Adaptation to these constraints involves varietal selection and development of suitable cultural techniques.

In ecological zones suited to cotton cultivation, income generated by the crop allows farmers to use inputs. Crop intensification, in this case, is often associated with the development of animal-drawn or motorized cultivation, and crop diversification.

Rapid population growth has made crop intensification an imperative. Fertilizers, pesticides, and mechanization can be used beneficially in areas where water supply is no longer the main limiting factor (eg, favourable climatic conditions or irrigation). The task before research programmes is to seek methods for coherent management of these inputs and to design farming systems adapted to diverse situations.

Vegetable consumption, particularly in cities, is increasing. There is a high demand in the south for research on market garden crops. One CIRAD-CA research programme focuses on farming systems involving such crops.

Sugarcane was designated a mandate crop of ex-IRAT right from its inception. In the new research structure, a separate programme is devoted to the crop. This is warranted by the fact that the crop is either closely linked to the sugar industry or it is grown on smallholdings and can thus impel agricultural development.

All CIRAD-CA programmes emphasize the diversity of cropping systems and their environments. In-situ diagnostic methods and decision-making aids are developed for the purpose of obtaining operational results.

The main challenge is to conceive research recommendations as other than normative technology packages, which are too general for diverse situations. Farmer participation in research has yielded results that have led to the design of suitable farming systems.

To be relevant, research projects must look beyond crops and farming systems to include the end products, grains and fibres, processing technology, and sectoral economics. The projects are conducted in collaboration with other CIRAD departments; French and European research institutes; and national, regional, and international agricultural research organizations.

Smallholder Food Crops

Our objective is to propose technical itineraries and settled farming systems that ensure sustainable productivity increases and soil fertility improvement

without high input use. They must also be acceptable to smallholders and fit into a market economy.

High-Altitude Rice in Madagascar

Half of Madagascar's 1.3 million ha of rice fields are located above 1000 m. Our work with the Centre national de la recherche appliquée au développement rural (FOFIFA), Madagascar, focuses on the cultivation of upland rice at 1200–1600 m and of aquatic rice at 1600–2000 m.

Three recently introduced upland rice varieties yielded 2–3.5 t/ha. The first products of the joint breeding programme will be recommended for release at the end of the 1992–1993 cropping season. The new varieties were suited to the local environment and yielded 5–6 t/ha in field trials.

We are beginning to overcome the constraints of bacterial disease and cold in aquatic rice. Potential cultivars in the final development stage produced more stable yields than the local control Latsidahy. The aim of recurrent selection is to increase suitability of the plant material.

We are testing different cultural techniques to amend soils with high organic material content and low biological activity. Possible solutions include application of various types of mineral fertilizers; off-season cropping; crop residue burning; and transplanting and direct sowing.

Research on high-altitude rice concerns all tropical, subtropical, and Mediterranean countries confronted with problems of cold due to altitude and latitude. Certain rainfed lines tested in Nepal performed satisfactorily.

Varietal Improvement in Groundnut

New drought-tolerant varieties were released as a result of a varietal screening programme for drought resistance in groundnut. We collaborated in this programme with the Institut sénégalais de recherches agricoles (ISRA) and the Botswana directorate of agricultural research.

One of our strategies was to identify varieties with extreme earliness through backcrossing and pedigree breeding because early maturity permits the crop

ANNUAL CROPS DEPARTMENT

CIRAD-CA

Director	Didier Picard
Research Director	Jean-Claude Follin
Programmes Director	Alain Derevier
Director, International Relations	Harry Palmier
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Smallholder food crops	Michel Raunet
Smallholder cotton crops	Michel Déat
Sugarcane	Michel Hoarau
Intensive systems	Etienne Hainzelin
Vegetable crops	Hubert de Bon

Research Units

Plant improvement	Michel Jacquot
Crop physiology	Pierre Siband
Farming systems	Patrick Bisson
Soil and land-use management	Francis Ganry
Water management	Francis Forest
Plant pathology, weed management	Jean-Loup Notteghem
Applied entomology	Jean Cauquil
Biometrics, computer services	Alain Joly
Cotton technology	Serge Goebel
Cereal technology	Jacques Faure
Economy of commodities	Claude Freud

Support Services

Publications, information, documentation	Hervé Saint Macary

to avoid drought periods. Two varieties, GC 13 and GC 8-35, that we developed matured 10 days earlier than currently grown varieties. In addition, compared with the Senegalese variety 55-437, cv GC 8-35 recorded higher pod yield (+160 kg/ha) and 100-seed weight (+22%). New F_4 lines are also highly promising.

Another strategy involved incorporation of different drought resistance factors in a single variety. The factors include an efficient root system, mechanisms that regulate transpiration, membrane resistance, and redistribution of assimilates. We subjected eight varieties to two cycles of random crosses. Selection of useful lines through pedigree breeding is in progress.

Germplasm exchange with the Peoples' Republic of China resulted in the identification of cv Fleur 11 for Senegal, where it was released. Yields of cv Fleur 11 are 30% higher than cv 55-437. In addition, its seed quality meets the standards of the confectionery groundnut market, which ensures higher returns than the traditional oil market.

Land-Use Management in Côte d'Ivoire

Rapid degradation of the natural environment in Côte d'Ivoire is a source of concern. In the cotton-growing area of the north, intense erosion diminishes crop yields. Scarce firewood, depleting soil fertility, and insufficient feed for livestock in the dry season are other signs of a critical situation. In the forest zone of the south, shifting cultivation for food crops (mainly upland rice) contributes to the rapid disappearance of forests.

Together with the Institut des savanes (IDESSA), Côte d'Ivoire, we set up a novel research project in farmers' fields and with the participation of farmers and development agents.

The agricultural landscape was transformed. Erosion-control ridges with perennial crops (cash crops, firewood, fodder crops) and quickset hedges were established to protect the land against erosion and wandering animals. Such forms of alley cropping offer opportunities for combining various systems—including some with a livestock component—and different levels of crop intensification.

Within 4 years, net profit from the farms and labour productivity increased twofold for the best systems.

Our next step is to reduce tillage and establish a permanent cover (mulch, cover crop). Farmers have shown keen interest in this solution because it reduces manpower and checks erosion.

Such research projects also serve as demonstrations for training farmers, scientists, and development agents. Farmers in the north are rapidly adopting the new field and hedge systems and techniques.

Permanent Soil Cover in Réunion

In the western highlands of Réunion, sole cropping of scented geranium has leached the soil and encouraged proliferation of weeds and diseases. The constraints have a detrimental effect on yields.

We worked with farmers to improve cropping systems by intercropping geranium with food and vegetable crops. The systems are characterized by minimum soil tillage and permanent crop cover. Since 1991, we have compared three soil treatments: bare soil, Kikuyu grass (*Pennisetum clandestinum*) cover, and greater lotus (*Lotus uliginosus*) cover.

In addition to erosion control, the cover improves infiltration of water in the soil, physicochemical characteristics of the soil, restitution of organic matter, and microbial activity.

Crop damage is reduced because of the effect on insect pests, mainly white grub (*Hoplochelus marginalis*) and a leaf feeder (*Cratopus humeralis*) in geranium, and *Ophyomia phaseoli* in bean.

Although the plant cover limits weed proliferation, it also hinders crop growth and cultural operations. It must therefore be managed by means of specific herbicides such as fluazifop-*p*-butyl against Kikuyu grass and bentazone against greater lotus. Runner type species such as *Arachis pintoi* and *Axonopus affinis* also provide a good plant cover.

Products for Development

Maize-Based Products for Africa

The traditional Mexican method for making tortillas is based on alkaline treatment of maize. Cooking maize in lime eliminates the need for husking. Our cereal technologists adapted this technique and introduced it in Senegal, where it is unknown. The technique has since been applied to major maize cultivars. The taste of lime was neutralized by adding lemon juice to accommodate local tastes.

Several new products were developed. A production unit was established at Ziguinchor by local partners, including the Senegalese Centre régional d'enseignement technique féminin (CRETF). The enterprise has proved to be profitable.

Various granulated products such as aklui, yéké-yéké, *arrowroot, and couscous are traditionally produced in Africa from different cereals. We determined optimum conditions for flour granulation and hydration on a semi-industrial scale with souna millet and 10 maize varieties from Mali, Senegal, and Benin. The process was modified according to the parameters, and output of end products reached 90%.*

Our first prototype of a roller-grader was constructed in France and installed at the faculty of agricultural sciences in Cotonou. A second, simplified roller was designed for a capacity of 40 kg/hr; it is being tested by CIRAD-SAR.

Striga Control in Mali

Striga hermonthica is the most destructive weed of cereal crops in the Sudanian zone. For the past 4 years we have collaborated with the International Crops Research Institute for the Semi-Arid Tropics (ICRISAT) to test simple, low cost control methods in farmers' fields in Mali.

We found that foliar applications of herbicides such as 2,4-D, turflon, and triclopyr, either before or after crop emergence, reduced incidence of *Striga* by 60% and thereby increased cereal yields by up to 115%.

Manual weeding at 70 days after sowing was found to check *Striga* growth effectively. We developed a weeding implement with adjustable tines for draught cultivation (donkey traction) in the groundnut-growing areas. The new implement was widely adopted by farmers because it accelerated weeding and improved efficiency.

Cereal cultivars ready for release are not resistant to or tolerant of *S. hermonthica*. Two cowpea varieties, APL-1 (from Nigeria) and 87-2 (from Niger), however, proved to be resistant to *S. gesnerioides*. They also possessed good tolerance of *Alectra vogelii*, which has the same effect as *Striga*.

Water Supply Risk Models

Yields of rainfed crops vary greatly in the groundnut-growing area of Senegal. Our agroclimatology studies with ISRA aimed to establish the respective shares of climatic conditions and cultural practices in yield instability.

Climatic indicators based on cumulative rainfall and vapour deficit are inadequate for characterizing crop

water supply. We defined more appropriate indicators based on the following water balance terms: actual evapotranspiration (AET) during the crop cycle, and the ratio of AET to potential evapotranspiration at flowering and maturation. These indicators characterize water supply during phases when the crop is specially susceptible to stress.

In a project sponsored by the Fonds d'aide et de coopération (FAC), France, we measured millet yields in more than 100 smallholdings representing different farming systems in the groundnut-growing area. We were able to identify the limiting factors by relating yield data to water balance indicators and cultural practices. The most important were: low recycling of nutrients; poor weed control, and, in the southern part of the region, high runoff.

We also studied the direct effects of cultural practices on crop water supply in on-station trials. The results were used to improve models predicting the effects. The improved models can assess risks run by farmers due to inappropriate cultural practices.

The models can explain why certain development policies linked to crop intensification failed. They also serve to determine the product and input price system that will facilitate intensification in a given region.

Competitiveness of Guinean Rice

We surveyed rice cultivation systems and analyzed the economics of the rice industry in a new observation area—the forest region of southern Guinea. Preliminary results confirmed the conclusion of the World Bank that Guinean rice can compete with imported rice. But high transport costs can reduce its competitive edge on the domestic market. Large markets such as Conakry and Labé are located too far for farmers to sell their rice at a competitive price.

The two types of rice systems that need to be further developed in Guinea are lowland rice with small-scale irrigation and rainfed rice.

Smallholder Cotton Crops

For millions of smallholders in the south, cotton is the only source of income. Fertilizers and equipment purchased from this income benefits farm productivity and ultimately improves living standards. Development in cotton-growing areas aims at yield increase based on ecological principles, improvement of product quality, and diversified uses of cotton. We contribute to such efforts through our work on sustainable systems and other aspects of the cotton industry: varietal improvement, cultural techniques, processing for value-added end products (yarn, oil, flour), and sectoral economics.

Pesticide Resistance in Insects

Indiscriminate use of pyrethrinoid provokes pesticide resistance in certain insect pests. This response was observed in the leafworm *Spodoptera littoralis* in the cotton-producing countries Egypt, Turkey, and Madagascar.

We therefore undertook studies on the mechanisms involved in this form of resistance. Bioassays on insect sensitivity to pesticides showed that the lethal dose of deltamethrin for a pesticide-resistant Egyptian biotype of *S. littoralis* was 1000 times higher than that for a pesticide-sensitive biotype. However, there was no difference in pesticide penetration through the cuticles of the larvae of both biotypes.

Pesticide resistance is due to physiological rather than physical factors. We found that enzyme metabolism was one of the mechanisms that induces resistance. Our investigations showed higher oxydase activity in the pesticide-resistant biotypes; esterase activity also appeared to be higher.

Crosses between resistant and sensitive biotypes revealed that pesticide resistance was polygenic.

Cotton Cultivation in Southeast Asia

Research on remedial measures to check decline in cotton production in Thailand was started in 1991 in cooperation with Kasetsart University, Bangkok. The project was located in the western province of Kanjanaburi. We studied changes in the landscape and in pioneer crops through satellite imagery, farm surveys, and experiments with farmer participation. We were able to determine limiting factors from the results and allot priorities for further investigations.

The market value of cotton products must be improved by selecting varieties with high ginning outturn and good fibre quality. Glandless varieties also need to be introduced.

We promote ecological measures such as the use of specific pesticides against *Helicoverpa armigera* and selection of hairy varieties to enhance natural host defenses against sucking insects.

Physiological disorders such as the premature fall of cotton bolls were studied by modelling crop processes. This work is linked to studies conducted in Montpellier and Cameroon, in collaboration with the University of Mississippi.

The Thai operation forms the core of a regional network to support cotton research in Southeast Asia. The network made good progress in Laos. Viet Nam joined it recently and Cambodia will follow in 1993. Training is a priority area in all these efforts.

Cotton Yield Prediction

Prediction of cottonseed yields is a yearly exercise at the Compagnie ivoirienne pour le développement des textiles (CIDT), Côte d'Ivoire. Forward planning for ginning operations, transport logistics, and sales is based on the results. The predictions are calculated from information supplied by smallholders on cropped area and yield estimates based on a sample of fields. But the system is empirical and relies mainly on the experience of extension agents. We therefore need to develop a systematic yield prediction method.

The Prevert model is currently used for predicting average yields in the 48 production areas covered by CIDT. It has the following variables: rain and sunshine (climatic variables); potential evapotranspiration

Products for Development

A New Crop Protection Treatment

Pesticide application by ultra-low volume spraying (ULV) became popular in Africa because it is relatively simple compared with conventional techniques, which required 150–200 L water/ha and knapsack sprayers. However, ULV spraying is effective only in specific conditions. The small quantity of chemical applied may not reach insects such as Bemisia tabaci *that are located on the lower leaf surface. The treatments may also not be effective against sucking insects as they are less sensitive to this type of treatment.*

We therefore developed a low-volume technique (10 L water/ha). It retains the advantages of the ULV treatment, but overcomes its drawbacks. The same equipment is used but a 5-litre tank is connected to the ULV sprayer. The new technique improves application efficiency. It was widely adopted after successful tests in Cameroon. It is estimated that, in 1993, the new technique will be used to treat around 200000 ha (95000 ha in Chad, 40000 ha in Cameroon, 20000 ha in Mali, and 45000 ha in Senegal) of the 1.2 million ha of cotton crops in western Africa.

and water balance based on interpolations and simulations (agroclimatic variables); fertilizer application, crop protection, and crop maintenance (farming systems variables).

We collected the results for each production area during 1983–1991 for a principal component analysis based on 450 basic factors. According to this analysis, the 48 areas fell into three groups (north, west, and centre), each with its submodel. Simulations based on the model gave satisfactory results, except in years with erratic climatic conditions.

Fibre Quality Measurements

Cotton breeders have to create new varieties that meet the ever-higher quality standards set by spinning mills. Technological parameters—fibre length, strength, elongation, maturity, and fineness—must be measured at each stage of the selection process. Test frequency was increased to improve selection efficiency. But conventional measuring methods are long and costly. We therefore considered adapting the high volume instruments (HVI) currently used for grading cotton marketed by the United States.

In the first HVI that we tested, the operating mode was modified to suit the ginning method (roller or saw). Ten measurements were needed per sample to obtain sufficiently accurate data. The modified version is expected to carry out a large number of tests at lower cost than conventional methods.

Certain member countries of the cotton network coordinated by the regional Conférence des responsables de la recherche agronomique africains (CORAF) have started acquiring equipment to grade their cottons. National research programmes are setting up fibre quality testing systems based on the HVI model. They work together with the Société burkinabé des fibres textiles (SOFITEX) in Burkina Faso; CIDT in Côte d'Ivoire; and Compagnie malienne pour le développement des textiles (CMDT) in Mali.

International Cooperation

Strategies for Cotton Crop Protection in Central Africa

We organized a meeting from 3 to 5 February 1992 in N'Djamena for coordinating research on cotton crop protection in central Africa. Participants included over 90 scientists, development agents, and representatives of agrochemical companies. The recommendations marked a shift towards more ecological and cost-effective measures; they stressed that the strategies should also consider other crops grown in rotation with cotton.

The number of studies on pest biology is increasing. But biological control alone is not adequate; the ultimate goal is integrated pest management. An intermediate method must be introduced before implementing the integrated methods. Such an approach was adopted for cotton in Cameroon and for cowpea in Chad.

Sugarcane

Improvement of sugarcane farming systems is the main dement of work on new agricultural methods for the French overseas departments. The Centre français de la canne et du sucre (CFCS) was recently created in Réunion to promote these efforts.

Biotechnology and Crop Improvement

Interspecific sugarcane hybrids possess more than 100 chromosomes, of which less than 20 are derived

from a wild species. Molecular markers (RFLP) have shown that the "wild" chromosomes are transmitted almost intact to the progeny. Only a few markers are needed to tag the chromosomes. Molecular screening can now facilitate manipulation of the characters that they control. Studies on the progeny of the popular Réunion variety R 570 are under way.

Progress in in-vitro technology has largely benefitted conservation, distribution, and multiplication of selected varieties. Cryoconservation was successfully applied to embryogenic calluses and shoot tips, in collaboration with the Institut français de recherche scientifique pour le développement en coopération (ORSTOM). Shoot tips were taken from plantlets of five varieties and encapsulated according to a technique developed by the French Centre national de la recherche scientifique (CNRS). The survival rate of plantlets conserved in liquid nitrogen ranged between 40% and 90%. Shoot tips are used for this purpose because they are expected to preserve genotypic stability, which is an essential factor in varietal conservation. These techniques will be useful for quarantine operations and the in-vitro collection in Montpellier.

Resistance to Leaf Scald Disease in Sugarcane

Disease-resistant varieties represent the best means to control leaf scald (*Xanthomonas albilineans*) in sugarcane. Varietal screening is based on symptom expression following artificial inoculation. However, it is known that the interval between infection and appearance of symptoms on sugarcane is sometimes long. Markers for leaf scald resistance identified through our research in Guadeloupe are more reliable than simple observation of disease symptoms.

Resistance is directly related to pathogen density in the host. This new criterion allows us to identify resistant material without relying on symptoms. The method is used for screening new sugarcane varieties produced by our Guadeloupe programme.

White Grub Control in Sugarcane

White grub (*Hoplochelus marginalis*) was first reported in 1981 following its accidental introduction into Réunion. The pest put the sugarcane crop, especially in smallholdings, at risk and jeopardized the island's principal export.

We were commissioned to organize biological control operations. The fungus *Beauveria* sp., which is specific to white grubs, was imported from Madagascar and we studied its efficacy in controlling white grubs. It has been introduced in a number of locations on the island since 1987. The effect was immediate and spread; in 1992 white grub populations fell below the economic threshold. This successful method was developed in collaboration with the Institut national de la recherche agronomique (INRA), France; FOFIFA, Madagascar; and the Réunion development services. It has incited scientific interest and warrants more detailed studies on the pest.

Efficient Water Management

Irrigation recommendations based on water balance models require comprehensive knowledge of how the soil - plant - atmosphere continuum works. IRRICANNE, a software tool for irrigation management, is now used in the Réunion systems.

The model's accuracy is to a large extent determined by that of the water balance terms. We developed new methods to accurately determine water mechanisms in the soil and plant. Hydraulic conductivity of irrigated soils was determined by means of controlled suction permeametry. The results were integrated in the soil map (1:10000) of the area. Time-domain reflectometry was used to measure speed of electromagnetic waves in the soil, which indicates moisture content.

The method is also used for monitoring the spread of moisture in drip irrigation. We could therefore calculate the optimum dimensions of the surface

network and determine the best mode of irrigation. Our research also focused on a precise assessment of actual evaporation from the crops by measuring sap flow and on the correlation between water deficit and agronomic performance.

Intensive Systems

The technological level of intensive agriculture warrants high investments and input use. Such systems are part of a market economy. The main constraints are diminishing soil fertility, weeds, parasites, and returns on investments.

Development of Rice Hybrids

We established a breeding programme for tropical rice hybrids in French Guiana and Brazil jointly with a private company. The programme is based on genocytoplasmic male sterility systems mainly in *indica* material. Among these, the system with WA cytoplasm is the most widely used.

For the short term, we screened rice varieties available in French Guiana, most of which originate from Latin America. The rare maintainer lines were backcrossed to be converted into A lines. We selected two of them for the hybrid programmes. Restorer lines were purified for 1 year and directly tested against available A lines. By late 1992, 120 restorer lines and 200 new hybrids were produced and will be evaluated during 1993.

We also developed economic seed production techniques. For example, male sterile and pollinating lines were transplanted in alternate rows or seed mixtures of both parents were broadcast by aeroplane.

Rice hybrids for the Mediterranean region were developed from *japonica* rice. Three cytoplasmic sterility systems—WA, BT, and Gam—were used. Although many *japonica* varieties were sterilized using these systems, very few restored sterility. The cross-pollinated species *Oryza longistaminata* has long stigmata. We are attempting to transfer this character to *japonica* lines to enhance the cross-pollination rate in male steriles.

Analysis of Yield Stability

Both yield stability and production are important objectives in breeding programmes. Yield stability can be evaluated from multilocation trials in different environments. Conventional methods for determining stability are, however, not always suitable.

We developed a new method to evaluate 2 years of data collected from the Amul network, a multilocation maize hybrid trial covering the entire tropical belt. The method was efficient and led to the identification of a remarkably stable variety, IRAT 354. It was also applied to Béryl, an early hybrid produced by Rhône-Poulenc for the French market.

The method involves a grouping of trials based on statistical significance prior to an analysis of genotype x environment interaction. In addition to standard yield stability analyses, we carried out principal component analyses and automatic classification to represent the interaction, which is interpreted by covariance analysis.

Vegetable Crops

Vegetables, flowers, aromatic plants, and spices are cash crops that are grown on smallholdings, but with

high inputs. The end products have high value added. The 1992 studies focused on vegetable crops.

Market Gardening in Africa

Analysis of the market gardening sectors in Congo, Central African Republic, and Madagascar revealed satisfactory performance of the local distribution systems. In spite of production instability and transport constraints, vegetables were supplied to urban consumers at reasonable prices and with minimum shortages. We now have the strategic task of setting up regular supply lines and limiting imports. We shall therefore focus on leaf vegetables, onion, and tomato, for which there is a high local demand.

Liriomyza trifolii Control

The leaf miner *Liriomyza trifolii* is one of the most common insect pests of vegetable crops. Our applied entomology laboratory worked with INRA breeders to develop *Liriomyza*-resistant tomato varieties. The material was tested in Senegal in collaboration with ISRA. There was a fourfold decrease in leaf mining in the nine tomato lines compared with the susceptible control Flora Dade.

We also observed other differences in varietal susceptibility. There were four times less larvae on cv Tropimech than on Xina, a widely cultivated variety in Senegal. Yield losses can reach 7.7 t/ha. They can be reduced by 60% by combining tolerant or resistant varieties with chemicals (cyromazine or abamectine) that do not affect useful fauna (*Hemiptarsenus varicornis, Opius dissitus*).

Control of Tomato Spotted Wilt

Tomato spotted wilt virus (TSWV) is transmitted by the vector *Frankliniella occidentalis*. The disease was detected in September 1991 in Réunion. Since then we have studied disease epidemiology and population dynamics of the vector on tomato and china aster.

Primary infection is caused by the early arrival of wind-borne thrips. Damage is higher when the tomato seedlings are at nursery stage. Secondary infection is transmitted from one plant to the next. Studies on vector dynamics showed that outbreaks occur as a result of multiplication peaks and migration. Early and regular destruction of TSWV-infected plants reduces the rate of disease spread in the field.

The four-point disease prevention strategy involves: protection of nurseries against insect vectors; clearing of field borders; appropriate spatial arrangement of crops; chemical control of the insect population, particularly during the early stages of crop growth; elimination of primary sources of inoculum in the field.

Products for Development

Vegetable Varieties for Cultivation under Shelter

In the tropics, crops are increasingly grown under shelter to obtain year-round harvests. The type of variety is a crucial factor in this confined system. A list of varieties was established in Martinique after 4 years of studies:

- *tomato: Capitan, Carmello, Tropic Boy*
- *melon: Savor, Andès*
- *pepper: Narval, Pacific, Drago, Tenno*
- *lettuce: Minetto, Ostinata, Sierra, Laura, Divina*
- *cucumber: Genuine, Victory, Tropi Cuke*

Factsheets describing fertilization, irrigation, and crop protection techniques for the recommended varieties were distributed among farmers.

Theses Completed in 1992

CIRAD Trainees

Evaluation de la diversité génétique et du comportement en croisement des sorghos (*Sorghum bicolor* L. Moench) de race *guinea* au moyen de marqueurs enzymatiques et morphophysiologiques [Evaluation of the genetic diversity and crossing behaviour of guinea race sorghum (*Sorghum bicolor* L. Moench) varieties using enzymatic and morphophysiological markers] by Isabelle Degremont (France); Université Paris XI, Centre d'Orsay.

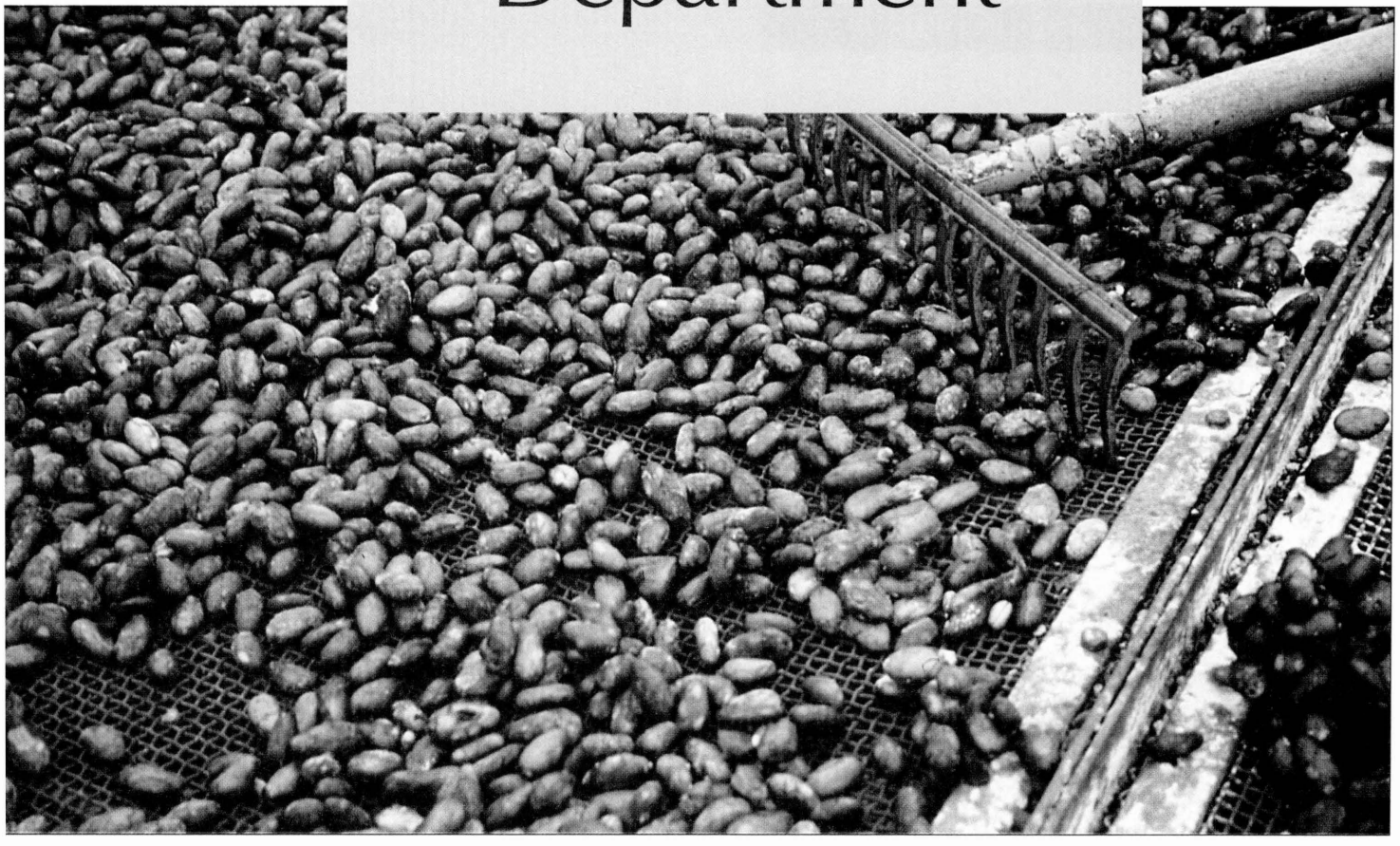
Biologie et écologie de la mineuse nord-amércaine des feuilles, *Liriomyza trifolii* (Burgess), ravageur des cultures maraîchères au Sénégal : études des possibilités de lutte [Biology and ecology of the North American leaf miner, *Liriomyza trifolii* (Burgess), vegetable crop pest in Senegal: studies on control methods] by Emile Victor Coly (Senegal); Université Aix-Marseille III.

Biologie et écologie de *Cryptophlebia leucotreta* en Côte-d'Ivoire : implications agronomiques [Biology and ecology of *Cryptophlebia leucotreta* in Côte d'Ivoire: agronomic implications] by Germain Ochou-Ochou (Côte d'Ivoire); Ecole nationale supérieure agronomique, Montpellier.

Les relations entre la culture cotonnière et les cultures vivirières au Bénin [The relationship between cotton and food crops in Benin] by Claude Cossi Chedeme (Benin); Université Montpellier I.

Diversité moléculaire RFLP et cartographie génomique chez la canne à sucre (*Saccharum* spp.) [Molecular RFLP diversity and gene mapping in sugarcane (*Saccharum* spp.)] by Yun Hai-Lu (China), Université Paris XI, Centre d'Orsay.

Tree Crops Department



Cocoa, coffee, coconut, natural rubber, and oil palm play a significant role in many national economies. They are grown in both smallholdings and commercial plantations and share similar ecological and economic environments. CIRAD-CP, the new tree crops department, was created recently to pool long-standing experience on these crops and to develop it further. Research and development activities focus on technological quality and postharvest processing, and on the productivity of sustainable cropping systems as they compete for scarce resources

Reorganization within CIRAD led to the creation of the Département des cultures pérennes (CIRAD-CP), the tree crops department, on 1 November 1992. It was formed by merging three departments: IRCA (natural rubber), IRCC (stimulant crops), and IRHO (perennial oil crops).

Preparations by the three departments for the merger proceeded without interrupting ongoing research. The groundwork involved definition of strategic objectives, reflection on the medium-term research programme, harmonization and modernization of procedures, and dialogue between staff. The new department is thus suitably equipped to become fully operational in 1993.

CIRAD-CP will capitalize on the long-standing and diverse experience of its former departments and adapt its capacity to achieve excellence in research for economic development.

Tree crops were often developed for export markets as pioneer crops on deforested land. Coffee and cocoa were grown on individual family farms whereas crops such as oil palm, coconut, and rubber were generally grown on estates or smallholdings. But these crops have now reached their limits. Rampant deforestation has drawn the attention of the international community towards the need to preserve forests. Population growth and land shortage are additional limiting factors to development.

Researchers face the daunting challenge of designing environment-friendly and sustainable farming systems for the humid tropics.

The immediate objective is replantation so that costs and yields are maintained at a more competitive level than pioneer crops.

The fall in world prices for these commodities calls for lower production costs and higher value added through better product quality. Production costs can be reduced through economical production technologies that increase labour productivity and lessen input use.

CIRAD-CP's research priorities for the coming years were defined according to this context. Stable research capacity and strong thematic thrusts will enable CIRAD-CP to strengthen its research activities in major production areas, to train scientists from its own staff and from partner organizations, and to participate in development efforts.

Joint operations by the department's programmes generate synergy. Some operations are already under way (management of genetic variability, in-vitro culture, chemistry); others need to be reinforced (economics, resource management, agrophysiology). In addition, the operations will be less scattered geographically to achieve greater cohesion.

A dynamic cooperation policy will be adopted to promote stable partnerships with research organizations, development agencies, and the private sector in the north and south.

Regular brainstorming on long-term and mainly economic perspectives will guide the department's activities and maintain their relevance to development needs.

Cocoa

The problem of overproduction continues to beset cocoa crops worldwide despite a slight fall in 1992. Given this context, our concern is to improve profitability and product quality.

Yield Improvement

Breeding for high yield is important because it is one way of reducing the cropped area and input use. Land

TREE CROPS DEPARTMENT

CIRAD-CP

Director	Alain Weil
Deputy Director	Christian Brunin
Research Director	Jacques Meunier
Programmes Director	Paul Gener
Administrative and Fiscal Director	Robert Jouanique

Research Programmes

Cocoa	Denis Despreaux
Coffee	Daniel Duris
Coconut	François Rognon
Natural rubber	Hubert Omont
Oil palm	Bertrand Tailliez

Research Units

Agronomy	Robert Ochs
Tree crop improvement	Dominique Nicolas
Crop protection	Jean-Luc Renard
Chemistry and technology	François Challot
Economics	Claude Freud
Biometrics	François Bonnot

Support Services

Information, communication	Christine Nouaille

productivity is improved primarily through the use of high-yielding varieties.

Our varietal development programme with the Institut des forêts (IDEFOR), Côte d'Ivoire, neared completion of the second cycle. Hybrids of selected clones were markedly superior to the first-generation hybrids, which had already been widely distributed. The best hybrids produced more than 3 t/ha of commercial cocoa.

Productivity is also enhanced through the creation of varieties that combine high disease (*Phytophthora* sp.) and pest (mirids) resistance with satisfactory yield. We launched a recurrent selection programme in 1990 in Côte d'Ivoire to develop such varieties and 250 new hybrids were planted in 1992.

Work on resistance to the cocoa swollen shoot virus (CSSV) continued in Togo. Among recently released varieties, two clonal hybrids showed good resistance in inoculation tests carried out on young beans. In another study with the Institut national de la recherche agronomique (INRA), France, the complete genome sequence of the virus was identified. We can now develop new diagnostic methods.

In Montpellier, we used DNA markers to examine about 300 clones in a cocoa genetic diversity project. Restriction fragment length polymorphism (RFLP) and random amplified polymorphic DNA (RAPD) techniques were used to map the cocoa genome. Such a map will facilitate location of genes encoding desirable characters such as disease resistance and organoleptic qualities.

In collaboration with Francereco of the Nestlé group, we determined the conditions for producing somatic embryos from petals of nine genotypes. Approximately 100 plantlets regenerated from somatic embryos were transferred to pots for hardening in the greenhouse.

In Cameroon and Vanuatu, we identified sources of resistance to black pod (*Phytophthora* sp.) based on avoidance. The pod maturation period and time of production apparently influence outbreak of epidemics.

We started work with the University of the West Indies to develop a procedure for exchanging material between the international collection in Trinidad and other cocoa research centres. In the first year, work focused on developing thermal and chemical treatments against witches' broom. This disease is caused by a fungus, *Crinipellis perniciosa*, which has, until now, only been detected in the Americas.

Crop Management

Some of our pest and disease control techniques are based on innovative management. New chemical control techniques against *Phytophthora* and mirids that halve the number of applications were promoted throughout Cameroon. We also identified several parasitoids of the rose beetle for biological control of the pest in Vanuatu.

A new project currently conducted in Vanuatu aims to define optimum parameters related to light energy for a coconut - cocoa intercrop. For this we established photosynthesis balances for several types of intercrops and sole crops.

Fruit Quality

Our recommendations usually aim to produce cocoa of satisfactory quality for industry. However, manufacturers also need high-quality cocoa for top-of-the-range products.

We studied the properties of high-quality cocoa and the factors involved at each processing stage to devise suitable techniques.

High quality depends on the efficiency of postharvest operations. We developed a programmable automatic fermentor in collaboration with the French company Gauthier. The project received support from: Agence nationale de valorisation de la recherche (ANVAR), general council of the department of Hérault, and Ministry of Research and Space.

We undertook laboratory studies to establish chemical models of aroma formation in cocoa. Preliminary studies defined the role and nature of precursors of the Maillard reaction, secondary phenolic compounds, and theobromine. Roasting of model systems of certain precursors revealed the influence of heat treatment parameters, sugars, amino acids, and epicatechins on the development of aldehydes, the key components of cocoa aroma. However, although roasting of simple systems can indicate the formation of different compounds present in cocoa aroma, it does not supply much information on the formation of the aroma itself.

Publication

Cocoa Agronomy

L'Agronomie du cacaoyer *is an overview of CIRAD's research on cocoa agronomy. It collects findings of experiments mainly in Côte d'Ivoire and Togo, but also in Cameroon, Madagascar, Uganda, and Gabon. The publication comprises four parts: multiplication and preparation of plant material; planting and crop establishment; yield improvement; and replantation. The publication is also intended for development agencies and extension services because it serves as a ready reference on existing techniques for crop intensification and protection.*

Coffee

Coffee planters throughout the world are seriously affected by the collapse in world coffee prices. In such a situation, they need to raise productivity, reduce production costs, and improve quality. Our research and development activities aim to support them in their efforts.

Coffee Quality

Burundi coffee suffers a price cut of 10% compared with an average arabica coffee because of its potato

flavour. The cause is an insect-transmitted bacterium. Our efforts in collaboration with the Institut des sciences agronomiques du Burundi (ISABU) first focused on eradication of the insects from coffee plantations. But preliminary results did not establish any clear correlation between berries damaged by the insects and the potato taste. A temporary solution to reduce risk was to remove berries that float in pulping tanks.

We sought to obtain a Kenyan-type washed coffee at lower cost. Such coffees fetch higher prices at auctions than on forward markets.

Wet processing of coffee is extremely polluting. In Mexico, a pilot depollution unit based on anaerobic fermentation of waste water was installed at a pulping station belonging to a farmers' organization. We calculated that such a unit can generate sufficient methane to provide energy for the entire coffee drying process.

We also undertook research on the determinants of coffee quality, in collaboration with Francereco.

Crop Profitability

Our recommendations for reducing the cost of crop protection treatments drew on the results of epidemiological studies on leaf rust and coffee berry disease. The studies were carried out in Cameroon, Laos, Papua New Guinea, and Central America; fungicide trials were undertaken simultaneously in Cameroon.

We identified a new parasitoid to control the coffee berry borer in Togo and a mass rearing programme of the parasitoid is under way. Various biological control methods against the borer were tested in Nicaragua. Soil pest studies (scale insects, nematodes) were undertaken within the Central American Promecafé network. Grafting of *Coffea arabica* onto *C. canephora* Robusta is currently recommended for protection against nematodes.

In erosion control studies in Burundi, we demonstrated that planting of *Leucaena* sp. in alternate rows can stabilize the soil. The technique is now ready for use in farmers' fields. Constant mulching in smallholdings has led to a cationic imbalance in the soil. A network of trials in farmers' fields was established to restore soil fertility.

In Mexico, farmers applied fertilizers that were available on the market, but their composition varied from year to year. Using results of soil analyses, we were able to recommend more balanced formulas and reduce the amount of fertilizer. Yields now range between 450 kg/ha and 800 kg/ha. Another positive outcome is the decline in leaf rust incidence, probably as a result of better plant nutrition.

Networks

Research Network for African Coffee

In an attempt to overcome declining plantation productivity and product quality in Africa, the Organisation interafricaine du café (OIAC) sought the support of the Commission of the European Communities (CEC) to revitalize coffee research. We were commissioned to investigate the problem. After discussions with OAIC, CEC, and the Technical Centre for Agricultural and Rural Cooperation (CTA), The Netherlands, we recommended the creation of a coffee research network under the aegis of OAIC. The network will be formed by OAIC's 23 member countries and it will be officially inaugurated in March 1993.

Coconut

In spite of an appreciable increase in copra oil and copra prices in 1992, coconut remains a low-income crop. But it is often the only crop that smallholders can grow and represents their sole source of income. Our objective is to increase the efficiency of coconut-based farming systems and to obtain higher value-added end products.

Environment and Agronomy

We continued studies of production factors and development of technology packages for the diverse environments in which coconut is grown.

Unusually, the Lampung experimental network in Sumatra experienced drought in 1992. But it served to confirm the strong response of coconut hybrids to chlorine. This element acts as both resistance factor in water stress conditions and production factor in normal supply or low deficit conditions. Chlorinated fertilizers should be applied outside areas with adequate water supply (eg, coastal areas). The critical level is 0.5% of chlorine in the dry matter of leaf 14.

Varietal trials under dry conditions highlighted the role of fatty acids in leaves. Cell and chloroplast membranes of leaves probably function better at low fatty acid levels. In spite of poor water supply, hybrid PB 121 is likely to have performed well because of this reason. The other determining factor is high stomatal conductance. These findings open the way for new research based on the composition of these fatty acids.

We studied nitrogen transport in coconut palms aged 4 years using isotope ^{15}N. The study was conducted in collaboration with IDEFOR and the International Atomic Energy Agency (IAEA).

We observed that nitrogen was distributed throughout the plant 3½ months after fertilizer application. We also observed that minerals and metabolites from old leaves were channelled towards organs at active growth stage. Coconut meat derives its nitrogen more from the husk and shell than from applied fertilizer. It would take 8–10 months for nitrogen fertilizer to act on coconut meat.

We launched a new project to study competition for light, water, and nutrients in a coconut-based intercropping system. Preliminary results obtained in collaboration with IDEFOR in Côte d'Ivoire showed that only a small percentage of light passes through a coconut canopy to the ground, at least at palm densities recommended for maximum coconut yields. For a density of 115 palms/ha, 29% of light reaches the ground, compared with only 12% for a density of 180 palms/ha.

Coconut Improvement

Tests designed for families of half-sibs to evaluate combining ability of individuals proved to be reliable and conformed to coconut biology. They were applied in the second breeding cycle conducted in Côte d'Ivoire.

We succeeded in improving the productivity of hybrid PB 121 (Malayan Yellow Dwarf x West African Tall) by 15% within a single generation; factors of tolerance of *Phytophthora katsurae* were also identified in the new generation. In 1992 we completed evaluation of the first families that were planted—there was a total of 300 families of half-sibs in the second cycle. Varieties will be released in the course of the next few years.

In collaboration with the Institut français de recherche scientifique pour le développement en coopération (ORSTOM), France, we successfully produced functional somatic embryos of coconut. It is a significant step in the development of reproducible vegetative propagation techniques. The plantlets were

Networks

Genetic Resources of Coconut

The coconut genetic resources network set up by the International Board for Plant Genetic Resources (IBPGR) in 1991 entrusted us with the task of building an international database on the genetic resources of coconut. Officers in charge of germplasm collection from the network met in Montpellier in May 1992 to discuss guidelines for the establishment and management of the database. The software was presented at the first meeting of the network's monitoring committee, which was held in Singapore in December.

produced from leaf and inflorescence explants extracted from several clones of different genotypes.

Crop Protection

We organized a seminar at the Manado research station in Indonesia to present the results of the CEC-sponsored programme on *Phytophthora*. Four species—*P. palmivora, P. arecae, P. nicotianae* var. *parasitica,* and *P. katsurae*—are responsible for hartrot and coconut fall. *P. katsurae* has not been detected in Asia. Isozyme profiles revealed a common genetic origin for *P. palmivora* and *P. arecae*. Certain West African Tall lines that gave good results in Indonesia could be introduced in hartrot resistance breeding programmes. Inoculation tests on fallen nuts also identified cv Green Dwarf as a source of resistance. In-vitro tests revealed the antagonist reaction of two other fungi, *Myrothecium roridum* and *M. verrucaria,* to *Phytophthora*. But although this form of resistance can be used on young plants, it is not easily applicable in the field.

We observed that leaf diseases had clearly receded in the Socôco plantation in Brazil. Two fungi, *Septofusidium elegantulum* and *Acremonium*, were found to regulate the development of *Catacauma torrendiella* by drastically reducing the appearance of perithecia. Development of *Botryosphaeria* sp., the secondary parasite that is associated with *C. torrendiella*, was also limited. Leaf desiccation had almost stopped and the number of green leaves increased from 17 to about 25.

We successfully reared *Myndus taffini* (Hemiptera)—the vector of the coconut wilt virus in Vanuatu—in the laboratory on roots of a host (*Hibiscus tiliaceus*) of the preadult stages. These virus-free insects will be used to study transmission of the pathogen.

Copra Technology

We found that protein content of copra oilcake can be increased by 50% by adding a simple filamentous fungus strain to the mass. Protein and probiotic enrichment of copra meal by fermentation on solid medium will be studied for developing an animal feed. On this project we shall work together with INRA, ORSTOM, and the Autonomous University of Mexico.

Natural Rubber

Annual supply and demand for natural rubber balance out at approximately 5 million t, which accounts for 30% of world consumption of rubber. Natural rubber must be made more competitive if it has to maintain—and increase—its market share. Our objective is therefore to lower production costs and to improve suitability to users' needs.

In 1992 our work concerned mainly evolution of soil fertility and plant studies to improve plantation

management techniques; we also created a new type of rubber.

Crop Physiology

We worked together with the ecology department of the Ecole normale supérieure (ENS), France, and IDEFOR, Côte d'Ivoire, on a project for the evaluation of the relationship between biological processes and soil fertility in rubber plantations. The project was funded by the French Ministry of the Environment. Cultivation of rubber does not appear to modify greatly the initial physical and chemical parameters of soil fertility, but it affects soil fauna. The forest floor supports a varied fauna that is predominated by earthworms. They play an important role in maintaining the physical parameters of soil fertility. But rubber plantations favour the development of termite populations, which feed on wood cuttings and proliferate at the expense of other species. It takes 5 years for the earthworm population to regain its earlier position.

Various methods are used to study the laticifer system. Mechanisms controlling transfer of sugars across laticifer cell walls were identified by electrophysiology. We found that ethylene, the main factor in yield stimulation, affects activity of certain key enzymes in the metabolism of isoprene. We are also analyzing systems that control senescence (eg, thiols).

Latex diagnosis serves to rationalize tapping systems by evaluating the physiological state of the rubber tree. It is useful for field experiments and in commercial plantations. We monitored more than 50000 ha in Cameroon, Côte d'Ivoire, and Indonesia by this method.

Plant Material

We can now recommend *Hevea* clones that are suited to various agroecological conditions by using the results of long-term, large-scale comparative trials. The seven countries for which the recommendations were made included: Cameroon, Côte d'Ivoire, Gabon, Guatemala, Guinea, Kampuchea, and Viet Nam.

Rigorous management of budwood gardens for vegetative multiplication of *Hevea* is critical because any error can have an exponential effect. We use enzyme markers to ensure that the clones are true to

Products for Development

New Processes for Manufacturing Rubber

The liquid natural rubber development programme sponsored by the United Nations Industrial Development Organization (UNIDO) through the International Rubber Research and Development Board (IRRDB) ended in 1992. The final phase focused on the development of a procedure for manufacturing three products. During this phase we worked with IDEFOR, Côte d'Ivoire; Université du Maine and the Institut de recherches appliquées sur les polymères (IRAP), France. The three products are:

- *liquid natural rubber, with a molecular mass between 8000 and 16 000 and storage stability;*
- *epoxidized liquid rubber, with epoxidation levels of 10% and 25%;*
- *modified or nonmodified liquid rubber, blended with field latex at liquid polymer levels of 5% and 10%.*

We established contacts in the tyre industry for using liquid rubber to develop more homogeneous mixes. Certain applications are already undergoing large-scale tests.

type. With the laboratory kit developed in 1991, we can now analyze material on site and control the composition of budwood gardens in several countries.

We developed a technique to produce plantlets of several clones by microcutting. But the technique needs to be developed further for large-scale application.

We studied the biochemical and histological characteristics of *Hevea* calluses and young embryos. As a result, somatic embryogenesis has evolved into a reliable process for most of the test clones. We also have better control on the development from embryo to plantlet and on embryogenic capacity.

We developed a method for identifying and evaluating components of resistance to the fungus *Microcyclus ulei* in controlled and field conditions. The method is based on several years of work in French Guiana. It will be integrated in a *Hevea* improvement programme in Latin America, the first phase of which began in 1992 in collaboration with a large estate company in Brazil.

Economics of Smallholder Production

Agricultural economics research for rubber has focused on the smallholder sector. Our field research on smallholder strategies led to innovative recommendations for sectoral policies. In Indonesia, for example, analyses of the strategies of smallholders not covered by government replanting schemes prompted the authorities to set up a development assistance programme and several networks for trials in farmers' fields.

In Thailand, we studied the interaction between the public and private sectors for a development project focusing on the distribution of selected rubber varieties. Multiplication of plant material is a delicate operation, which determines rubber yields in the long term. This task was entrusted to private enterprises such as budwood gardens, nurseries, retailers, as they can respond rapidly to demand. Genetic origin and quality of plant material produced by these enterprises are controlled by organizations such as the Rubber Research Institute of Thailand (RRIT) and Office of the Rubber Replanting Aid Fund (ORRAF). The success of ORRAF's clone replanting programme is based on this distribution of tasks between private enterprises and public organizations.

Oil Palm

Palm oil accounts for nearly 20% of world vegetable oil production and ranks second after soybean oil. Productivity can be increased through the use of high-yielding plant material, having tolerance of the main diseases with known (vascular wilt disease) or unknown (hartrot) epidemiology. It can also be increased through environment-friendly techniques that prevent soil compaction and control erosion, and through rational fertilizer application.

Cultural Practices

In 1992 we concentrated on the development of environment-friendly cultural practices specifically suited to plantations. This technical assistance was requested by various plantations: Palmindustrie, Côte d'Ivoire; Socapalm and other plantations, Cameroon; Socfindo, Indonesia; and Palmas del Espino, Peru.

In Indonesia, we measured the residual effect of phosphate fertilizers applied over several years at optimum rates. The effect on nutrition lasts for 4 years after fertilization has been stopped; on production, it lasts for 6 years. This allows planters considerable flexibility in fertilizer management.

In Cameroon, we improved determination of the optimum balance between potassium and magnesium in highly desaturated sandy ferralitic soils, which are characterized by deficiency in the two elements.

Oil Palm Agronomy

Agronomic studies of oil palm contribute to a better understanding of limiting factors linked to the resource base. Models derived from these can provide planters with precise diagnostic tools.

Monitoring of water balances showed that in adequate water supply conditions, evapotranspiration from the canopy was equivalent to 80% of potential evapotranspiration. In the dry season, water available in the root zone (up to a depth of 5 m) exceeded 40% because of early stomatal closure. Palms survived on gas exchange although this was extremely slow, but bunch production was halted.

In western Africa, bunch yields do not exceed 20–23 t/ha even without water stress because cloud cover reduces sunlight. The same plant material yields at least 30 t in Southeast Asia where there is 30% more sunlight.

Plant Material Quality

In Côte d'Ivoire we undertook a diagnostic study covering 130 000 ha of oil palm at the request of Palmindustrie. We found that for plants of the same age, replantations produced, on average, 25% more than the first planting. The yield gain can be attributed to improvement in plant material over the past 20 years.

In northern Sumatra, where climatic conditions are particularly favourable, we compared various origins of plant material. Deli x La Mé hybrids at 10–16 years attain annual oil yields of 6.6 t/ha, compared with 5.4–6 t for other sources. Yield reduction after 8 years, due to competition between trees, was also less marked and slower in these hybrids because of their smaller size.

Superior crosses in the second cycle of recurrent reciprocal selection have an oil yield that exceeds 8 t/ha in northern Sumatra. Clones selected from the high-yielding palms are expected to have a potential of more than 10 t. We demonstrated that the best oil palm clones can produce 25–30% more than the average yield of the hybrid progeny from which they originate.

The somatic embryogenesis procedure that we perfected in collaboration with ORSTOM produced 2500 ha of regenerated plants that were distributed throughout the world. This multilocation experiment highlights the difficulties in transferring a technique from the laboratory to the field, and suggests ways of overcoming them.

Service for Development

Technical Support for a Peruvian Company

The Palmas del Espino company in Peru has 4600 ha of oil palm plantations, which were established between 1982 and 1987. For the past 10 years we have advised the company on cultural techniques. Bunch yields were 18.5 t at 4 years and levelled off at an annual average of 24 t/ha, with an oil extraction rate of 24%. These results were also due to the excellent quality of the plant material. They are entirely satisfactory considering that sunshine levels are relatively low (1700 h/yr) and that temperatures fall to less than 18°C for 2 months in a year. Artificial pollination by dusting pollen on mature flowers and the release of the pollinating weevil Elaeidobius kamerunicus *have contributed to this success.*

International Meetings

Towards Cooperation on *Phytomonas*

We organized the second international workshop on Phytomonas *jointly with the Centro de Investigaciónes en Palma de Aceite (CENIPALMA), Colombia. The workshop was held in Santa Marta, Colombia, from 5 to 8 February 1992. About 20 speakers reviewed research on plant trypanosomes and the two diseases—marchitez of oil palm and hartrot of coconut—caused by them. Much progress had been made since the first workshop, which was held 5 years ago. Scientists can now use* Phytomonas *cultures and biotechnology to characterize strains. Several insect vectors have also been identified. These are encouraging results for rapid development of integrated management of the diseases caused by* Phytomonas.

Review of Oil Palm Breeding Programmes

We joined the Palm Oil Research Institute of Malaysia (PORIM) in organizing the symposium of the International Society of Oil Palm Breeders (ISOPB). It was held from 1 to 3 July 1992 in Montpellier and was attended by many oil palm breeders worldwide. The objective was to review work on the major themes of oil palm improvement for better productivity and disease resistance.

Abnormal floral morphogenesis in adults was explained by determining endogenic plant hormones. Calluses with this potential abnormality can be eliminated after identification by molecular markers.

Reduction of plantlet production costs is one of our priorities. The use of embryogenic cell suspensions in liquid medium should be a routine procedure in some years. Its advantage is that it saves on manpower and laboratory space.

Protection of Palm Groves

In Ecuador, there is increasing evidence that leaf-sucking insects of the genus *Molomea* (Cicadellidae) transmit hartrot disease of oil palm. Once this is confirmed, we need to develop a method to control the vector and to determine the nature of the pathogen.

Two important results emerged from the CEC-sponsored work on marchitez of oil palm and hartrot of coconut. The pathogens of both diseases are suspected to be trypanosomes. We succeeded in mass rearing the vector (*Lincus* sp.) over several complete cycles. These bugs can be used to inoculate plants to confirm trypanosome pathogenicity. The other important finding was that trypanosomes living on grass weeds in the groves were different from those on palms.

We also participated in the CEC-sponsored project on biological control of *Chromolaena odorata* in Côte d'Ivoire and Indonesia. This invasive plant occurs in the Far East and Africa. A leaf-eating caterpillar, *Pareuchaetes pseudoinsulata*, was successfully introduced in the plant's range to check its spread.

Theses Completed in 1992

CIRAD Scientists

La maladie sud-américaine des feuilles de l'hévéa : étude en conditions naturelles et contrôlées des composantes de la résistance partielle à *Microcyclus ulei* (P. Henn.) V. Arx [South American leaf blight: study in natural and controlled conditions of the components of natural resistance to *Microcyclus ulei* (P. Henn.) V. Arx] by Frank Rivano; Université Paris XI.

CIRAD Trainees

Les composés phénoliques foliaires de l'hévéa et leur implication dans la résistance à *Colletotrichum gloeosporioides* Penz. et *Microcyclus ulei* Henn. [Phenolic compounds in *Hevea* leaves and their role in resistance to *Colletotrichum gloeosporioides* Penz. and *Microcyclus ulei* Henn.] by Pascale Berger (France); Université Montpellier II.

Mécanisme du brunissement en culture *in vitro* : facteurs d'influence et potentiel embryogène des cals chez *Hevea brasiliensis* [Browning mechanism in in-vitro culture: determining factors and embryogenic potential of *Hevea brasiliensis* calluses] by Fatima Housti (Morocco); Université Montpellier II.

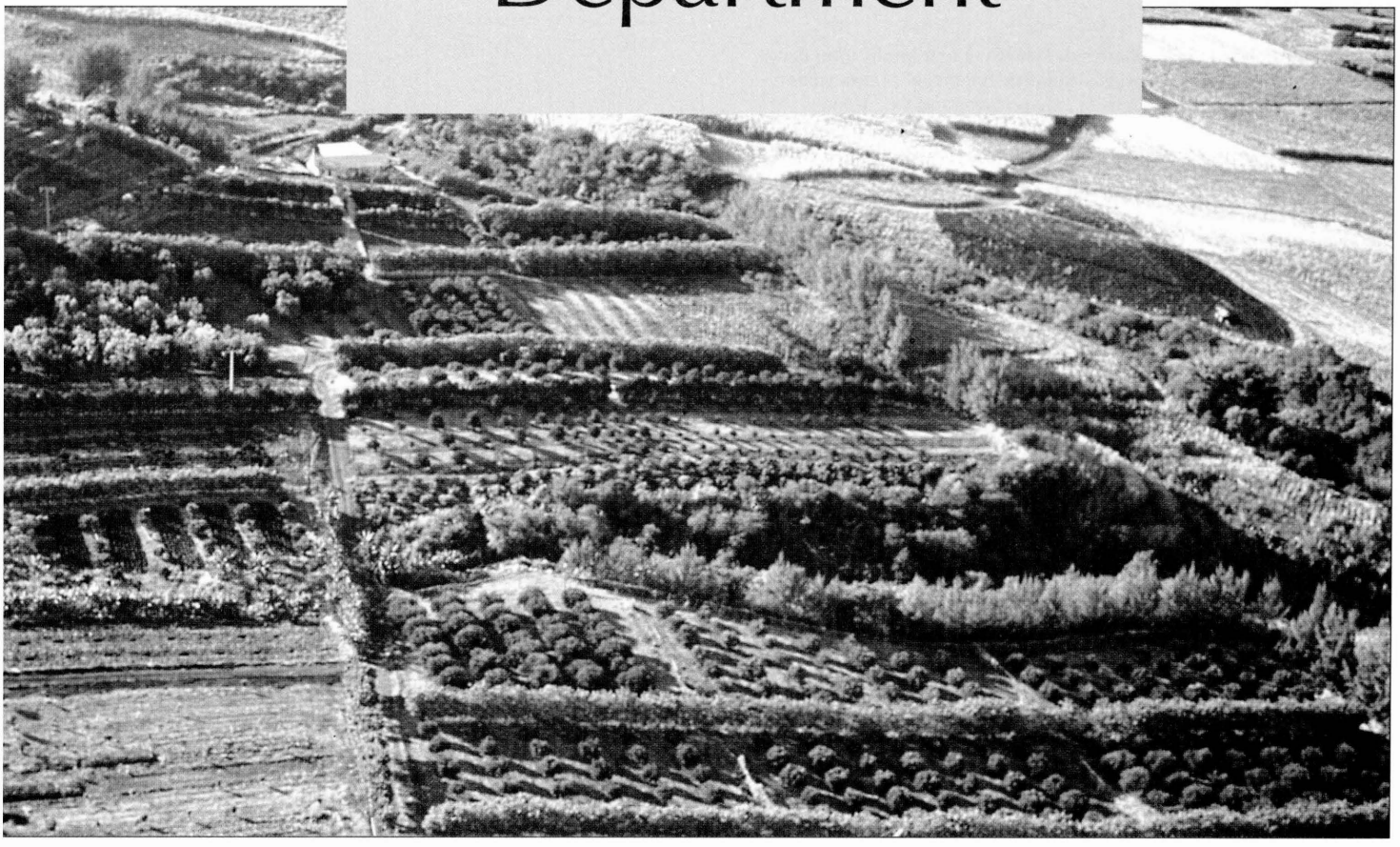
Approche par enquête et expérimentation de l'effet de l'état structural du sol sur la nutrition azotée et l'élaboration du rendement [Study by surveys and experiments of the effect of soil structure on nitrogen nutrition and yield components] by Gede Wibawa (Indonesia), Institut national agronomique, Paris-Grignon.

Bioraffinage : désacidification enzymatique des huiles hyperacides [Biorefining: deacidification of hyperacid oils using enzymes] by Amélie Ducret (France), Institut national polytechnique de Toulouse.

Recherche du déterminisme hormonal de l'anomalie de la morphogenèse florale liée à l'embryogenèse somatique chez le palmier à huile (*Elaeis guineensis* Jacq.) [Determination of the role of hormones on floral morphogenesis in somatic embryos of oil palm (*Elaeis guineensis* Jacq.)] by Isabelle Besse (France); Université Paris VI.

Utilisation de la culture *in vitro* d'embryons zygotiques pour la collecte et la conservation des ressources génétiques du cocotier (*Cocos nucifera* L.) [In-vitro culture of zygotic embryos for collecting and conserving germplasm of coconut (*Cocos nucifera* L.)] by Béatrice Assy-Bah (Côte d'Ivoire); Université Paris VI.

Fruit Crops Department



Two hundred million tonnes of fruit are produced annually in the tropics and subtropics. They contribute to food security and nutritional needs in the tropics and Mediterranean region. Fruit crops account for a significant proportion of farmers' income. Crop diversification opens new domestic and export markets. In forest regions, fruit trees feature prominently in environment protection campaigns. At CIRAD, through our research programmes and involvement in development operations, we are concerned with all aspects of the fruit industry: plant improvement, crop production, integration of fresh or processed fruit in the economy

The tropical fruit industry is one of the rare growth sectors in world trade. IRFA has responded to this heightened interest by enhancing the scientific content of its programmes, and by reinforcing and redeploying its field units.

The Centre régional bananiers et plantains (CRBP) was created in Cameroon with financial support from the European Community (EC) for the purpose of strengthening regional cooperation. In eastern Africa, cooperation with member states of the Communauté économique des pays des Grands Lacs (CEPGL) took a concrete shape as two promising projects were launched. One of them concerns high-altitude bananas and the other, fruit and vegetables in Burundi.

In Costa Rica, the pathology component was reinforced for the plantain project at the Centro Agronómico Tropical de Investigación y Enseñanza (CATIE). In Colombia, the fruit project of la Valle del Cauca and the project for cultivating Plantain in the central coffee zone are yielding results that are already influencing practices in Andean countries.

The Pocquereux research station in New Caledonia is now adequately equipped to serve as the hub for regional cooperation in the Pacific.

In Réunion, regular dialogue with the local authorities enables us to align our research to the island's needs. Development projects in collaboration with the local chamber of agriculture have led to a substantial increase in fruit production. Cooperation is growing in the Indian Ocean region, particularly with Mauritius.

In Guadeloupe and Martinique, 1992 was marked by instability in the banana economy due to the forthcoming creation of the Common Organization of the Market (COM) of the European Community. Innovative technology is needed to ensure better competitiveness and long-term environment protection. This implies increased research capacity, adaptation of programmes to fit regional and international cooperation requirements, and stronger interaction with those involved in the industry.

Together with the International Network for the Improvement of Banana and Plantain (INIBAP), we organized a symposium on genetic improvement of banana for resistance to pests and diseases. It was held in Montpellier from 7 to 9 September 1992. The meeting gave further impetus to international cooperation, which has already progressed rapidly through INIBAP.

Early 1993 will mark an important milestone in the department's history. Its mandate has been broadened to include vegetables, and ornamental, aromatic, and medicinal plants. The department will also have a new name to match its widened mandate. It will be called the Département des productions fruitières et horticoles—fruit and horticultural crops department—or CIRAD-FLHOR. Its objective is to improve supply of fresh and processed fruit and vegetables as well as flowers to local and export markets.

CIRAD will then be able to include horticulture in its strategy to respond more effectively to the needs of its partners. CIRAD-FLHOR will work closely with the annual crops department (CIRAD-CA) and food technology and rural systems department (CIRAD-SAR).

In keeping with its new mandate, CIRAD-FLHOR will undertake a geostrategic reorganization of its regional cooperation activities.

Citrus

Citrus cultivation techniques are designed, improved, and tested so that orchards draw maximum benefit from agricultural and economic conditions in

the tropics and subtropics. Our efforts therefore focus on germplasm management and use, genetic improvement and biotechnology, pest and disease control, ecophysiology and yield components, food technology, and essential oils.

FRUIT AND HORTICULTURAL CROPS DEPARTMENT

CIRAD-FLHOR*

Director	Jean-Louis Rastoin
Deputy Director and Programmes Director	Jean-Pierre Gaillard
Research Director	Jacky Ganry
Administrative and Fiscal Officer	Catherine Pacherie-Simeral

Research Programmes

Citrus	Bernard Aubert
Pineapple	Pierre Martin-Prevel
Banana and plantain	Hugues Tézenas du Montcel
Other tropical and subtropical fruit trees	Bernard Aubert

Research Units

Genetic resources and plant improvement	Patrick Ollitrault
Parasite and pest biology, disease control	Xavier Mourichon
Agronomy and farming systems	Jean-Joseph Lacoeuilhe
Economics and management	Jean-Louis Rastoin
Technology and quality control	Max Reynes
Biometrics and computer services	Xavier Perrier

Support Services

Publications, documentation	Chantal Loison

* After 1 March 1993.

Germplasm Management and Use

A computerized system was developed in Martinique for managing the citrus germplasm collections. It is useful for varietal screening. The system notes the tree's location in an orchard in addition to its genetic origin, background, and performance. Fruit tree specialists at the Institut national de la recherche agronomique (INRA), France, are interested in extending it to other ligneous fruit species.

The publication of a catalogue of species and cultivars held in the Corsican collection is expected to expand the market for elite budwood and seed of rootstock. The virology unit screens the material according to strict standards to keep it disease-free. Local authorities in the French West Indies, New Caledonia, and Réunion order this material to stock nurseries on the islands.

We also studied thorny hedges that can be used as impenetrable enclosures around protected sites. *Poncirus trifoliata* is the most important species that is used for these defensive barriers.

Genetic Improvement and Biotechnology

The use of molecular markers for genetic evaluation has shed new light on the taxonomy and evolution of citrus.

The identities of the three ancestral taxons of cultivated *Citrus* species were clearly established. The nuclear and cytoplasmic genomes of mandarin, citron, and pomelo have distinct allele composition and structure. We observed by flow cytometry that there was approximately 10% variation in the size of nuclear genomes in the genus *Citrus*. The smallest genomes are those of mandarin, while the biggest are those of citron. The majority of economically important cultivars have complex genotype structures.

Improvement of citrus cultivars, particularly for disease resistance, can only be achieved through well-targeted modification of the genome.

A preliminary genome map was drawn for citrus. It was produced by means of more than 100 random amplified polymorphic DNAs (RAPDs), restrictive fragment length polymorphisms (RFLPs), and isozyme markers. It was based on progeny of the intergeneric cross *Citrus* x *Poncirus*. The *Poncirus* genome is known to contain several resistance genes against tristeza, *Phytophthora*, and nematodes. In coming years, scientists could use progeny of the intergeneric cross to locate these resistance genes.

We succeeded in producing somatic embryos from nucellar tissue of ovules. The technique was used to conserve a collection of about 12 cultivars in the form of embryogenic calluses. Encouraging results for cryoconservation of cell suspensions should lead to the establishment of a cryoconservation bank of major cultivars; the cultivars will be used subsequently for gene transfer. We can now regenerate plantlets from calluses and cell suspensions. Techniques for isolation and regeneration of protoplasts were developed in collaboration with the University of Florida at Lake Alfred, United States. We completed preliminary work on gene transfer combined with the use of the reporter gene GUS. In parallel, we obtained somatic hybrids that are now in the regeneration and hardening phases.

Pest and Disease Control

Our Réunion team worked with the Beltsville team from the United States Department of Agriculture (USDA) to develop a diagnostic technique for citrus canker (Asian form). A fragment of Ti-plasmid constructed with the canker DNA (PFL 62.42) was cloned in *Escherichia coli*. Polymerase chain reaction is a sensitive detection method and it will be used for epidemiological studies and for detection of the pathogen in plant material.

This advanced technique is valuable, particularly as regulations covering citrus imports into the EC, mainly from South America, are being revised.

We are carefully monitoring the spread of tristeza in the Caribbean region because the main vector, the aphid *Toxoptera citricidus*, has spread into the Dominican Republic.

The technique of successive electrophoresis runs in polyacrylamide gel was adapted for detecting the complex of 12 viroids that affect citrus.

In Réunion, flies attack about 30 fruit species and cause annual losses of about US$1.2 million. We concentrate on the Natal fruit fly, *Ceratitis rosa*, which is responsible for the highest damage. Our studies of fruit attractivity showed that, unlike most other pest species, this fly is influenced mainly by the fruit's odour. This observation should lead to practical applications. We developed integrated pest management techniques against the fruit fly with two

Campaign for Development

Successful Eradication of Fruit Fly in Réunion

A new fruit fly of Asian origin, Bactrocera zonata, *which is particularly active, has been spreading across Mauritius since 1986. The proximity of this threat prompted the chamber of agriculture, plant protection services, and scientists in Réunion to undertake early trapping campaigns in directly exposed areas in 1991 and 1992. The fly was eradicated in the months following its appearance on the island. Surveillance, however, continues.*

International Meetings

Citrus Fruits for the Caribbean

The regional conference on citrus cultivation in the Caribbean was jointly organized by CIRAD and the Instituto Interamericano de Cooperación para la Agricultura (IICA), Costa Rica. The conference was held on 18 and 19 February 1992 at Fort-de-France, Martinique. It was funded by the French Fonds interministériel français pour la Caraïbe (FIC). About 20 representatives from Martinique and Guadeloupe, and about 30 from Trinidad and Tobago, Dominican Republic, Dominica, Saint Lucia, and Guyana attended the conference. The papers presented innovative technologies related to soil preparation, choice of rootstock and cultivars, and screening for viral diseases and their vectors. The results of citrus studies undertaken in Martinique over the past 10 years were also presented. At the close of the conference, participants unanimously adopted a motion for strengthening collaboration between the Caribbean countries for citrus research.

International Pineapple Network

Our scientists presented eight papers at the first international symposium on pineapple, which was held in Honolulu from 2 to 6 November 1992. CIRAD and the University of Hawaii, United States, led the working group that was formed within the tropical commission of the International Society for Horticultural Science (ISHS). The international awareness created during the symposium will be favourable for cooperative research on pineapple. CIRAD was nominated to organize the second symposium, which will be held in 1995.

Hymenoptera—egg parasite *Biosteres arisanus* and parasite of young maggots *B. vandenboschi*. Poisoned traps are as efficient as conventional chemical control, but they cost less and are environment-friendly. Pheromone trapping serves as an early warning system for starting a treatment. These techniques are already used by farmers.

The Réunion team contributes its expertise on fruit fly in a project conducted with Greek partners, which is supported by the Commission of the European Communities (CEC). Our Greek partners include the University of Thessalonika and the insect group of the Institute of Molecular Biology and Biotechnology (IMBB).

In another CEC project we work with the Instituto Valenciano de Investigaciones Agrarias (IVIA), Spain. The project aims to diagnose and prevent potentially harmful organisms that may attack European fruit crops.

Ecophysiology and Yield Components

We undertook continuous micrometric measurements of different organs—branches or fruit—of clementine in Corsica to evaluate intensity of water stress. With this information we shall be able to develop water management systems without affecting yield and quality.

We carried out a preliminary study on the formation and use of sugars and starch in the above-ground parts of clementine in the climatic conditions of Corsica.

Twenty years of data collected during a long-term trial in Corsica on clementine rootstock were synthesized. Citrange and *Poncirus* conferred higher productivity than sour orange. *Poncirus* also showed the best results in hydromorphic soils.

In Martinique, we successfully tested Flying Dragon rootstock in an experimental orchard. The rootstock produces dwarf to compact trees and it will be

valuable for modernizing the layout of tropical orchards.

Food Technology

We are currently developing enzymatic and biophysical methods to reduce bitterness in citrus juices. We also signed a contract with the company Marie Brisard, France, to start work on detecting adulteration of citrus juices.

Pineapple

Our programme focuses on the diversification of commercial varieties. We create varieties and study mechanisms involved in obtaining yield and quality. Related research aims to improve pineapple cropping systems in the Andes region, Caribbean, Africa, and Mascarene islands.

Varietal Improvement

We no longer look for a single model of pineapple. Our selections from progeny of crosses vary according to market demand. For example, different lines are selected for canned slices, fresh fruit exports (for a wide range of varieties), or fruit juice. We must also cater for consumer preferences in domestic markets. The current demand for ornamental pineapples opens a new line of selection.

The CEC funded a new series of germplasm collecting trips in the Amazon basin by Franco-Brazilian teams. The team collected 500 new accessions in Amapa, Acre, and Mato Grosso. We refined techniques for evaluating accessions by combining three multifactor analyses and applying them to a set of 45 quantitative and qualitative criteria.

Publication

Quality Criteria for Pineapple

Pineapple: Quality Criteria *was produced in collaboration with the Comité de liaison Europe-Afrique-Caraïbes-Pacifique (COLEACP), an association of importers from Europe and exporters from the African, Caribbean, and Pacific countries. The publication presents optimum characteristics of fruit quality, factors likely to affect this quality, abnormalities, and evaluation criteria for each cropping and marketing stage. Photographs with detailed comments allow those working in the pineapple industry to clearly define observed flaws, determine causes, and establish solutions.*

This important publication was produced in French, English, and Spanish to reach a wider public.

In the same CEC project, we collaborated with the Université catholique de Louvain-la-Neuve, Belgium, and partially elucidated the conditions for pollen and ovule viability and incompatibility mechanisms.

The seed represents the first step in standard crosses. Until now, the degree of compatibility between the parents could not be evaluated. The possibility of removing incompatibilities temporarily will widen the spectrum of crosses. These studies also allowed us to clarify the taxonomy of certain ill-defined groups.

Evaluation of Yield and Quality

Our work in Côte d'Ivoire resulted in the modelling of fruit weight and yield according to climatic parameters.

The model is intended to help farmers in decision making. It was tested under local conditions by the University of Hawaii, which also developed its own model. This collaboration will be mutually beneficial for both models.

DIANA is a valuable expert system for adjusting pineapple cultivation to different ecosystems. It can be used on site for a diagnosis of the state of a pineapple crop based on soil characteristics, fertilization, climate, and parasite pressure.

Cropping Systems

We continued our efforts to reinforce contacts for crop intensification in Latin America and Asia.

We drew on knowledge acquired through multilocation experiments for recommendations on fertilization in Colombia. We also participated in local germplasm collecting expeditions and compared the performance of cvs Manzana and Cayenne in different cropping systems. We offer consulting services mainly in Ecuador, Costa Rica, Honduras, and Nicaragua. We work with the Instituto Nacional de Investigación Agraria y Agroindustrial (INIAA) in a CEC-funded programme aimed at the improvement of pineapple cultivation in the Amazon region in Peru. A similar project is planned for Bolivia.

In Viet Nam, pineapple is one of the rare crops that can be grown in the acid sulphate soils of the Mekong delta. It is suitable for baseline studies on resistance to different types of stress, and on innovative techniques for crop management and production.

In the Philippines, pineapple is intercropped with coconut, the basic family enterprise, for rapid monetary returns. Our studies aim to help farmers gain maximum benefit from each component. Moreover, pineapple provides an excellent cover to control erosion for better soil management.

Banana and Plantain

Our main objective is to select and produce banana varieties with tolerance of the main diseases; to develop integrated pest and disease management methods; to design cost-effective, environment-friendly cropping techniques and systems; and to adapt production to local needs.

Genetic Improvement and Pathology

For classification studies we combined molecular marker techniques (isozyme electrophoresis, RFLP) and morphological descriptions. Standard descriptive sheets were used with MUSAID, a computer software for determining varieties, for the morphological studies. This information is basic to all breeding work.

Observations on character segregation in progeny and polyploidization now enable us to understand the genetic mechanisms that control transmission of agronomic characters and disease resistance. Cytogenetic studies also contributed to current knowledge of inter- and intraspecific relations, and factors contributing to sterility.

Work on genetic mapping using molecular marker techniques (RFLP) progressed well. The map will allow breeders to locate specific genes on the genome.

Biotechnologies are a valuable support to conventional breeding strategies. We developed techniques for rescuing zygotic embryos of banana; our work also confirmed that induced androgenesis and parthenogenesis were viable techniques. The development of somatic embryogenesis and protoplast regeneration techniques will facilitate varietal creation through genetic transformation of triploid cultivars or potential diploid parents. Our results in preliminary trials using particle

bombardment indicate that this method can be applied to banana.

As our knowledge of resistance mechanisms against the *Cercospora* diseases increases, we can formulate a better strategy for genetic improvement.

Environment-friendly farming systems involve the use of disease-free plant material—produced in vitro, for example—in a disease-free environment. We collected useful information on pathogenic soil fungi (cycle, pathogenicity, interactions with nematodes) through our work on the underground system. The information will be useful for devising diagnostic methods and control techniques against soil parasites. We clearly observed endomycorhization in banana.

Fruit Quality

Quality determines the competitiveness of a product in an export market. We analyzed purely physiological factors before turning to pathological factors. A spore trap was adapted to banana for studying sources of and variations in inoculum of *Colletotrichum musae* and *Fusarium* sp. With this tool we shall be able to test a variety of techniques for reducing inoculum.

Agronomic and Economic Surveys

Expertise acquired in banana agronomy by our scientists is used for multifactor agronomic surveys under different cropping conditions. The surveys identify and rank the principal limiting factors related to soil and fertility. The results are directly used for advising farmers and guide the choice of research topics for improving production in the long term. The last survey conducted in Colombia—after Cameroon, Guadeloupe, Martinique, and Rwanda—confirmed the utility of the approach.

We inventoried and analyzed Plantain cropping systems in southwestern Cameroon. The results highlighted the expansion of Plantain as a cash crop and the determining agroecological influence of pests.

International Meeting

Genetic Improvement of Banana

The Symposium on the Genetic Improvement of Banana for Resistance to Diseases and Pests was held in Montpellier from 7 to 9 September 1992. It was jointly organized by CIRAD and INIBAP. The meeting was attended by 151 participants from 37 countries. The main themes were: plant-related constraints, constraints related to pests and diseases, and improvement strategies. Participants reviewed existing problems and various operations conducted worldwide. Partners involved in the banana project for the CEC programme on Life Sciences and Technologies for Developing Countries presented the results of 8 years of close collaboration in 30 papers. Research organizations participating in the project include: Katholieke Universiteit (KU) Leuven, Belgium; Université Paris-Sud, France; CATIE, Costa Rica; CRBP, Cameroon; and CIRAD. Participants also learned about other approaches and objectives through presentations of work by other teams (eg, FHIA, Honduras; IITA, Nigeria).

The borer weevil, in particular, forces farmers to shift their crops and encroach on forest land. The pest must be eradicated before farmers can settle in the region.

Distribution of Plantain in Cameroon is the same as in other banana-growing regions in Africa. In spite of remarkable organization, transaction costs in the sector are unprofitably high and could be reduced. Postharvest losses (less than 5%) are low. Innovative packaging is not needed as the distribution channels are short. Nevertheless, such innovations could become important with the development of an interregional market.

Other Tropical and Subtropical Fruit Trees

Cultivation of tropical fruits other than banana, pineapple, and citrus serves two purposes: to increase availability of fresh fruit for local consumption in the producer countries, and to develop exports of fresh and high value-added products. The priorities are: crop protection, ecophysiology, and transformation and conservation technologies. Development of techniques offers short-term solutions, while varietal improvement is of fundamental importance.

Genetic Improvement

Our collections of mango, litchi, and passion fruit were enhanced with new accessions. We can now select certain varieties for specific characteristics from these collections: for example, papaya tolerant of bacterial disease in the French West Indies, passion fruit rootstock tolerant of *Fusarium oxysporum*, earlier litchi, and mango tolerant of both anthracnose and bacterial spot.

Material from our collections is guaranteed disease-free; elite plant material from the collections can therefore be multiplied and distributed. We supplied more than 100 000 grafted plants to farmers in about 20 countries. A programme on the multiplication of endangered, rare fruit species is under way in Réunion.

Crop Protection

In New Caledonia, we undertook an inventory of fruit pests to identify those likely to impede the establishment of new crops. The most serious threats are fruit fly and fruit-piercing moths.

We now have evidence that mango buds play a major part in the conservation and spread of the bacterium *Xanthomonas campestris mangiferae*. Grafting conditions were modified to adjust to this finding.

Technology

We provided technical and research support for specific projects in several countries. In Colombia, we developed a technique for extracting pectin from the peel and pips of passion fruit. It will serve as a basis for new products from juice and concentrate. In Burundi, we developed a process for making papaya vinegar. In Tunisia, we recommended physical methods for eradicating date pests.

Agronomy and Ecophysiology

We conducted comprehensive physiological studies to understand reiteration in guava and the behaviour of peach and vine in regions without cold conditions. Knowledge acquired on the growth and development

Products for Development

Device for Eradicating Date Pests

After harvesting, chemicals must be applied to dried fruit to protect them from pests. This is particularly true of date, which has an annual production of around 2 million t. We therefore developed a method for physically eradicating pests. Preliminary results indicate 100% mortality of Ectomyelosis ceratoniae *eggs and larvae; this pest is the main cause of postharvest losses. The method obviates the use of chemicals, particularly methyl bromide, which will soon be prohibited by European regulations. We are now developing a device that is adapted to small and medium production levels.*

of these crops enables us to recommend suitable pruning techniques that stimulate yield.

Our work in Réunion and Côte d'Ivoire led to innovative technical recommendations for litchi, peach, and mango.

In Réunion, strawberry cultivation has expanded considerably and local consumption has increased fivefold in less than 10 years. The entire technical itinerary from production of plant material was set up with the assistance of local professional groups. This type of system ensures complete control over strawberry production in the tropics. Following this success, we were invited on expert missions in other tropical and subtropical regions.

Theses Completed in 1992

CIRAD Scientists

Etude dynamique de la croissance et du développement des bourgeons de quelques cultivars de pêchers cultivés à diverses altitudes sous le climat tropical de la Réunion [Study of bud growth and development of certain peach cultivars grown at various altitudes in the tropical climate of Réunion] by Philippe Balandier; Université Blaise Pascal, Clermont-Ferrand.

Etude des interactions hôte-parasite chez des bananiers sensibles et résistants inoculés par *Cercospora fijiensis*, responsable de la maladie des raies noires [Study of host-parasite interactions in susceptible and resistant bananas inoculated with *Cercospora fijiensis*, the causal agent of black leaf streak disease] by André Beveraggi; Université Montpellier II.

Etude architecturale du goyavier [Architectural study of guava] by Jean-Yves Rey; Université Montpellier II.

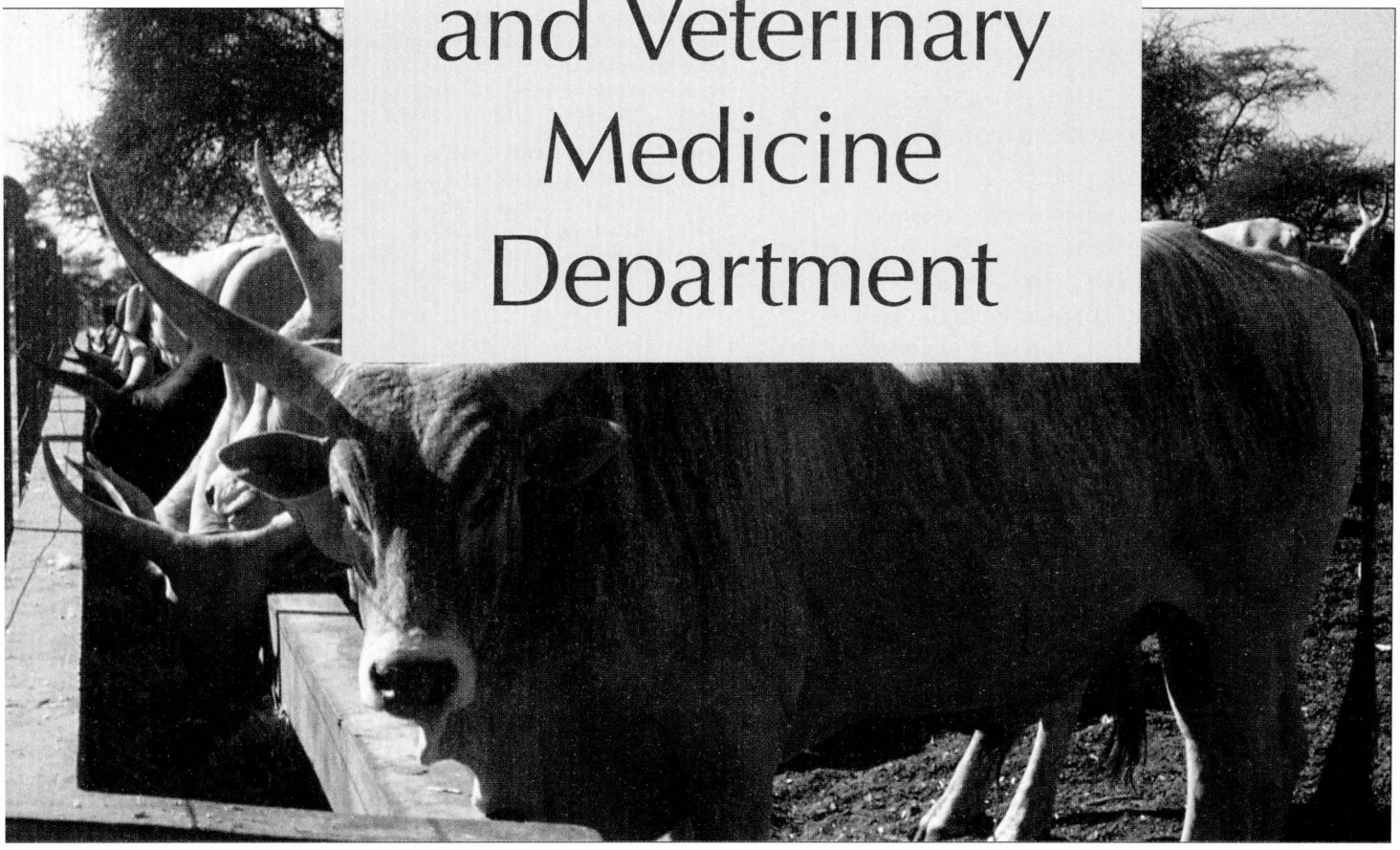
CIRAD Trainees

Régénération chez *Musa* sp. : recherche des conditions d'établissement de suspensions cellulaires d'espèces diploïdes et triploïdes [Regeneration in *Musa* sp.: determination of conditions for the establishment of cell suspensions of diploid and triploid species] by Cécile Chatelet (France); Université Paris XI, Centre d'Orsay.

Contribution à l'étude des ressources génétiques des passiflores forestières de Guyane française pour l'amélioration de la culture des fruits de la passion [Contribution to the study of forest *Passiflorea* germplasm from French Guiana for improving passion fruit cultivation] by Olivia Delanoe (France); Université Montpellier II.

Le chancre bactérien des agrumes (*Xanthomonas campestris* pv. *citri*) : étude épidémiologique et écologique dans le cadre de l'île de la Réunion [Bacterial canker of citrus (*Xanthomonas campestris* pv. *citri*): epidemiological and ecological study in Réunion] by Christian Vernière (France); Université Paris XI, Centre d'Orsay.

Livestock Production and Veterinary Medicine Department



Although meat consumption in the south has risen steeply, livestock producers in these countries have to compete in a global market. To help producers adapt to the change, development policies strive to improve small systems and combine crop and livestock production. Our research addresses ecological concerns and the need to preserve biodiversity through: livestock diversification, improvement of breeds suited to local environmental conditions, development of disease resistance, and rangeland management

Research priorities at CIRAD-EMVT are: to improve production of the diverse species and breeds of livestock in tropical and subtropical countries; to integrate animals in farming systems; and to protect animal health. Consequently, emphasis is laid on research aimed at improved animal nutrition, specifically: rangeland management, pasture improvement, use of crop by-products, and fodder conservation. The main concerns of the veterinary medicine programmes are: economic impact of diseases in various production systems, preventive measures, and adaptation of certain diagnostic tools and vaccines to difficult field conditions. Progress was made in the control of trypanosomiasis and tick-borne diseases, which are common problems in the humid tropics.

Our research is conducted in collaboration with mainly francophone Africa, Madagascar, and the French overseas departments and territories (French Guiana, Guadeloupe, New Caledonia, and Réunion). We also work in eastern Africa (Ethiopia, Sudan, and Zimbabwe), in Asia (Malaysia and Thailand), and tropical America (Brazil and Colombia).

In Africa, we participated in the establishment of international and regional research groups including the Centre international de recherche-développement sur l'élevage en zone subhumide (CIRDES), Burkina Faso, and the small ruminants project covering Cameroon, Chad, and Niger. Bilateral cooperation with national research organizations represents, however, a significant part of our activities.

In the Americas, the base in the Caribbean and outreach centres in French Guiana and Brazil focus on animal pathology (trypanosomiasis, ticks, and tick-borne diseases). Research on pasture resources and production systems was initiated in French Guiana and Brazil.

In Southeast Asia and Oceania, new agreements were reached in both the public and private sectors for conducting projects (eg, deer production in Malaysia) from the New Caledonia base.

We are linked through partnerships to the main French research organizations—Institut national de la recherche agronomique (INRA), Institut français de recherche scientifique pour le développement en coopération (ORSTOM), Institut Pasteur, Muséum national d'histoire naturelle—and universities. We also work closely with the international agricultural research centres (IARCs) including: International Laboratory for Research on Animal Diseases (ILRAD), International Livestock Center for Africa (ILCA), and Centro Internacional de Agricultura Tropical (CIAT).

We participated in three animal nutrition and four animal health projects, which were cofinanced by the Commission of the European Communities (CEC) and conducted by organizations in tropical countries with technical and scientific support from European laboratories.

Feed Resources

Our efforts to develop new techniques, to improve rangeland management, and to increase knowledge of animal nutrition aim to help herders provide adequate and nutritive forage and other feeds to livestock round the year.

Monitoring of Pasture Resources

Vegetation observation systems were developed by CIRAD-EMVT for western Africa to minimize the effects of drought on herds, and to improve emergency relief measures in the Sahel. Early assessments of grass production are useful for directing herds towards more favourable areas and for planning emergency feed supply.

LIVESTOCK PRODUCTION AND VETERINARY MEDICINE DEPARTMENT

CIRAD-EMVT

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Animal pests	Gerrit Uilenberg
Ecopathology	Pierre-Charles Lefèvre

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Documentation	Geneviève Thierry
Publications	Dominique Lasserre
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The systems were developed in collaboration with the Centre régional de formation et d'application en agrométéorologie et hydrologie opérationnelle (AGHRYMET), Niger. They use the normalized difference vegetation index (NDVI) derived from high-resolution NOAA satellite imagery. Vegetation biomass values that correspond to the NDVI classes were collected through a ground network of representative sites. Maps of the vegetation biomass are prepared each year according to this method. National services in Burkina Faso and Chad have also adopted the method.

We worked with researchers from ORSTOM and the Centre national de la recherche scientifique (CNRS), France, to establish the first map of the vegetation biomass in northern Senegal based on a climatic model. Rainfall was estimated from the temperature at cloud summit as measured by the Météosat satellite. Quantitative data on vegetation collected on site served to establish the value of the coefficients for the model.

In the savanna zone, livestock production depends on the distribution of pastures and cropped areas. For a regional map of land use, based on previous field work, we drew on statistical data collected through regular groundtruth surveys and satellite imagery. The map covers parts of Burkina Faso, Côte d'Ivoire, and Mali. Data can be extracted regardless of the scale.

Forage Production

In the humid tropics of Africa, large areas of overexploited savanna are invaded by the weed *Chromolaena odorata* and livestock can no longer graze in large tracts of traditional grazing lands. An integrated weed management method that we developed in the Central Africa Republic can check further spread. According to this method, the quantity of herbicide is based on the phenological stage of the plant. Other cultural techniques and physical means such as fire are also used.

In northern Senegal, we provided technical assistance to the Institut sénégalais de recherches agricoles (ISRA) for its trials of forage grasses with salinity tolerance. *Echinochloa pyramidalis, Diplachne fusca, Chloris gayana,* and *Sporobolus robustus* were found to grow well in saline-sterilized irrigated plots. By growing forage in rice fields, farmers can raise livestock on land otherwise unfit for food crops.

Grass ensilage is now possible in the tropics. In New Caledonia, the buffer capacity of various grass species was measured to select those that acidify rapidly such as *Panicum maximum* and *Brachiaria decumbens*. In Réunion we worked with CIRAD-SAR

to develop an ensilage technique by which round bales are sealed in a plastic cover. A preservative such as formic acid is added for temperate grasses (eg, ray grass). Tropical species harvested in spring do not require additives.

A seed bank was created in Montpellier to supply experiment stations with material to diversify forage species. It currently comprises about 20 tropical species and varieties of different geographic origin.

Animal Nutrition

In 1992 we joined a database on feed value, which is maintained by various animal nutrition professionals. The composition of tropical by-products was added to the database; reciprocally, users in the tropics and subtropics can benefit from current information from industrialized countries.

With INRA, we conducted a study on the nutritive value and ingestibility of forage grasses cultivated in Guadeloupe, New Caledonia, and western Africa. We also studied copra and oil palm oilcakes. The study led to the publication of tables based on food value assessment models.

A CEC programme conducted by five African and four European organizations focused on the role of African forage trees and shrubs in livestock production systems. More than 700 samples were used for calculating metabolizable energy. We found that, for forage grasses, enzyme degradability measurement was more accurate than chemical analysis for energy assessments. Nitrogen degradability measured by the pronase method can be an accurate indicator, if insoluble nitrogen in the acid detergents is also determined. Tannin content was measured in 350 samples to establish their effect on digestibility, particularly of nitrogen.

Previously, animal performance studies were based on ration quality, whereas today we observe the animal's relationship to its local environment. In southern Senegal we considered herd movement in different types of vegetation, forage types, restitution of fertilizing elements, and animal products to determine performance. Differences in results for various herds indicated the influence of herders' practices.

Consumption of white meat and eggs is rapidly increasing in the tropics and subtropics. In several African and Caribbean countries, we offered consulting and diagnosis services concerning monogastric animals to professionals in the sector, development projects, and research programmes. Poultry research

Publication

An Atlas of Livestock Production and Rangeland Potential in the Sahel

The Atlas de l'élevage et des potentialités pastorales sahéliennes *is a compilation of 40 years of previously unpublished scientific knowledge. The atlas covers an area of more than 1.3 million km² across Chad, Niger, Burkina Faso, Mali, Senegal, and Mauritania. The main themes are: forage resources (botany, agropastoralism, animal nutrition, water resources, and rangeland use), and animal resources and health (animal production, pests and diseases, and veterinary infrastructure).*

The agropastoral maps are based on an inventory of the Sahelian vegetation cover; they make up 34 pages of colour plates on a 1:500 000 scale. Maps for the other themes are on a smaller scale.

The text was written—in French—in collaboration with specialists from several African and French organizations. An atlas of northern Cameroon, compiled along the same lines, was added to the series.

focused on separate feeding and the use of cottonseed oilcakes with high gossypol content.

In commercial farms, fowls are raised exclusively on industrial compound feeds, and cannot feed selectively according to their needs. In contrast, free-running fowl in the tropics and subtropics feed on high-energy cereals and quality feed supplements. This system supports thermoregulation. Moreover, such feeds are made from locally available products. We tested the technical and economic advantages of this method in collaboration with INRA and the Institut des savanes (IDESSA), Côte d'Ivoire.

Animal Resources

We contributed to the design of a reliable system for characterization and evaluation of diversity in tropical livestock including cattle, small ruminants, dromedaries, and certain wild animals.

Cattle Surveys

We undertook a large-scale inventory to evaluate the cattle production potential in Cameroon. It covered close to 200 000 km^2 in the provinces of Extrême-Nord, Nord, Adamaoua, Ouest, and Nord-Ouest. There were more than 3 million cattle, 1.5 million sheep, and 1.5 million goats for more than 6 million inhabitants. Forty-two specially trained investigators conducted interviews for 10 weeks, and obtained more than 38 000 responses. A total of 2035 herds were surveyed, including 73 000 cattle (2.4% of total), 9000 sheep, and 7000 goats. The entire exercise was completed within 1 year. The survey technique thus proved to be a reliable tool for assessing herd productivity.

The herders were divided into 10 categories, ranging from herdsmen who only raised cattle to farmers who owned a few goats. Population and production parameters were established for each category and livestock type. Researchers were able to simulate herd development over the next 10 years from the 200 new sets of data.

The survey revealed an "accident" in 1990–1991 as there were no animals aged between 1 and 2 years. The hypothesis of a rise in the mortality rate and a steep decline in the birth rate needs to be verified. The phenomenon is, however, not significant because the effects are expected to disappear completely by 1995. But we observed that first births were delayed for all the species. Cows, for example, produced at 6 years and no longer at 4 years.

Similar surveys were conducted in Burkina Faso, Chad, Comoros, Guinea, and Niger. We designed a database for comparative studies on herds from different countries. Work began in 1992, with the identification of relevant comparative criteria based on surveys using KALAO software. Data input was improved. Our concern now is to simplify and accelerate the work by using limited but specific criteria for new survey areas.

External Aspect and Biodiversity

Databases on external aspects, body measurements, and diverse phenotype data on livestock are useful for detecting intrapopulation differences, which are sometimes more significant than differences between populations.

Current theory prescribes the characterization of animals not intrinsically but in relation to a specific environment or a particular use. Using a complete and functional set of monitoring and evaluation tools that were updated in 1992, we succeeded in determining objectively the status of livestock production. Variability is still higher in Africa compared with other continents.

Our wild fauna projects aim to preserve biodiversity and to diversify livestock. Knowledge of rusa deer

production acquired in New Caledonia was used to develop the same in Réunion and Southeast Asia (primarily Malaysia). We also participated in the development of game management in Zimbabwe. These operations also facilitated the development of MILAN software for monitoring game production.

Livestock Production Systems

Sustainable farming systems and conservation of renewable resources allow rural communities to remain on their land. Better knowledge of livestock production systems through field studies allows us to propose appropriate improvements.

Improved Animal Production

Livestock systems in the northern province of New Caledonia were surveyed in 1991. Subsequently, a network of reference farms was created to design a system for on-site experiments. Over the course of the operation, we developed a rewarding partnership with the local development services.

In Sudan and Niger, we studied camel herds to identify production constraints, to test solutions in the field, and to propose them to extension services. In Niger (as in Sudan in 1990), 600 animals were identified and monitored monthly using PIKBEU software. In Kenya, the camel survival rate up to weaning depends on the quantity of milk taken by the herder. Collaboration with the Arab Center for the Study of Arid Zones and Dry Lands (ACSAD), Syria, was strengthened through the publication of *Camel Newsletter*. In addition, experimental protocols for observing dromedary feeding habits and for monitoring meat and milk technology were set up for Morocco and Tunisia.

In Cameroon, Chad, and Niger, the regional programme on small ruminants comprised 16 experiments. They concerned characterization of livestock and of local production systems, as well as the disease situation in each country. In Cameroon, cattle monitoring in the Garoua area revealed that food costs were largely compensated by reproduction performance.

In French Guiana, the sectoral plan for developing cattle production was implemented by all those involved in the sector.

International Meetings

Rabbit Production in Africa

For the first time, a regional symposium on rabbit production was held in Africa. It was organized by CIRAD, INRA, and the Centre cunicole de recherche et d'information du Bénin (CECURI). The symposium took place in Cotonou from 16 to 20 March 1992. It is evidence of the growing importance of rabbit production in the seven participating countries.

Livestock Production Systems

The Second International Symposium on Livestock Farming Systems was held in Zaragoza, Spain, on the initiative of the Centre international de hautes études agronomiques méditerranéennes (CIHEAM), INRA, and CIRAD. The Symposium was held from 23 November to 4 December 1992. It was attended by 126 participants from 33 countries. It highlighted the recent trend towards convergence of approaches adopted by livestock scientists in Europe and certain southern countries.

Relationship Between Livestock and Crop Production

In Garoua, Cameroon, animal traction research focused on pulling capacity in relation to animal type, body condition, and work intensity. Animal-harness-implement relationship and tilling efficiency will be studied at a later stage.

At CIRDES, Burkina Faso, we participated in a multidisciplinary study on herd productivity and trypanotolerance. Crop and livestock production were linked through forage crop experiments. Forage improvement based on *Panicum maximum* (cv C1) and *Stylosanthes hamata* intercrops gave satisfactory on-station yields. Adaptation of the intercrop to conditions in farmers' fields is under way. Further trials were undertaken to produce manure by feeding cotton stems to stalled animals.

Aquaculture and Fisheries

We continued our work on the biology of aquacultural species and related production systems at the IDESSA fisheries research centre in Bouaké, Côte d'Ivoire. We are also responsible for the implementation of the third phase of the aquacultural development project in Niger.

Biology of Aquacultural Species

In terms of production, tilapia ranks third after carp (Cyprinidae) and Salmonidae. World production of tilapia is estimated at 500000 t.

We collaborated with INRA, ORSTOM, and Université de Bordeaux to study why the growth rate is higher in males than in females among *Oreochromis niloticus*. The objective was to distinguish factors linked to masculinization. Preliminary results showed that production factors can lead to the early appearance of dimorphism, which can be linked to gonadic ontogenesis and accompanying endocrine modifications.

We observed that stress caused by repeated fishing raised cortisol and prolactin levels in fish populations and slowed down growth. We therefore need to develop production techniques that reduce handling of fish to a minimum.

A "clean" and economical production technique based on thermosensitivity for sexual differentiation among *Oreochromis* yields a high proportion of male fry. We determined the thermosensitive period which, at 36°C, did not exceed 10 days and started around 10 days after fertilization.

We obtained viable intergeneric *O. niloticus* x *Sarotherodon melanotheron* hybrids as a result of our efforts to combine resistance to brackish water and optimum growth. The male parent, *O. niloticus*, has good growth potential and the female parent, *S. melanotheron*, can withstand brackish water.

We studied 34 populations of 9 tilapia species for enzyme polymorphism; the studies were conducted in collaboration with INRA's fish genetics laboratory. No difference was noted among *O. niloticus* populations. In Bouaké, high heterozygosity and the presence of alleles specific to two groups can be explained by the different origins—Volta and Nile rivers—of the populations.

We developed techniques for polymerase chain reaction (PCR) and DNA mitochondrial sequencing on frozen or alcohol-preserved material. In most cases, we were able to distinguish different species and populations by studying a part of the gene encoding cytochrome B.

Development of Aquaculture in Niger

The aquaculture development project in Niger is a follow-up of the operation that began in 1981. It was implemented on behalf of the Nigerien Ministry of Water Resources and the Environment. The project was financed by the French Ministry of Cooperation and Development. ADAN, the association of Nigerien fish farmers, will take over the activities on completion of the development phase.

In 1992 fry production was resumed at the Sona station. Commercial fish production in floating cages was undertaken on a small scale at three sites along the Niger river. Expected production figures are 40 t for 1993 and 120 t for 1994.

Priorities include a reduction in production costs and the development of a local market despite the fall in purchasing power. Research concerns cost reduction in floating cage systems, fry production for all-male progeny, and feed.

Products for Development

Diagnostics and Vaccines

CIRAD-EMVT is a reference laboratory of the Food and Agriculture Organization of the United Nations (FAO) for mycoplasmoses of ruminants. We are also the depository for Africa of the vaccine strain T1-SR against contagious bovine pleuropneumonia. We are responsible for quality control of the vaccine strain and its distribution to veterinary laboratories in Africa.

The ELISA kit for diagnosing contagious bovine pleuropneumonia is being tested by African and European laboratories under the supervision of the International Office of Epizootics (IOE) and the International Atomic Energy Agency (IAEA). Diagnostic kits need to be tested and approved by external organizations before they can be distributed by international agencies.

Infectious Diseases

Infectious diseases cause significant losses of cattle and small ruminants. We concentrate on the design of early or field-usable diagnostic techniques and stable vaccines for tropical climates.

New Diagnostic Techniques

The N, H, and F protein genes of the viruses that cause rinderpest and peste des petits ruminants were cloned and sequenced in collaboration with the Pirbright Animal Health Institute, United Kingdom. The result of this work was a cold probe for diagnosing rinderpest. It is an oligonucleotide corresponding to the variable fragment of the gene coding for the N protein of the virus; it is labelled with biotin. It is specific and can detect rinderpest in the early stages when it is applied on circulating lymphocytes. However, background noise must be reduced before the probe can be used for routine diagnosis.

We also used a baculovirus as a vector for expressing N and H proteins. They are used as antigen in diagnosis tests such as the enzyme-linked immunosorbent assay (ELISA) and latex agglutination test.

Preliminary results demonstrated the specificity and reliability of the latex agglutination test. Vaccinated animals can now be screened on site. The test is also

useful for serological monitoring after vaccination campaigns. It will be finalized in 1993.

We also worked on the development of nucleic acid probes and DNA amplification techniques (polymerase chain reactions). The probes serve to diagnose various types of mycoplasma species: *Mycoplasma mycoides mycoides* SC (contagious bovine pleuropneumonia); *M. capricolum* and *M. putrefaciens* (contagious agalactia and pleuropneumonia of small ruminants).

International Meetings

Tropical Veterinary Medicine

The Association of Institutions of Tropical Veterinary Medicine (AITVM) held its seventh conference from 14 to 17 September 1992 in Yamoussoukro, Côte d'Ivoire, on Animal Production as an Essential Part of Sustainable Agriculture. The conference was coorganized by the Côte d'Ivoire national committee and CIRAD. It was attended by 250 participants from 54 countries. The main topics of discussion were: livestock production and environment protection (wild fauna in particular); dairy production; privatization of veterinary services; and reorganization of animal health services in African countries.

Veterinary Epidemiology, Diagnostics, and Disease Resistance

We organized a workshop on veterinary epidemiology and diagnostic methods in Crete from 2 to 6 November 1992. It was followed by a workshop on animal resistance to disease at the Université de Bruxelles. The workshops were attended by 48 participants, who are involved in CEC-funded European projects.

Despite their sophistication, probes and PCR are useful techniques for detecting pathogens that are otherwise impossible to isolate in poorly preserved samples.

We developed two tests based on monoclonal antibodies—a competitive ELISA for rinderpest and an immunocapture test—to detect and differentiate the respective viruses of rinderpest and peste des petits ruminants.

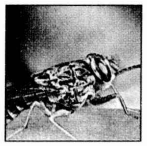
A group of monoclonal antibodies specific to *M. mycoides mycoides* SC was developed for designing new diagnostic tests (ELISA competition, immunocapture tests).

We improved diagnosis of contagious caprine pleuropneumonia due to *M. mycoides* sp. F38. Composition of the culture medium was modified to accelerate growth of the mycoplasma, which is particularly difficult to culture. We also developed an immunoperoxidase strip test. Pleural liquid is applied to nitrocellulose strips; once they have dried they can easily be sent to the laboratory. A specific serum, a peroxidase-labelled anti-IgG conjugate, and a substrate are used for the test.

Transfer of Vaccine Technology

The thermostable vaccine against rinderpest was produced in African laboratories and field-tested in rough conditions, mainly in southern Sudan. Our research partner for this CEC-funded project was Tufts University, United States.

The homologous vaccine against peste des petits ruminants was field-tested with African partners. More than 20 000 small ruminants were vaccinated in Chad, Côte d'Ivoire, and Mauritania. Serological tests are conducted regularly on 2000 animals in Mauritania. We observed that 95% of the animals were positive 1 month after vaccination, and 75% were positive 2 years later. The vaccine does not have an abortive effect on gestating females.



Animal Pests

We evaluate the effects of parasites on ruminants and seek economical and ecological solutions to control them. In the tropics, parasitic diseases limit ruminant production. They also hinder genetic improvement of local breeds because exotic breeds used in breeding programmes are highly susceptible. Our main concerns are: ticks and tick-borne diseases, and trypanosomiasis and its vectors (especially tsetse fly).

Cowdriosis and Its Vectors

The network for research on cowdriosis and its vectors—which we coordinate—was reinforced by the CEC. The main objectives are diagnosis, disease immunology, vaccination, genetic resistance, and vector control. Our research on cowdriosis and the tick *Amblyomma variegatum* is conducted in Guadeloupe and at Maisons-Alfort in Greater Paris.

In Guadeloupe, we studied genetic resistance to cowdriosis among Creole goats. We observed that natural resistance increased with exposure to the pathogen and it varied with the male parent. The three test flocks were made up of resistant parents, susceptible parents, or resistant x susceptible progeny. We tested the progeny to determine heredity of resistance or susceptibility characters and to identify genetic markers for the two characters, which would enable rapid selection.

The possibility of creating a synthetic vaccine against cowdriosis was confirmed. We demonstrated that inoculation with killed *Cowdria* protected goats from infection.

Dermatophilosis

We participate in the dermatophilosis network mainly through our Guadeloupe laboratory. The network is coordinated by the Royal Veterinary College, United Kingdom, and financed by the CEC. The objectives are to study the influence of various factors on the immune response, pathogenicity, role of *A. variegatum*, and genetic resistance to disease.

In Cameroon, infestation intensity can range from one to ten depending on the degree to which the ticks are attracted to the animals. We conducted a study to select animals that are less "attractive" to ticks and examined heredity of the character. During our observations we found that nursing cows had a low infestation rate because the udders were naturally deticked due to feeding.

Trypanosomiasis

Our research on trypanosomiasis and tsetse fly, the vector, is conducted in collaboration with CIRDES, Burkina Faso; the Agence nationale de développement de l'élevage (ANDE), Central African Republic; and ORSTOM. Mass rearing of tsetse fly was transferred to Montpellier and is now jointly undertaken with ORSTOM.

Work on tsetse fly traps continued for western and central Africa; target species included those that transmit human trypanosomiasis. We checked the tsetse fly-collecting device at the top of the trap, location of the odour diffusion system, and efficiency in capturing other biting insects. Based on such criteria, the plastic bipyramidal trap was found to be the most cost-effective for herders in the Central African Republic. Cost savings compared with the conventional cloth trap were equivalent to US$125/100 heads of cattle. The trap is used in Nola, a hot spot location for sleeping sickness in the Central African Republic.

We also studied the tsetse fly sensory systems to further improve trapping techniques. Electron microscopy and fine electrophysiology revealed that

the chemoreceptor hairs on the wings were taste rather than olfactory centres.

In Burkina Faso, pour-on applications of synthetic pyrethroids were effective against tsetse flies and ticks. Trials are under way in the Central African Republic.

We used the ELISA-AG technique developed by ILRAD to survey disease incidence at two locations in the Central African Republic. The parasite was widespread and occurrence of mixed or multiple infections was significantly high. We found 70–80% of the animals to be positive, whereas conventional tests showed only 10–15% positive results.

In Adamawa, Cameroon, CIRAD's remote sensing unit worked in conjunction with the Ngaoundéré tsetse fly eradication mission to locate the vector's biotopes. They used SPOT satellite data and the output was a 1:100 000 map of the forest systems (wooded savanna and residual forests) that are potential resting sites for *Glossina morsitans submorsitans.*

Ecopathology

Our ecopathology investigations examine issues that are essential to the implementation of development programmes. Ecopathology based on a global view of animal health problems supplements the widely used systems approach. It is essentially an applied discipline because it aims to provide simple solutions that can be implemented directly.

In the Nordeste region in Brazil, we completed collection of field data on abortion incidence among goats in traditional systems. The study covered a population of 1300 goats divided into 34 flocks. It was based on a retrospective survey involving questionnaires followed by monthly monitoring. The data are being processed. Preliminary results for the main parameters are: female's age at first birth, 626 days; kidding interval, 404 days; abortion rate, 13%; and kid mortality rate before 6 months, 24%. The results are available as technical factsheets and tables that can be used directly by livestock departments and producers.

Training

Courses in Livestock Production and Veterinary Medicine

In 1991–1992, the DESS[1] in livestock production in the tropics and subtropics was organized in collaboration with the following French institutions: Institut national agronomique, Paris-Grignon (INA-PG), Ecole nationale vétérinaire d'Alfort (ENVA), and Muséum national d'histoire naturelle. The course was taken by 21 students, including 7 foreign students. The specializations offered were aviculture, small ruminants, and large ruminants.

The diploma course in tropical animal health, intended for veterinarians, was attended by 20 trainees. Twenty-one trainees from 13 countries participated in the international training programme on sheep and goat production and pathology.

The fourth session of the training programme on epidemiology and veterinary economics was organized in Rabat in collaboration with the Institut agronomique et vétérinaire Hassan II, Morocco, and the University of Minnesota, United States. The session was held in October 1992 and lasted 3 weeks.

1. Diplôme d'études supérieures spécialisées. *Final degree for advanced studies; equivalent to a master's degree.*

In Senegal, ecopathology investigations were conducted as part of the small ruminant pathology and production programme. We used PANURGE software to monitor flock population and certain health parameters. Processing of data on small ruminant respiratory diseases will be completed in 1993.

The majority of these investigations were conducted in collaboration with INRA's ecopathology unit. A tropical ecopathology committee was established in 1992; other members include the INRA unit and the Rhône-Alpes ecopathology centre.

Theses Completed in 1992

CIRAD Scientists

Etude de la variation phénotypique dans le groupe *Sporobolus indicus* (L.) R. Br et incidence sur le plan systématique [Study of phenotype variation in *Sporobolus indicus* (L.) R. Br and the effect on classification] by Gilles Mandret; Muséum national d'histoire naturelle, Paris.

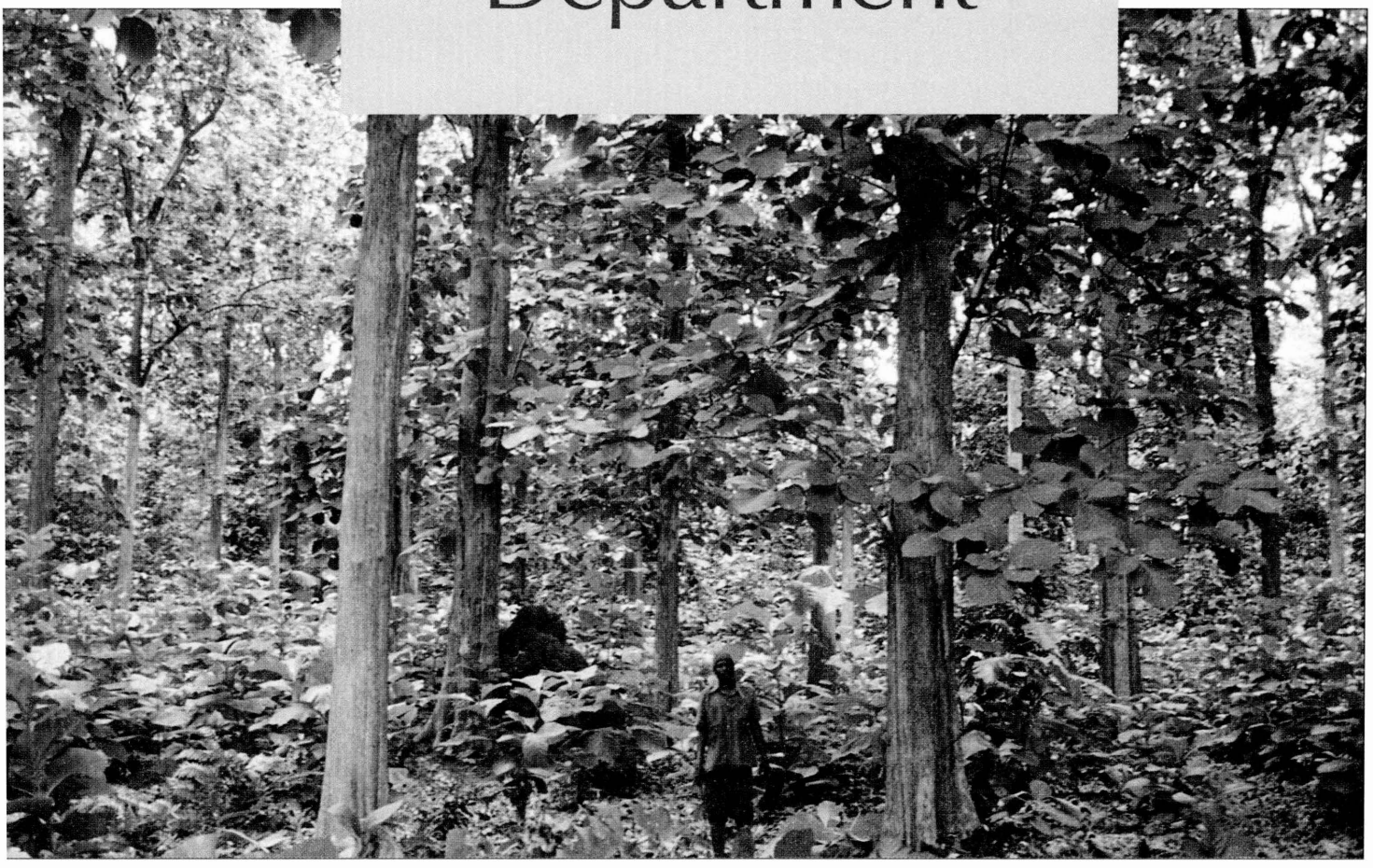
Recherches sur les carences en oligo-éléments affectant le cheptel domestique ruminant dans la Rift Valley éthiopienne et les régions afro-montagnardes limitrophes ; influence de quelques facteurs de l'environnement [Research on trace element deficiencies in domestic ruminants in the Ethiopian Rift Valley and surrounding highland areas; influence of certain environmental factors] by Pierre-Luc Puglièse; Université Paris XII.

CIRAD Trainees

Production d'anticorps monoclonaux spécifiques de *Mycoplasma capricolum* ; application potentielle à un test de diagnostic rapide sur des laits suspects [Production of *Mycoplasma capricolum*-specific monoclonal antibodies: Application to rapid testing of suspected milk] by Baya Belaid (Algeria); Université Paris XI, Centre d'Orsay.

Situation et conditions de développement du secteur productif au sein d'une filière laitière en milieu tropical insulaire : le cas des Antilles françaises [Situation and conditions for developing livestock production in the dairy sector in a tropical island: Case of the French West Indies] by Annick Jordan (France); Institut national agronomique, Paris-Grignon; trainee at INRA-CRAAG and CIRAD-EMVT.

Forestry Department



The Tenth World Forestry Congress and the Earth Summit warned public opinion of the dangers that threaten the planet's forests. Exploitation of this resource is vital for human needs, but it must be counterbalanced by measures that allow natural or artificial regeneration. Development and environment are inextricably linked. This conviction informs research programmes at CIRAD-Forêt on protection of biodiversity, creation of new trees, design of new forest management methods, agroforestry, and product innovation for tropical woods

The period following the Tenth World Forestry Congress in Paris in September 1991, which culminated in the Earth Summit in June 1992, was one of intense international debate. Conservation of tropical forests and biodiversity, and the impact of development on the environment were on top of the agenda. We contributed through our press campaign and participation in Forest 92 in Rio de Janeiro just before the Earth Summit.

We also assisted in planning the tree breeding programme of the Centre for International Forestry Research (CIFOR), the latest addition to the Consultative Group on International Agricultural Research (CGIAR). The Centre institutionalizes the scientific and economic interest in tropical forest management and conservation.

We represented France at the European tropical forest research network that was launched in 1992 on the initiative of the Commission of the European Communities (CEC).

The Silvolab agreement was signed with various French organizations to coordinate development of forestry research activities in French Guiana. Other signatories were: Institut national de la recherche agronomique (INRA), Ecole nationale du génie rural, des eaux et des forêts (ENGREF), Institut français de recherche scientifique pour le développement en coopération (ORSTOM), and Office national des forêts (ONF). Silvolab is thus made up of major organizations working on forest ecosystems in French Guiana; the Centre national de la recherche scientifique (CNRS) will join in 1993. Silvolab is, however, open to other collaborations, particularly through the inter-regional forestry research programme PIRFAG in Amazonia and French Guiana.

"Forests, a heritage for the future" was the slogan of the World Forestry Congress. The future of this heritage is at stake. It affects the global and local environments, and all users of forest products.

The Declaration on forests adopted at Rio de Janeiro states unequivocally that the only realistic solution is to consider environment and development together.

This approach is reflected in CIRAD-Forêt's research programmes. The overall objective is to develop tools and methods for tropical forest management, including natural forest silviculture, creation of plantations, production of improved plant material, and wood processing. Studies are also being conducted on incorporating trees in farm systems and the role of trees in crop protection and production.

Agroforestry, Soil and Water Conservation

Agroforesters and socioeconomists work together to seek technical and political solutions for including trees in the farm system, protecting the environment, and conserving animal and plant biodiversity.

Rural Fuelwood Markets

In the World Bank-sponsored Energy II project, we provided technical assistance for surveys to assess the wood requirements of the five biggest towns in Niger and for forest inventories and satellite image processing to determine the tree population in the savanna zone. Uncultivated land, including fallow and parklands, was also surveyed in 1992. We found, for example, that annual fuelwood production from a fallow area with *Guiera senegalensis* can yield as much as 300 kg/ha, enough to cover the needs of one person.

We also provided technical assistance for setting up the first rural fuelwood markets that were organized in the Say region in collaboration with the Nigerien Ministry of Water Supply and the Environment and the Ministry of Industry, Energy, and Mining. Villagers

FORESTRY DEPARTMENT

CIRAD-FORÊT

Director	Jean-Marc Dubois
Research Director	Jean-Claude Bergonzini
Administrative and Fiscal Director	Claude Thevin

Research Programmes

Agroforestry, soil and water conservation	Régis Peltier
Forest management	Henri-Félix Maitre
Tree improvement	Hélène Joly
Wood technology	Bernard Parant

Research Units and Support Services

Biometrics and computer services	Jean-Claude Bergonzini
Biotechnology of tropical forest symbioses*	Emile Duhoux
Documentation and library	Lucien Trong
Publications	France Lavaux
Training	Hélène Laforge
Marketing	Jean Estève

*Joint CIRAD-ORSTOM unit.

agreed to follow a silvopastoral management system combining wood production and grazing, which allowed regeneration of the natural resources. The government supported these efforts and reduced taxes on wood sold by the silvopastoralists. This is one example of the transfer to village communities of the prerogatives on forest management formerly held by the state.

In the medium term, logging and wood sales are expected to encourage the extension of the agrosilvopastoral system throughout the country. Adoption of this innovative system by the rural communities is the result of the joint efforts of economists, sociologists, forest inventory and remote sensing experts, pastoralists, and legal and fiscal experts. The World Bank, encouraged by the project's success, intends to repeat the experiment in other Sahelian countries, starting with Mali and Senegal.

Pioneer Fronts and Reforestation

Remote sensing studies on pioneer fronts were carried out in Cameroon for the northeastern Bénoué project sponsored by the European Development Fund (EDF). They revealed how the pioneer fronts advanced as migrant farmers slashed and burned the savanna woodland for cultivation. In approximately 10 years, about 100 000 people have settled in the region. Cropped area is estimated at 100 000 ha, which represents 10% of the total area. The crops are grown along the roads radiating from the town of Garoua.

A study carried out in collaboration with the Institut de la recherche agronomique (IRA), Cameroon, and development organizations showed that local communities turn to resource conservation only when land and wood requirements become serious issues. They then adopt methods for planting and using trees that were developed through research to control erosion, to produce poles and fuelwood, and to regenerate or maintain soil fertility.

The annual demand for wood in Garoua is estimated at 100 000 t, representing US$5 000 000. In 1992 local farmers bought about 50 000 forest and fruit trees from the project's rural nurseries. The resulting plantations and reforested savanna should gradually satisfy the wood requirements of Garoua.

Tree Cutting in the Savanna

We collaborated with the Institut de recherches en biologie et écologie tropicale (IRBET), Burkina Faso, on a study of tree exploitation in the Sudanian zone. According to our findings, the savanna woodland can produce annually nearly 3 m^3/ha when it is completely coppiced every 5 years. However, this method of

indiscriminate cutting diminishes biodiversity as it can cause the disappearance of many useful species, such as *Butryospermum paradoxum,* within the medium term. Moreover, it does not really meet farmers' needs.

Different management methods should be used; they should take into account wood requirements, tree growth rate, and ability of major tree species to regrow. Such new approaches will probably contradict recommendations by many ongoing projects.

Tree Fallow Improvement in Humid Zones

We participated in a CEC-sponsored project in southern Côte d'Ivoire with two other CIRAD departments; the national organizations Institut des forêts (IDEFOR) and Institut des savanes (IDESSA); and Bayreuth Universität, Germany. The team developed simple methods for improved fallows, which were more efficient than natural fallows. The methods involved the use of nitrogen-fixing rhizobia with *Acacia mangium* or *A. auriculiformis.* The trees are expected to yield 70–140 t of fuelwood 8 years after planting. Such fallow enhancement techniques will contain deforestation and facilitate the establishment of long-term farming systems.

Know-How for Development

Afforestation for Erosion Control

In Madagascar, we participated in the erosion control project with a team of scientists from the Centre national de la recherche appliquée au développement rural (FOFIFA), Madagascar, and the Bureau pour le développement de la production agricole (BDPA), France. The team worked with local communities affected by erosion in the lake Alaotra region. In recent years, nearly 500 ha of rice fields have been buried under sand from the surrounding hills. Annually, 650 000 m^3 of sediment is removed from irrigation canals.

Afforestation on hill slopes is one of the most efficient measures for controlling erosion. Encouraged by research and development organizations, the lake Alaotra farmers undertook the afforestation work themselves. It was a modest, but positive, response to the state disengagement policy on these services. In 1992 the farmers planted about 100 000 trees—procured from their own nurseries—on hills and in lavaka *(large erosion cones). The impact of afforestation was enhanced by planting fascines of bamboo cuttings and protecting natural flora.*

Forest Management

Baseline studies on the spread and dynamics of natural and artificial forests are a significant component of the programme. We can then develop appropriate methods for the establishment, protection, and exploitation of tropical forest stands that will ensure sustainable production of timber, construction wood, and fuelwood to meet local needs.

Natural Stands of Okoume

We studied almost pure, natural stands of okoume (*Aucoumea klaineana*) in the coastal area of Gabon to understand how they evolve. Using trunk analysis involving anatomical counting of growth rings and observations over 5 years (1987–1992), we predicted changes in stands and production according to soil fertility. We could also reconstitute their evolution in

International Cooperation

Monitoring Deforestation in Southeast Asia

In October 1992 we organized, together with the French consulting company Scot Conseil, a seminar in Manila to mark the completion of the SEAMEO project. The aim of the multilateral project was to monitor deforestation in six Southeast Asian countries. It was launched in 1989 mainly with French funding. The findings and conclusions of the project were presented.

Participants stressed the importance of adopting a common nomenclature based on the FAO system. They also underscored the need to install permanent computerized systems for satellite image processing in the countries affected by deforestation. Extension of training programmes and transfer of know-how on deforestation monitoring was also recommended. In the second phase, the project will be extended to other countries of the Indochina peninsula. New tools will be used, including geographic information systems and radar imagery.

the past and determine their age. Growth models were developed on a short-term basis. We also defined the thinning pattern for the projected forest management plan for Estuaire, Gabon.

Fires in Dense Rain Forests

An accidental fire occurred in a population dynamics experiment in Côte d'Ivoire and led to a study on the effect of fire in dense natural forests.

We found that forests opened for logging were more vulnerable than closed forests. The degree of destruction is reflected in subsequent transformation of the forest area: no regeneration, gradual appearance of shrubs, or emergence of secondary forest. Depending on the degree of destruction, burned forests can be reclaimed through agriculture, reforestation, or natural regeneration.

Thinning in the Forests of French Guiana

We evaluated thinning practices in a modelling study conducted at the Paracou research centre in French Guiana. Information was also provided by the silvicultural experiment network of the programme on Latin American, African, and Asian forest ecosystems. The results enabled the Office national des forêts of French Guiana to improve the efficiency of its forest development operations.

Forest Plantations in Viet Nam

A Franco-Viet Namese joint venture was established for a pulpwood programme in the Song Be province to the northwest of Ho Chi Minh City. The aim was to develop plantations of fast-growing species such as eucalyptus and acacia for the paper industry. We were commissioned to manage research and development activities in this programme.

The main thrusts of the programme were species diversification, estimation of plantation production levels, and silviculture improvement. Trials were established in 1990 and 1991 over 150 ha. We first selected suitable plant material and developed techniques for land preparation, nursery management, and establishment of plant stands.

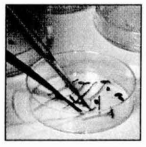
Preliminary results indicated a potential for clonal propagation, creation of varieties, and fertility enhancement. A complementary programme will be added in 1993 with French interministerial financing. A large-scale commercial undertaking is expected to emerge ultimately from the project.

National Forestry Master Plan for Guinea Bissau

The national forestry master plan for Guinea Bissau was developed within the framework of the Tropical Forestry Action Plan, which is jointly funded by: CEC, World Bank, Food and Agriculture Organization of the United Nations (FAO), and the Japanese government.

We presented the plan at the second national round table meeting in November 1992. A new land use planning policy was established through 14 priority projects. They covered a wide range of factors: land tenure, development of community forests, agroforestry, sustainable forest management, forest and grassland survey, fiscal and customs regulations, and conservation of biodiversity.

Formulation of national forestry policies jointly with international donor agencies—as in the case of the Guinea Bissau plan—is an important concern of the department.



Tree Improvement

Our tree improvement programme focuses on fast-growing species (eucalyptus, *Acacia mangium*, pines), timber species (teak, *Terminalia, Gmelina, Cedrela, Swietenia*), and multipurpose species (*Acacia albida, A. senegal*). It also has the mission to safeguard the future of forests by conserving genetic resources. Our germplasm collection comprises 7000 seed batches; its conservation plots are located in several countries. Genetic diversity is determined through comparative trials of provenances and progeny, and through the use of genetic markers.

Genetic Diversity of Sahelian Acacias

We worked with the Institut sénégalais de recherches agricoles (ISRA) in Senegal, and with IRBET in Burkina Faso, for evaluation of genetic diversity and research on selection criteria for multipurpose species.

Comparative trials of *A. albida* provenances have been conducted in Burkina Faso since 1984. The collection currently represents 35 provenances from 9 countries within the range of the species. Similar comparative trials were also established for *A. albida* and *A. senegal* in Senegal, and *A. nilotica* in Burkina Faso.

Results of our collaborative studies with ORSTOM in Senegal indicated little variation in *A. senegal*. Diversity of *A. albida* was studied in a CEC-funded collaborative project with ENGREF, France; IRBET, Burkina Faso; ISRA, Senegal; and the Oxford Forestry Institute (OFI), United Kingdom. Enzyme electrophoresis revealed wide genetic diversity for the species, particularly between populations from eastern and western Africa. The results were confirmed by field trials, which demonstrated that provenances from eastern Africa were not suited to the low rainfall conditions in western Africa. They could not survive two dry seasons in spite of good initial growth. Moreover, cross-pollination exceeded 95% in five *A. albida* populations. The species presents a high degree of cross-pollination and, probably, self-incompatibility.

Eucalyptus Improvement

Our collaboration with the Congolese forestry research centre and the Unité d'afforestation industrielle du Congo (UAIC) continues for eucalyptus improvement. The reciprocal recurrent selection design, which has been developed over the years, is based on interspecific hybrids *Eucalyptus urophylla* x *E. grandis* and *E. urophylla* x *E. pellita*.

We have now acquired a better understanding of the genetic structure of parent and hybrid populations. Variability observed in hybrid populations is mostly derived from *E. urophylla*; it is expressed more strongly in young hybrids with *E. grandis* than with *E. pellita*. Inheritance of the main characters at 2 years is mainly additive. Three trials were established to evaluate correlations between the juvenile and adult stages.

International Cooperation

Biotechnology Laboratory in Malaysia

*We have worked with the Sabah Foundation, Malaysia, since 1989 as part of our efforts to expand activities in Asia. The Foundation is committed to the development of the Sabah state and one of its activities is the establishment of forestry plantations. Our biotechnological know-how has been useful for genetic improvement and seed production of rattan, fast-growing acacias (*A. mangium, A. auriculiformis*), and timber species (eg, teak,* Swietenia*).*

A joint biotechnology laboratory was established in Tawau to provide the necessary facilities and tools for efficient and rapid tree improvement. The laboratory design drew on our experience in this field. The vegetative propagation programmes focus on true-to-type multiplication for rattan (mainly Calamus manan*) and rejuvenation of* Tectona grandis *and* A. mangium. *The laboratory has the capacity for annual production of 250000 plantlets.*

Enzyme electrophoresis equipment was procured for determination of genetic diversity and analysis of breeding systems for different rattan species.

We are conducting several floral induction trials to increase control over seed production. The trials are established in Congo and in the eucalyptus germplasm collections that were recently set up in French Guiana.

We are also collaborating with INRA, France, for genetic mapping of eucalyptus by means of molecular markers (RAPD, RFLP). The research is conducted at the INRA laboratory in Bordeaux.

Seed Orchards for Timber Species

Collaborative timber breeding programmes with IDEFOR focus on teak because this widely-grown species also predominates in timber plantations in Côte d'Ivoire. Since 1970, 24 provenances have been introduced through international trials. Clones were created by grafting and a seed orchard was established in Sangoué. The trees started setting seed in 1990. We then conducted progeny trials for selective thinning based on genetic characters. All teak plantations in Côte d'Ivoire now procure improved material from the seed orchard.

A multiclonal variety derived from cuttings is now available for *Gmelina arborea*. Two seed orchards with 115 clones of *G. arborea* were established in Anguédédou and Sangoué to produce the next generation of breeding material.

A multiplicative park was planted for *Cedrela odorata* with 100 selected trees. The next phase will involve the establishment of a seed orchard and clonal tests.

Nitrogen-Fixing Symbioses

Nitrogen-fixing trees are valued for their ability to grow on less fertile or eroded soils. This is the result of a symbiosis between the tree and certain root bacteria. The ORSTOM-CIRAD unit for biotechnology of tropical forest symbioses seeks to understand the establishment and development of such symbioses

through studies on the *Casuarina-Frankia* association and that of certain acacias with rhizobia.

We found that physical and chemical properties of the soil, particularly iron content, strongly influence the establishment of *A. mangium*-rhizobium symbiosis. Genetic transformation methods were used for more detailed studies of symbiotic mechanisms. We studied *Casuarina* and *Acacia* genes involved in nitrogen fixation so that they could be modified to increase symbiotic efficiency.

Results of trials conducted in Côte d'Ivoire, Benin, and Cook Islands on *A. mangium* inoculated with different rhizobium strains were analyzed. At 2 years, height and circumference of inoculated trees were, on average, 10–15% more than those of controls. Immunonoassays confirmed that this extra growth was due to the selected strain, which was still present in all the root nodules 2 years after inoculation. To study competition between selected and native strains we shall use molecular techniques (PCR, RFLP).

Wood Technology

Our studies aim to elucidate the anatomy, durability, and physical, mechanical, and thermal properties of tropical woods from natural forests. Plantation woods are analyzed at each processing operation (sawing, drying, gluing, and impregnation). Thermal properties of wood and waste material are also examined. With this information we can advise producers and users in the wood industry.

Forest Species of Madagascar

Madagascar, with an area the size of France, has more than 1000 tree species. Of these, 880 species belonging to 363 genera of 95 botanical families, have already been studied.

Anatomical descriptions facilitate identification of the species, which is often difficult because many of the genera exist only in Madagascar. Dichotomous keys exist for major families producing very similar types of wood. Each genus is illustrated by three microscopy photographs of the transverse, tangential, and radial sections.

Anatomical studies are useful not only for botanical classification but also for forest inventories.

Solid Wood Panels

We developed a process for making reconstituted solid wood panels from glued laminates. The advantages of the product are its dimensional stability under variable humidity, relatively low cost, and versatility (for furniture, exterior work, and construction). Reconstituted solid wood needs no drying or welding and can be used directly by manufacturers and craftsmen.

These wood panels have been increasingly used for constructing wooden houses in French Guiana over the past 5 years. Until recently, the panels were made on a small scale, using saw-waste or secondary species.

As demand increased, a local enterprise scaled up the operation to an industrial level. We worked with a machinery manufacturer to equip the enterprise with an automatic gluing machine. The enterprise received expert advice for trials, initial production series, and marketing. Panel quality improved considerably and the enterprise can even consider exporting its products.

A similar technology transfer experiment is under way in Cameroon in collaboration with the Office national du développement des forêts (ONADEF), a forest logging firm, a sawmill, and a furniture factory.

Products for Development

Use of Agroindustrial Waste to Generate Heat

Waste management and drying of wood, rubber, copra, or similar products are problems in both wood and food processing industries. Gasification of waste material produces fuel for industrial burners and saves on fossil fuels.

The pilot operation we mounted in 1992 with three French manufacturers for gasogenes, burners, and dryers can be easily scaled up to an industrial undertaking. Specifications for burners of lean gases were inferred from technical information obtained through the operation.

Our first industrial application of this technology concerned drying of natural rubber in Côte d'Ivoire. Installation of a dryer with an annual capacity of 4500 t is under way at the Société africaine de plantations d'hévéa (SAPH). The new technology will save 250 t of diesel oil annually, representing US$130000.

Technical and economic analyses suggest that the investment can be recovered within almost a year. Industrial guarantees and the possibility of constructing the plant locally are powerful incentives for this technology.

Wood from Coconut Palm

The Pacific islands import wood, whereas they could use wood from coconut palms that no longer produce fruit. We demonstrated that users could recover almost all the woody portion of the coconut palm, including the tender part, by adopting certain sawing techniques. This material could be used for producing reconstituted solid wood. Consequently, the Caisse française de développement (CFD) and the French Ministry of Foreign Affairs commissioned us to carry out a programme on innovative uses of coconut palm in the Pacific.

In 1991 sawing demonstrations and training sessions were conducted in Tahiti, Makemo, Rarotonga, Tonga, and Fiji. As coconut palm trunks are not thick, expensive sawing equipment is not needed and the mobile saw designed by the department amply fits the purpose. In 1992 demonstrations focused on uses of wood from the coconut palm. For example, reconstituted solid wood panels and glue-laminated beams can be used for wood fittings, doors, and furniture.

Soaking the planks in sea water prevents them from rotting for more than a year, even without chemical treatment. Such nonpolluting methods for preserving wood are of particular interest to the islands and their fragile lagoon ecosystems.

Local authorities are now convinced of the benefits of coconut palm wood; it reduces imports of raw wood and finished products, and creates jobs. Three workers' cooperatives for sawing and furniture making are planned for Makemo, Hao, and Rangiroa.

A programme on innovative uses of coconut palms and plantation pines was launched in New Caledonia with funds from the regional council and the French Commission de coordination de la recherche dans les départements et territoires d'outre-mer (CORDET).

Improvement of Traditional Carbonization Methods

Charcoal is the most commonly used fuel in urban areas and certain industries in the south. Dakar burns 200 000 t annually; Abidjan, 300 000 t; and the Brazilian iron and steel industry, 10 million t. With traditional wood carbonization processes, more than half the initial energy is lost as greenhouse gases.

Our research on this problem aimed to recover energy contained in wood smoke and to reduce the polluting effect of the smoke. We observed that the final carbonization temperature had a strong influence on energy loss. Emissions of nonrecyclable compounds other than CO_2 double between 450°C and 700°C. Low-temperature carbonization is thus recommended to reduce emission of greenhouse gases.

The Agence de l'environnement et de la maîtrise de l'énergie (ADEME), France, funded a laboratory study on total combustion of smoke from carbonization in pilot and small-scale units. Our observations revealed that only recyclable CO_2 is emitted after combustion, which reduces the contribution to the greenhouse effect by almost 75%.

We also compared two techniques for depolluting carbonization smoke, one by condensation and the other by combustion. We found that energy generated by combustion could be used more easily, whereas the condensates have no economic value.

Carbonization studies have progressed satisfactorily. Experiments on domestic use of charcoal and agroindustrial by-products are under way.

Theses Completed in 1992

CIRAD Scientists

Evolution d'un taillis de formation naturelle en zone soudanienne du Burkina Faso [Changes in a natural vegetation coppice in the Sudanian zone of Burkina Faso] by Yves Nouvellet; Université Paris VI.

Etude de l'effet du feu en forêt semi-décidue de Côte-d'Ivoire au sein d'un dispositif expérimental sylvicole [Study of the effect of fire on semideciduous forest in a forest experiment in Côte d'Ivoire] by Jean-Guy Bertault; Université Nancy I.

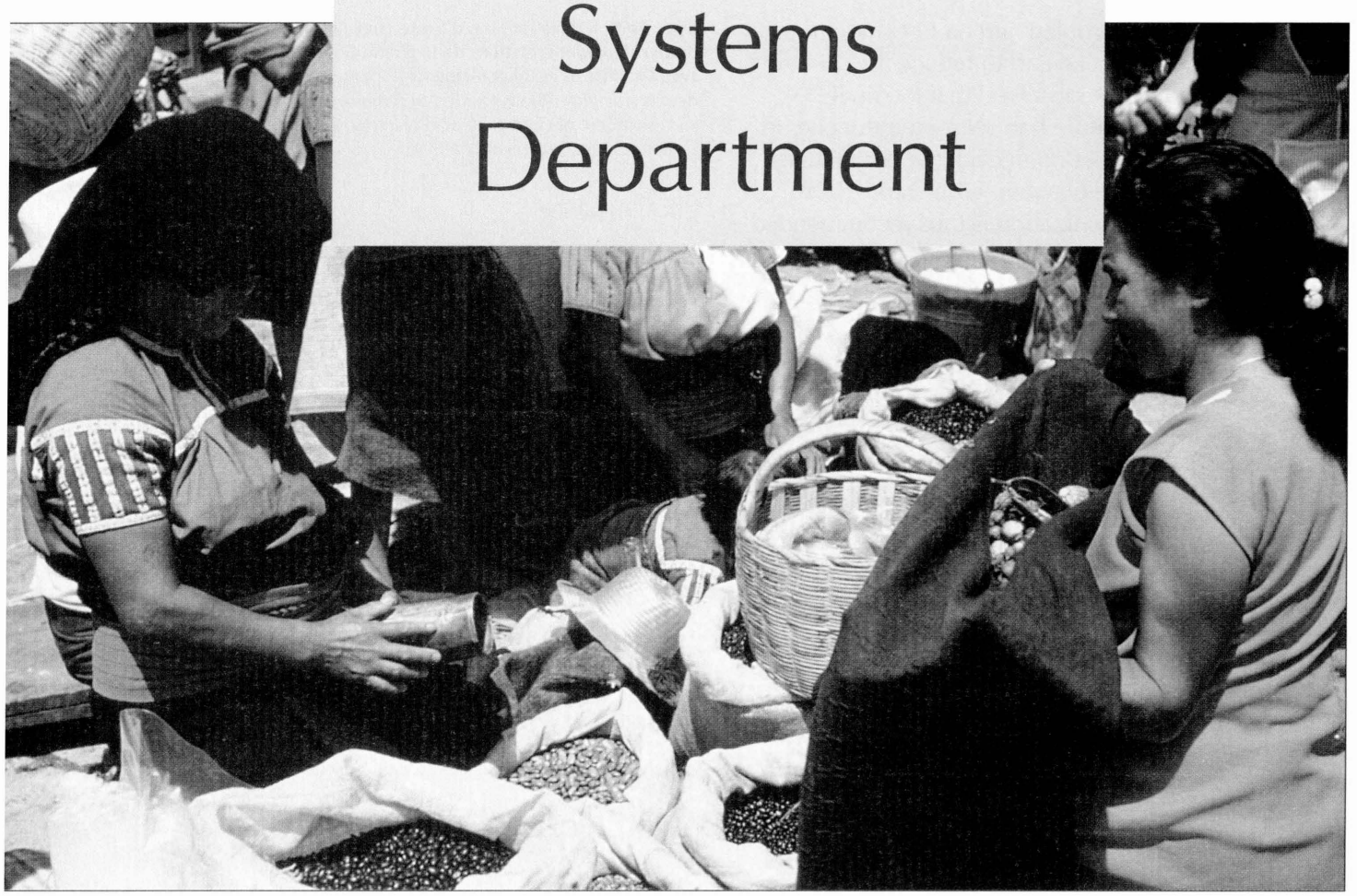
Etude de l'évolution des peuplements naturels d'okoumé, *Aucoumea klaineana*, dans le Sud-Estuaire du Gabon [Study of the evolution of natural stands of okoume (*Aucoumea klaineana*) in Sud-Estuaire, Gabon] by Laurent Rivière; Université Paris VI.

Optimisation de la fixation d'azote chez la symbiose *Acacia mangium-Bradyrhizobium* : relations de la plante-hôte et de la bactérie symbiote avec l'acidité et les oligoéléments [Optimum nitrogen fixation in *Acacia mangium-Bradyrhizobium* symbiosis: reactions of the host plant and symbiotic bacterium to acidity and trace elements] by Didier Lesueur; Université Paris VI.

CIRAD Trainee

Approche moléculaire du rôle de la plante hôte dans la symbiose *Casuarinaceae-Frankia* [Molecular analysis of the role of the host plant in Casuarinaceae-*Frankia* symbiosis] by Michèle Phelep (France); Ecole nationale du génie rural, des eaux et des forêts.

Food Technology and Rural Systems Department



The crisis in agriculture and urban growth are evidence of the extensive social changes that are metamorphosing rural communities. An important research priority is to support farmers, manufacturers, and policymakers in their decision making through detailed information on food technology, rural systems, and changing patterns. Efforts focus on sustainable management of natural resources and production factors, processing of agricultural products, and penetration of urban markets

Agricultural production must be considered comprehensively: management of natural resources and rural systems, markets and outlets, processing of agricultural commodities, and diversification of rural activities are all interconnected components. At CIRAD this concern was translated by merging CEEMAT (agricultural engineering, energy, and food technology department) and DSA (agrarian and farming systems department) to form the new department for food technology and rural systems, Département des sytèmes agroalimentaires et ruraux or CIRAD-SAR.

Crop intensification is the only alternative to ensure food security in the face of rapid population growth and land shortage. Technical options depend mainly on the degree of fragility of natural environments, climatic conditions, and population density. The social group and its responsiveness to innovations also determine the technological level. Access to information, capital, and markets is vital at this stage.

Structural adjustment and economic liberalization are globalizing national economies and transforming markets. Export-oriented crops compete with food crops intended for the expanding local markets. Cost reduction is a priority in all commodity sectors. Quality has become a determining factor for the food industry.

These changes are reflected in the initiatives—by individuals and groups—for the development or dissemination of technical innovations; management of savings and credit; and marketing and food processing. But the institutional structure is often obstructive. Research can contribute to the reorganization and adjustment of the structure to current needs.

These are the issues that determine the research priorities of CIRAD-SAR. Its chief concerns are: to counteract erratic climatic conditions and obtain stable yields; to develop sustainable farming systems; to introduce market economics in crop production; to supply food to urban centres; to organize rural communities and to monitor institutional changes.

Rainfed and Irrigated Farming Systems

The conclusions of a review published in 1992 on the African Sahel contrast with the current pessimistic mood. Rural communities in the arid zones are dynamic, responsive to innovations, and open to social changes. And yet, in Africa and Latin America, these communities are marginalized by disengagement or reduction of aid by the state.

The relationship between state aid and drought during the recent 10-year drought period shows that political will has waned with time. State interventions have proved to be inadequate and ineffective both in terms of development and the environment.

One of our priorities is to develop and test new tools for planning such operations and for subsequent monitoring and control.

Farming Systems and Market Economics

Communities respond to continuing population growth in diverse ways. One of our teams collaborated with relevant Chadian ministries for zoning the N'Djamena area according to resource potential, and proximity to the capital's market and the Niger and Cameroon borders. Three types of situations were observed: growth, development, or crisis.

Colonization of virgin lands to the east of river Chari represents a growth situation. Capital accumulation from diversification (trade, fishing, irrigated rice production, etc) in the border zones near urban markets represents development. Overexploitation of natural resources and subsequent deforestation, overgrazing, and soil degradation represents a crisis in the traditional relationship between livestock producers and farmers.

Similar scenarios were observed in the Nordeste region in Brazil, Burkina Faso, and Madagascar. Integration

FOOD TECHNOLOGY AND RURAL SYSTEMS DEPARTMENT

CIRAD-SAR

Director	Jacques Lefort
Deputy Director	Marc Le Moigne
Research Director	Jacques Faye
Programmes Director	Vincent Dollé
Administrative and Fiscal Director	Léandre Mas

Research Programmes

Rainfed and irrigated farming systems	Jean-Philippe Tonneau
Sustainable development in the savanna and wet tropical zones	Bernard Leduc
Promotion of rural output and urban food supply	Nicolas Bricas
Local development and institutional approach	Vacant

Research Units

Agronomy and mechanization	Guy Pocthier
Economics of rural systems	Michel Benoit-Cattin
Socioeconomics of innovations in rural systems and food technology	Jean-Michel Yung
Food technology and engineering	Anne-Lucie Wack
Software engineering, equipment design, biomass conversion	Gilles Vaitilingom

Support Services

Documentation	Marie-Dominique Lafond
Publications	Monique Pellecuer
Training	Jean-Luc Mazot

into a market economy therefore varies according to the comparative advantage of a given region.

We participated in the establishment of regional planning units, which implement research and development operations. Examples include the unit within the Juazeiro municipal team (state of Bahia) in Brazil and the cell for research and development in the Logone and Chari river valleys in Chad. Such units have started acquiring geographic information systems for monitoring changes in markets and farming systems.

Conservation Management of Natural Resources

In Madagascar, a faster land registration procedure was introduced in the lake Alaotra area. Ownership of *tanety* lands will be granted within 1 year, compared with 20 years at present. Access to land can motivate farmers to adopt measures for preserving and restoring natural resources (reforestation, soil fertility management, sanding control, etc).

In Burkina Faso, rangeland management has evolved under the impact of droughts and their socioeconomic consequences. Through experiments and analyses, we identified new linkages between crop and livestock production. We also tested methods for regeneration of rangelands and reconstitution of livestock. In Brazil, individual ranges created by means of enclosures aggravate social differences. We are now developing new ecological strategies based on community traditions.

Management of Irrigation Systems

State disengagement for irrigation services causes serious concern in areas that received significant state support. Moreover, the decisions are taken at a time when the type, size, and cost of irrigation systems have come under critical scrutiny.

Several workshops were jointly organized in 1992 by CIRAD, the World Bank, the French Ministry of Cooperation and Development, and the Caisse française de développement (CFD) to review the ecological risks of alluviation and soil salinity in irrigated fields. Participants stressed the social problems linked to

access to land and the economic constraints of markets for rice and diversified crops. These are serious obstacles to the transfer of responsibilities to smallholders for maintenance of irrigation systems and they affect the durability of the systems.

Establishment of farmers' organizations or structuring of rural communities is often recommended as a solution for system management.

In Madagascar, the small-scale irrigation project that we conducted with the national Office de développement rizicole (ODR) demonstrated the difficulties faced by farmers—even for relatively small systems—in taking on responsibility for water management, maintenance of irrigation networks, and payment of taxes. In contrast, rural communities in western Africa responded by constructing low-cost, unplanned networks outside established irrigation systems.

These observations reveal new challenges for research. The findings should guide policymakers and donors to choose the most appropriate investments according to the geographic and social situations. The results will also enable farmers to define rules for collective management (water, network maintenance, land use) and for technical and economic planning of their crop enterprises.

We work with several other CIRAD departments for an ongoing project to alleviate the negative impact of irrigation systems on the environment, to offer more efficient technology in response to new situations, and to facilitate market penetration. New arrangements that clarify the respective roles and functions of the state and farmers' organizations will also be proposed. Research operations that are under way in the Senegal river basin and the area of the Office du Niger, Mali, are included, with adjustments, in the project. In this case, CIRAD's researchers are integrated within the Conférence des responsables de la recherche agronomique africains (CORAF).

Publication

Agricultural Development in the Sahel

Le développement agricole au Sahel *is a multiauthor publication in five volumes on agricultural development in the Sahel. The first volume outlines the challenges and possibilities within which farmers operate. The techniques available for agricultural development are reviewed in the second volume, followed by 11 case studies of technological innovations in the third volume. The fourth volume summarizes the propositions of the earlier volumes and attempts to answer the questions: Which techniques can be used in the Sahel? What is still needed? What reasons and conditions influence a producer (farmer, herder, craftsperson, etc) to adopt or reject an innovation? The last volume is a bibliography.*

These analyses challenge the pessimistic views of theses and discussions on the Sahel, and their misgivings about the prospects for long-term development in the region. Sahelian societies are innovative: they have survived severe climatic and economic conditions over the ages by dint of their innovativeness. There is ample evidence of this capacity in their individual and collective (farmers' organizations) strategies to defend, improve, or even transform their lifestyles. When innovation is backed by incentives, it becomes a determining factor in the extension of technical progress.

In practice, the main question is: How to give full rein to the innovative capacity of producers? Solutions are suggested for the economic and institutional environment, and research programmes. They are intended to promote reflection within research organizations, development agencies, and professional and political institutions.

Diversification of Rural Activities

In Brazil, credit policies, developed and tested by us in collaboration with the Banco do Nordeste, allow farmers to diversify into vegetable farming, facilitate marketing of livestock products, and promote services. The Sertão state governments and municipal teams provided support for the establishment of small-scale rural enterprises. The creation of handicraft houses and renovation of schools characterize the dynamic approach to rural development in this region.

Privatization of veterinary services in Madagascar has led to the establishment of a network of veterinary product stockists in the lake Alaotra and Antsirabe regions. The agents receive training in rural practice and stock control sponsored by pharmaceutical companies.

Sustainable Development in the Savanna and Wet Tropical Zones

In spite of their production potential, the savanna and wet tropical zones cannot keep pace with population growth, changes in ecosystems, and price fluctuations on international markets for commodities such as coffee, cocoa, and cotton. Postpioneer systems in forest regions are confronted with the problem of replantation, whereas farmers in the savanna zone are resource-poor and have limited access to inputs.

The main objectives of our programme are: to encourage crop diversification; to enhance the role of livestock production; to reduce postharvest losses; and to bring about favourable conditions. In regions where farming is intensive and market-oriented, our activities focus on food processing, marketing, and support for farmers' organizations.

New Impetus to Coffee and Cocoa Production

In spite of the collapse of farm-gate prices (–60%) due to the slump in international trade, coffee and cocoa still represent the main sources of income for farmers in southern Cameroon. It is estimated that for the 1991/92 harvest, US$93 million were paid out to 3–4 million Cameroonians.

At the request of the Ministry of Agriculture in Cameroon, we studied ways of stimulating smallholder production of coffee and cocoa. We considered regional aspects and farmers' response to the new economic situation. The results indicated that the impact of the crisis varied with the crop (cocoa, robusta coffee, or arabica coffee), degree of crop specialization and intensification, crop diversification potential, plantation age, and access to markets.

Robusta planters in the Moungo zone, who specialized in intensive coffee cultivation, are now growing food crops for on-farm consumption. Arabica planters in the highlands, who had already started vegetable and food crop cultivation for income diversification, now concentrate on these crops rather than coffee. Cocoa planters, however, are able to maintain their activity because production costs for cocoa are low.

We also analyzed Cameroon's competitiveness on the international market. State disengagement, removal of price stabilization mechanisms, and liberalization of trade can give a fresh impetus. Current efforts at reorganization should provide a more effective mechanism for determining domestic prices in relation to the international market. They should also harmonize management of different activities in the sector.

The coffee and cocoa sectors are not completely at a loss. Planters' know-how and abundant land are valuable assets; and the possibility of an upturn should not be overlooked.

Our analysis aims at an upturn in coffee and cocoa production in the region. It provides facts and figures to

decisionmakers and in 1993 it will result in proposals for a regional action plan.

Coffee Smallholders and Agroindustries

On the initiative of a manufacturing company, Unicafé, we studied the possibility of integrating smallholders within the coffee sector in Côte d'Ivoire. The project was carried out in collaboration with a legal consulting company.

We focused on the planters, who had been struck by the fall in coffee prices and the disorganization of distribution channels. We also considered the prevailing antimonopoly measures and the authorization of hulling by small-scale mills. Both changes have a profound impact on coffee processing.

The study proposed the creation of support services for producers based on two components. The marketing component would be controlled by the private sector, and the technical component—to improve plantation management and output—would be entrusted to an association of professionals. The association would be responsible for the promotion of coffee cultivation in Côte d'Ivoire through training, information, advice, and research and development. It would be managed by groups of producers, exporters, and manufacturers; the association would represent the sector in discussions with the public authorities, who are reorganizing agricultural extension services in the country.

Harvest Conservation

A cotton crisis has hit the region of Garoua in northern Cameroon. Economic diversification and support for initiatives by farmers for food processing are the aims of a wide-ranging research programme that involves the Institut de la recherche agronomique (IRA), Cameroon, and several CIRAD departments. In this programme, we developed methods for small-scale conservation (cowpea and onion) and processing (maize, sorghum, and groundnut).

Onion conservation is a successful example of the contribution of this type of research. For the region's farmers, onion is a significant source of income; annual production is 30000 t and income is estimated at US$3.6 million. But, storage and transport losses during the rainy season can wipe out almost half the harvest, with repercussions on local prices. A 90-kilogramme sack of onions purchased for US$12.5 at harvest (February–April) is worth US$89.3 in November. Work on conservation of fresh onions carried out in collaboration with IRA showed that losses can be reduced from 42% to 18% by storing onions in closely

Products for Development

Technology for Réunion

We worked with sugar manufacturers in Réunion to design a whole-stick harvester. The harvester is intended to alleviate the workload for farmers who have no manpower, without altering the traditional system. After harvest, the farmers can gather and transport the canes in the same way as for manual cutting. Farmers can use their own loaders and trailers, which they cannot do with conventional chopper harvesters.

Livestock production systems in the highlands of Réunion are based on grass. But grazing and green fodder cannot adequately sustain dairy herds during the cold, dry winters (June–November). Surplus grass cut during the wet summer season is too moist to be stored by traditional methods. We developed a storage method using wrapped, round bales to improve both storage conditions and duration. The method ultimately increases livestock productivity by preventing shortages during the dry season.

stacked trays in a well-ventilated room. We also found that violet and orange-yellow varieties kept longest.

Adoption of Innovations by Farmers

Silvania (State of Goiás) is a typical central *cerrado* region in Brazil. In this region, large soybean and livestock farms are found next to small and medium-sized farms that combine multiple cropping and livestock production. According to the Empresa Brasileira de Pesquisa Agropecuária (EMBRAPA), slow agricultural progress in the region can be attributed to the low rate of adoption of innovations by the small and medium-sized farmers. These groups need to be defined as a first step in promoting innovations.

The relationship between family and farm determines farming strategies. Groups in which the workforce is made up of family members respond readily to ways of accelerating accumulation of capital (land, livestock) and improving productivity. The family workforce is reduced in those groups that hire labour or opt for mechanization. Such groups are accustomed to monetary exchange and their aim is to increase profits. In the third type of group, there is no direct link between farm and family. The farm is a source of additional income and the family does not live on it. These descriptions are useful for developing methods for providing professional guidance on farm management.

Intensification of Soybean Production in Southeast Asia

Sygap II is a soybean crop intensification project that we conduct in Indonesia and Thailand in collaboration with the Regional Co-ordination Centre for Coarse Grains, Pulses, Roots and Tuber Crops in the Humid Tropics of Asia and the Pacific (CGPRT), Indonesia.

Introduction of innovative technology was an important component in this project, which was conducted with a network of farmers. In certain locations farmers were reticent about adopting recommended techniques because of unstable yields. Appropriate soil preparation and sowing techniques can improve water use efficiency and reduce yield variations. Mechanization can cut down competition between soybean and rice for manpower. Better harvesting conditions can improve quality and sales value of the produce. Preliminary results are encouraging farmers to test certain recommended techniques.

Products for Development

Biofuels

Biofuels reduce dependence on oil supply. In addition, a study we conducted with the French Ecole supérieure de l'énergie et des matériaux (ESEM) showed that carbon dioxide emissions from diesel engines run on plant oil were lower compared with conventional fuels. A sedan run on rapeseed oil has already logged 4000 km since trials began.
A gasogene prototype using rice husks continuously produces combustible gas at an hourly rate of 100 m^3 (average minimum calorific capacity of 4.5 MJ/m^3). Waste products such as coffee parchment and groundnut shells can also be fed into the gasogene.

Promotion of Rural Output and Urban Food Supply

The programme on promotion of rural output and urban food supply was created in 1992 in recognition of the need to add greater value to local products by mobilizing processing and marketing enterprises. Development, implementation, and testing of operations are based on an analysis of demand.

The aim is to balance out urban demand for food and rural supply of produce.

Food Demand in Urban Areas

Surveys conducted in Dakar, Cotonou, and Garoua on food consumption trends showed no preference for imported products over local products. In Dakar, *nététu*, a traditional condiment prepared from *néré* seeds (*Parkia bigliobosa*), is still widely consumed by all population groups, in spite of the availability of manufactured condiment cubes. Maize consumption has increased in Garoua as food processing becomes easier with the growing number of mills.

These results are corroborated by those of surveys of food habits conducted over the past 20 years in the humid and subhumid countries of the Sahel. A study on the use of food crops in these countries—which we carried out for the Special Program for African Agricultural Research (SPAAR), United States—confirmed that local production was driven by urban demand. For example, the urban market for cassava and yam is expanding. Cassava *gari* (semolina) and *attiéké* (couscous) are produced only in certain areas, but are now sold in African towns where they were previously unknown. The studies revealed that town dwellers sought to diversify their diet despite low purchasing power. Consumption of rice and wheat has risen in the same way as maize, tubers, and vegetables. Studies such as these serve to adjust rural output and urban demand.

Food Microenterprises

Surveys of food habits also confirmed that the urban market was segmented and gave rise to a variety of food enterprises. We studied this sector in Benin, Cameroon, Congo, Senegal, Chile, Colombia, and Panama.

In Africa the food industry is characterized by the proliferation of microenterprises. In Brazzaville, for example, there are about 2500 workshops that produce *chikwangue* (paste) and *foufou* (flour) from cassava. The main advantages of such enterprises is that they correspond to demand; they are also flexible and innovative. However, once they expand they encounter financial, productivity, and quality control problems. These difficulties warrant the introduction of support operations in Benin and Burkina Faso.

Rural Agroindustries in Latin America

In Latin America rural enterprises are gaining ground in the food processing industry. They are usually managed by farmers (individuals or groups) or rural entrepreneurs and they play a very important role in adding value to local resources. They have also served as catalysts in organizing rural communities and in creating professional groups.

We work with regional institutions specializing in food technology R&D for operations designed to support the enterprises. PRODAR is the programme on development of rural agroindustries in Latin America and the Caribbean; participants include: Instituto Interamericano de Cooperación para la Agricultura (IICA), Costa Rica; Instituto Nacional de Tecnología Agropecuária (INTA), Argentina; and Instituto de Nutrición de Centro América y Panamá (INCAP), Guatemala. In Argentina jam produced by a network of small rural enterprises was marketed locally according to a distribution strategy developed under the auspices of this programme.

Technical support operations were strengthened. We studied the traditional methods used in Colombia and Brazil for producing starch from cassava. Fermented starch is the basic ingredient in bread (*pan de yuca* and *pan de bono*) in Colombia. This starch can rise although cassava is gluten-free. We seek to understand how fermentation and drying confer this property. These studies could lead to new ideas for adding value to other starchy tropical crops such as yam, millet,

International Meetings

Food Crop Processing and Innovation

Since 1988 we have collaborated with partners in Benin, Cameroon, Senegal, and France in a project for the development of innovative food technology. A workshop was organized in November 1992 in Montpellier to mark the completion of the project. About 100 participants attended the workshop. They recognized the importance of an integrated approach to food consumption, processing systems, and product innovation. Consumption in terms of food habits involves: products and prepared foods, supply mechanisms, processing and preparation, and consumption environment.

Our projects in Senegal with the Ecole nationale d'économie appliquée (ENEA), in Cameroon with the Institut de la recherche agronomique (IRA), and in Congo with Agricongo were presented as case studies. The economic, social, and cultural environment of an innovation was analyzed. As illustrations, we presented other projects: nététu *production in Senegal, in collaboration with the Comité d'action pour le développement du Fogny (CADEF) and the Institut sénégalais de recherches agricoles (ISRA); processing of cassava into* chikwangue *in Congo, with the Institut français de recherche scientifique pour le développement en coopération (ORSTOM), France; and adding value to cereals and onion in Cameroon, with IRA.*

sorghum, or maize. In another cassava starch project, we proposed technical improvements so that small enterprises in Colombia and Ecuador could improve extraction rates.

Local Development and Institutional Approach

A variety of private, individual or collective initiatives are taken for food production, processing, promotion, and rural services. The research programme on local development and institutional approach was created in recognition of the importance of these initiatives.

Development of Rural Finance Services

The project for developing financial services in rural areas aims to stimulate local economies by easing financial difficulties encountered by farmers. In Burkina Faso, we identified farming strategies and the specific financial needs of farmers. We tested new financial services suited to local demand, in collaboration with the Caisse nationale de crédit agricole and with support from CFD. Recovery rate was high for the 1000 small loans granted to farmers, artisans, and shopkeepers. The economic and social effects of these credit schemes need to be monitored and evaluated before designing regional and national financial service systems.

Farmers' Organizations

In 1985 CADEF, Senegal, was transformed into a *groupement d'intérêt économique* (economic interest group). At present, it covers 25 villages and has over 4000 members. We studied local development trends in a research project conducted with the Centre international pour l'éducation permanente et l'aménagement concerté (CIEPAC), the Fondation pour le progrès de l'Homme, and ISRA.

Degradation of the local environment prompted farmers to seek technical support. In response, we developed improved and diversified farming systems, which included livestock production.

The research team also assisted farmers in implementing the new systems. Service enterprises were formed,

including: well-digging service, itinerant forge, wire mesh production unit, seed bank, crop protection unit, veterinary pharmacy, and others. Contrasting results were observed for the credit system. Loans intended for diversification of economic activities recorded satisfactory recovery rates, whereas those for the acquisition of farm machinery had to be discontinued. This confirms the importance of diversification during the current agricultural crisis.

The network of village advisers on technical and management matters shows that farmers' organizations are gradually accepting their responsibility for developing their region.

Support for Research and Development Units

National agricultural research systems in the south and their member institutions are faced with a crisis. The situation, however, offers an excellent opportunity to involve new public, or private, research organizations and to consider the aspirations of farmers and their development priorities.

In 1992 we participated in the reorganization of research systems in Algeria, Angola, Burkina Faso, and Tunisia.

A team from the Basic Grain Research Project for Central America (funded by the Commission of the European Communities) participated in the organization of a regional system of food crop research. The network links institutions in six Central American countries. Research and development teams were formed, an information system was created, and scientific exchange was established in collaboration with IICA.

The training programme on research centre management is organized in collaboration with the Food and Agriculture Organization of the United Nations (FAO) and the Technical Centre for Agricultural and Rural Cooperation (CTA), The Netherlands. In 1992 it was attended by about 20 experienced research managers.

Other training programmes focus on the links between research and development. They were initially held in France, but they are now being exported. In Chile, for example, the nongovernmental organization Agraria hosted the fourth session of technical assistance to farmers. Twenty-seven participants from 16 Latin American countries and the Caribbean attended the 4-week course.

Theses Completed in 1992

CIRAD Scientists

Huiles végétales-biocombustible diesel ; influence de la nature des huiles et en particulier de leur composition en acides gras sur la qualité du carburant [Plant oils and diesel biofuel: Influence of oil type and, in particular, their fatty acid composition on fuel quality] by Gilles Vaitilingom; Université d'Orleans.

Huiles végétales-biocombustible diesel ; incidence des aspects thermiques liés au type de moteur à combustion [Plant oils and diesel biofuel: Effect of heat linked to the type of combustion engine] by Pascal Higelin; Université d'Orleans.

Propriétés physiques, hydriques et mécaniques des sols andiques de la Réunion ; facteurs d'évolution des horizons culturaux, implications agronomiques et écologiques [Physical and mechanical properties, and water dynamics in the andic soils of Réunion] by Sylvain Perret; Ecole nationale supérieure agronomique, Montpellier.

CIRAD Trainees

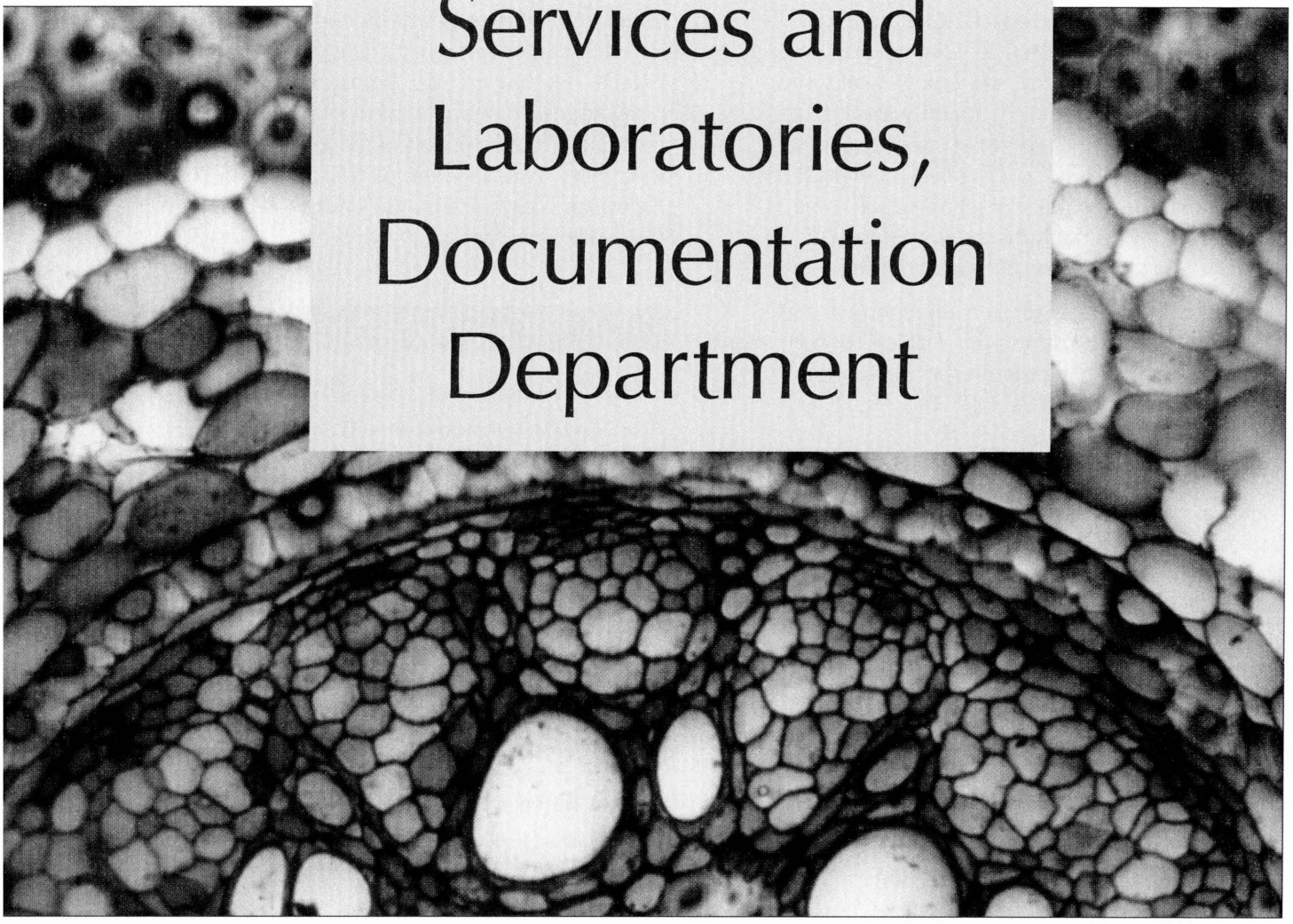
Déshydratation osmotique de produits végétaux ; application à l'obtention de concentrés de tomate [Osmotic dehydration of plant products: Application to the production of tomato concentrates] by Ana Perez Carvajal (Costa Rica); Université Montpellier II.

Le séchage du poisson (*Tilapia* spp.) ; étude de la relation procédé-qualité du produit ; application de terrain au Mali [Drying of fish (*Tilapia* spp.). Analysis of the relationship between the process and product quality. Field application in Mali] by Nadine Zakhia (Lebanon); Ecole nationale supérieure des industries agricoles et alimentaires.

Etude et mise au point de méthodes de mesure de la biodégradabilité des matériaux d'emballage [Study and development of methods for measuring the biodegradability of packaging materials] by Véronique Coma (France); Université de Reims.

Conception et réalisation d'un procédé automatisé de déshydratation-imprégnation par immersion [Design and development of an automated process for dehydration and impregnation by immersion] by François Giroux (France); Ecole nationale supérieure des industries agricoles et alimentaires.

Management, Common Services and Laboratories, Documentation Department



CIRAD-GERDAT occupies a special position among the departments as it is responsible for management, common services and laboratories, and documentation. It was the driving force during the consolidation of the Centre in 1984. Now it has two main responsibilities: providing administrative and financial support to the CIRAD management; and management of common research programmes, units, and services

The research component of CIRAD-GERDAT forms the institutional framework for developing the topics and analytical tools required by the Centre's research strategy. This work is carried out under the responsibility of the department and in close collaboration with the Office of the Research Director. The common units have steering committees with members from user departments. If a department builds special capacity in a given field, it is entrusted with the management of the relevant unit after approval by other departments.

The scope of our activities can change, depending on the overall research strategy and the requirements of other departments.

At present we have four common research units and one programme. The steering committees of the common units will be set up in 1993; they will be expected to encourage interaction with the departments to respond to their needs, and to strengthen the research capacity of the units.

Training, scientific and technical information, and computer services are part of CIRAD-GERDAT because they are used by all the departments and also have a coordination function.

Our concern for the future is to promote synergy within CIRAD and to collaborate with our partner organizations.

Operational Ecology and Acridology: Prifas

Locust outbreaks cause serious economic losses. We investigate the dynamics of outbreaks and develop control methods appropriate to the local economic and ecological conditions. We also participate in more general research on locust problems and make the results available to the international community.

In addition, we train scientists, exchange information with associate researchers, and provide consultancy and project management services.

In 1992 we set up fixed-term programmes in Brazil, Burkina Faso, and Senegal and extended our activities to China, Russia, and Yemen. We also approached counterparts in Costa Rica, Madagascar, Republic of South Africa, and Viet Nam.

Desert Locust Model

About 60 countries are prone to devastating outbreaks of desert locusts. Work on a model of this locust is funded by the Commission of the European Communities (CEC) and the French Fonds d'aide et de coopération (FAC); the objective is to develop a diagnostic tool that can be used for control operations. A prototype model was developed based on the reference period 1985–1992 and is now available for use. The model is based on population dynamics; it helps to understand recent events better and to simulate the effects of various hypotheses. Additional research was undertaken on classifying the ecology of habitats throughout the range of this species, which covers 30 million km^2. Data will be processed with a geographic information system.

Ecological Impact of Locust Control Treatments

In Burkina Faso we set up a collaborative project with the national crop protection department to evaluate the ecological impact of locust control. The project is conducted under the auspices of the Organisation commune de lutte antiacridienne et de lutte antiaviaire (OCLALAV), Senegal.

An international workshop on research methods in operational ecology in Africa was organized as a preamble. The CEC-sponsored meeting, which was held in Montpellier in February 1992, included both African and European scientists and field workers. They reviewed monitoring systems and research on

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Common Services and Laboratories

Biotechnology for tropical crop improvement	Jacques Schwendiman
Plant architecture modelling	Philippe de Reffye
Agricultural prospects and policies	Michel Griffon
Soil and plant analysis	Paul Fallavier

Support Services

Training	Marc Roesch
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the effect of pesticides on the environment, particularly nontarget fauna. The methodological aspects of this research mainly concerned interpretation of toxicological tests on land invertebrates and methods of studying the effect of pesticides on birds.

The first phase of field work consisted in developing a methodology for ecotoxicological monitoring. Reactions of acridians, birds, and certain groups of insects were studied when national locust control services carried out chemical treatment campaigns. The studies will be continued during the coming cropping seasons.

Locust Control Campaign in Western Africa

We provided scientific and technical assistance for the 1992 locust control campaign in Senegal, at the request of OCLALAV. A survey was conducted among the crop protection departments in each of the 10 OCLALAV member countries. The aim was to compile locust data for a bulletin. The survey focused on improving the quality of field observations and their interpretation, and on strengthening locust control operations. It demonstrated how data could be centralized efficiently at OCLALAV. The data will be processed at Prifas in Montpellier and the results will be communicated rapidly to the user countries.

Locust and Grasshopper Studies in Brazil

Locust outbreaks have been frequent since 1986 in the area bordering the Amazonian basin in Brazil. We are collaborating with the Empresa Brasileira de Pesquisa Agropecuária (EMBRAPA) in a recently established CEC-funded research project for developing a locust control strategy that is specific to the region. It will lead to the creation of a locust control unit in Brazil.

The research concentrates on particular locust and grasshopper species in the region; it aims to understand the causes of outbreaks and to study changes in the environment and their impact on the locust problem. We used satellite imagery to describe and seasonally monitor locust habitats in the region. Environmental and biological data will be integrated into a geographic information system, which is currently at development stage; the purpose is to facilitate monitoring of locust populations.

Biotechnology for Tropical Crop Improvement: Biotrop

At Biotrop, we adapt and develop methods in molecular and cell biology. These methods are not intended to replace but to improve the speed and efficiency of conventional plant improvement strategies. They are used in addition to existing breeding schemes.

The in-vitro techniques used for conservation and analysis of genetic resources are the most familiar type of biotechnology. At the varietal development stage, genetic transformation serves to incorporate particular characters in selected varieties. Micropropagation then allows true-to-type multiplication of the selected plant material.

Scientists from other departments work in the four Biotrop laboratories: genome studies of tropical crops; genetic engineering; in-vitro culture; and histology.

Genetic Diversity of Crops

Genetic diversity of crops was previously studied by isozyme electrophoresis. The studies now use molecular markers to examine restriction fragment length polymorphism (RFLP) and, if necessary, random amplified polymorphic DNA (RAPD). The results of genetic diversity studies of cocoa, rubber, and banana are reported by the relevant research programmes.

Genome Mapping

Genome mapping is also based on the use of molecular markers. Mapping of sorghum began in 1992; it is under way for sugarcane, cocoa, and rubber. The first genetic map of *Musa acuminata* diploid bananas has just been completed. Many of these research projects are funded by the CEC.

Polymerase chain reaction (PCR) was used in addition to these methods. For rubber, PCR simplified preparation of probes for RFLP studies by eliminating the plasmid purification stage. It also facilitates development of RAPD markers, which are used in addition to RFLP markers. RAPD is particularly suited to banana and 28 loci were added to complete the map established from the SF 265 x Banksii cross. We have now overcome certain problems in applying the method to cocoa; 28 RAPD markers were used to analyze UPA 409 x POR progeny.

Endogenous Growth Regulators

Research findings on endogenous growth regulators by CIRAD, ORSTOM, and Université Paris VI were combined to demonstrate changes in somatic and zygotic embryos of *Hevea brasiliensis*. Abnormal development of some of the somatic embryos was explained. We also developed a viable and reproducible technique for regenerating embryos into plantlets by adding abscissic acid or through slight desiccation.

In oil palm, abnormal floral morphogenesis following in-vitro culture was traced back to cytokinin deficiency. It occurs in abnormal female inflorescences due to the use of fast-growing calluses for multiplication. We now have specific markers for eliminating embryo cultures likely to produce abnormal individuals.

Somatic Embryogenesis in Liquid Medium

Expertise in somatic embryogenesis in liquid medium is useful for our studies on various mandate crops of CIRAD such as rubber, rice, banana, coffee, and oil palm.

For rubber, we were the first to upscale the laboratory process for plantlet production into a large vegetative multiplication operation. Analytical studies were also conducted to obtain friable calluses. The mechanisms that induce such calluses can now be controlled and reproduced.

Embryogenic cell suspensions obtained from zygotic embryos of diploid bananas were maintained by

eliminating systematically those fractions that exceed 500 microns in diameter. Maturation and germination ability were improved by modifying the macroelements in the first solid medium and by adding cytokinins to the final maturing medium. This sequence ensures uniform development of somatic embryos.

For triploid bananas, cell suspensions from young immature male flowers did not regenerate into whole plants. However, the temporary immersion system that we developed resulted in an exceptionally high cell proliferation rate. With this method, the medium can be changed without handling the plant tissues or cells. This novel culture system was initially developed for banana; it has since been applied successfully to microcuttings and embryogenic cell suspensions of coffee and rubber. The promising results encourage further development.

New histological methods were developed for studying cell suspensions. They led to the design of a range of rapid and easy staining techniques, mainly those based on fluorescent markers. The ploidy level of regenerated plants was determined by flow cytometry. We can now evaluate cell activity and rooting potential from peroxidase, phosphatase, or ATPase activity.

Genetic Engineering and Transformation

The bacterium *Bacillus thuringiensis* produces a range of natural endotoxins with insecticidal properties against a large number of lepidopteran pests. The toxins can be used to produce biopesticides.

Cloned toxin genes were first collected in collaboration with the Institut national de la recherche agronomique (INRA), Institut Pasteur, and North American universities. We could then produce the toxins corresponding to each gene. After purification, toxicity tests were carried out on mass-reared insects to establish their sensitivity. Histo-immunology studies were conducted to verify in vitro the existence of toxin receptors in the midgut membrane of larvae. The technique requires specific antiserums.

Several *B. thuringiensis* isolates showing unique characteristics were analyzed to broaden the range of sensitive insects. New insecticide toxins were isolated.

We tried to associate proteins having different modes of action with *B. thuringiensis* to avoid the development of insect resistance. A soybean protease inhibitor gene was cloned into a bacterial toxin gene in place of the sequence coding for the toxic subunit. The protease inhibitor was produced in crystalline form in the same way as the toxins produced naturally by *B. thuringiensis*.

The *B. thuringiensis* genes that encode the endotoxins were also used for constructing transgenic pest-resistant plants. We are now equipped for direct insertion of genes by protoplast electroporation and microparticle bombardment.

Expertise in rice protoplast regeneration was extended to new varieties used in pest resistance breeding schemes. Transitory expression of genes introduced by electroporation or polyethylene glycol is equally or more intense in comparison with reported results. The protoclonal lines obtained in 1991 showed intraline variation for agronomic characters in field tests, but they can still be used as parents in breeding programmes.

Plant Architecture Modelling

Plant architecture modelling is the expression of biological phenomena such as growth in mathematical form. It can be used for reducing the size and duration of field experiments. Results of such virtual experiments are then displayed in three dimensions by means of computer graphics.

In 1992, we worked with CIRAD's traditional research partners INRA and ORSTOM, and agroindustrial

concerns such as the Société d'exploitation industrielle des tabacs et allumettes (SEITA), greenhouse farmers, mushroom producers, and logging companies.

Modelling is a general tool that is used in vastly different disciplines (plant improvement, agroforestry, epidemiology, management of areas with plants). We installed application software for our partners. This network of pilot users is the first step in promoting our approach. The next step is the formation of teams for this work in client organizations.

New agreements were signed with computerized graphic image specialists; they are increasingly using our AMAP program for landscape design. Plants computed and simulated by AMAP are produced for various purposes (architecture, town planning, advertising, teaching, land development) at more than 100 locations worldwide.

Crop Architecture Modelling

We undertook modelling of tree crops in 1990. We can now supply applications for cocoa, coffee, and coconut to CIRAD-CP. Those for forest species were developed in collaboration with the French Institut de développement forestier (IDF) and INRA, and those for fruit trees with the French Centre technique interprofessionnel des fruits et des légumes (CTIFL) and INRA.

We have greater control over various cropping aspects (plant density, pruning, and training) as our knowledge of the architecture and growth of these crops increases. Better knowledge of flowering and fruiting allows more accurate analysis of production potential.

During 1992 new collaborations were established in specific domains: with CIRAD-CA for geranium in Réunion; with the Institut du tabac de Bergerac for tobacco; with the Coopérative agricole des champignonnistes du Saumurois (CACS) for mushroom; and with the Association méditerranéenne des régions productrices de fruits et légumes (AMIFEL) for fig.

Digital models were constructed for epidemiological studies on virus diseases of cassava (with ORSTOM) and *Phytophthora* diseases of coconut (with CIRAD-CP).

We also assessed the radiation balance in intercrops based on digital models. We computed the radiation balance for coffee under erythrin in Costa Rica. Our studies on coconut-based intercrops in Côte d'Ivoire will be followed up in Vanuatu, where we shall analyze cocoa - coconut intercrops.

Interactions between various species in agroforestry systems require complex analyses. Digital models should provide useful information on biomass production, crop maintenance, and pruning.

We were commissioned to model several Mediterranean plant species for creating a database on fuelwood, which will be integrated in a program for simulating propagation of forest fires.

Work on the modelling of an underwater phanerogam (*Posidonia oceanica*) was carried out under contract with coastal marine environment unit at the Université de Nice.

Computer Graphics

We developed interfaces with well-known computerized graphic image programs (Explore, Softimage, Wavefront) for AMAP. In this way, we hope to extend the use of the AMAP growth engine and vegetation databases.

We adapted AMAP for use on less powerful computers than graphics terminals. The vegetation databases are regularly enhanced and currently include more than 200 marketable parameter files. One application of current interest concerns natural environment management (reforestation, rehabilitation, railway and road construction, creative landscape management).

AMAP plants have already been adopted by image specialists because of their visual realism. They should also interest organizations involved in landscape modelling because of their scientific accuracy.

Agricultural Prospects and Policies

The two underlying considerations for our work are: structural adjustment policies do not have only positive effects on agriculture; and agricultural policies have limited cycles with difficult transition periods. We use long-term forecasts and models to construct possible scenarios that will guide decisionmakers in the definition of new policies.

Our main objective is to develop representative models of the agricultural sector and its integration in the economy; they also cover various types of socioeconomic behaviour. Simplicity and rapidity are stressed more than forecasting accuracy in these models, which are intended to be used mainly as decisionmaking aids.

Policy Analysis

In 1989 we had organized a seminar on structural adjustment policies with the Instituto Interamericano de Cooperación para la Agricultura (IICA), Costa Rica. As a follow-up we analyzed these policies in different Latin American countries.

We found that structural adjustment measures had increased the competitiveness of the agricultural sector. The fall in prices of most agricultural commodities on the world market led to a scramble for new export markets (mainly for fruit), but access was limited.

Agricultural Policies and Modelling

The models characterize behaviour of farmers and others involved in the agricultural sector. They simulate their responses to modifications in their economic environment. The models serve to identify the effects of different variables and to explore other scenarios.

We combined farm household models with equilibrium models used in comparative statics. After examining different modelling types, we proposed improvements in household models, subsectoral models, and computed general or partial equilibrium models.

Social and economic institutions were included under transaction costs in the commodity and agricultural sector models.

Various projects based on long-term forecasting aim to identify the main aspects of regional agricultural policies: market integration in Central America; diversification in Southeast Asia; regional free trade in western Africa.

We also participated in a study on the long-term agricultural research needs in tropical Africa. The study

International Meetings

Institutional Economics and Agriculture

We coorganized the Seminar on Institutional Economics and Agriculture with Michigan State University and Indiana University. It was held in Montpellier from 7 to 9 September 1992. About 100 participants from Africa, United Kingdom, United States, and France attended the Seminar. They reviewed institutionalist theories in the light of actual economic and social conditions. The contribution of these theories to analyses of the agricultural sector in southern countries was discussed: How should changes be proposed to promote sustainability? Can economic analyses of the performance of the basic social units (household, lineage) explain production practices in relation to price? Can the success of the cotton sector in francophone countries be attributed to the existence of contracts?

was part of the Special Program for African Agricultural Research (SPAAR) of the World Bank.

Agricultural Policies: Concerns and Proposals

The traditional concerns of agricultural policies are diffusion of innovative techniques, income level and distribution, and higher production and productivity. In addition, they must now address the problems of competitiveness of commodities, diversification of production, regional free trade agreements, and sustainability.

A policy is generally a complex set of measures that must respond simultaneously to different objectives. The relationship between means and objectives must be clearly established before defining a policy. Our research explores the objectives structure in relation to the new issues, particularly environmental concerns.

The crisis in African agricultural institutions combined with slow and difficult implementation of liberalization policies call for an in-depth analysis of the institutions and diversification of possible solutions. The theory of public choice and the principles of decentralization and subsidiarity offer a wide spectrum of possible institutional forms for agricultural services (eg, agricultural research, extension, veterinary services, credit, supplies, and marketing). Different institutional forms of ownership can also be defined for natural resources (soils, water, forests, pasture). These studies (eg, management of commons) represent a new research area in environment economics.

Soil and Plant Analysis

We conduct research in analytical chemistry and soil sciences to increase the precision of laboratory analyses. The studies attempt to explain physical and chemical mechanisms that influence soil and plant functions.

Copper in Peat Soils of Sumatra

CIRAD-CP has carried out experiments since 1987 in the project for planting coconut on peat soils in Sumatra. The results revealed significant copper deficiency. We studied retention and release of copper added to peat before recommending application rates and methods.

Preliminary results indicated the significance of two parameters: age of the peat and chemical form in which copper is applied. Drainage and compaction of peat soils during the first plantation establishment operations start a change. Observations over 4 years revealed that the retention capacity of peat increased considerably. The chemical form of fertilizers had little influence on copper dynamics. Copper sulfate was widely used and led to leaching of magnesium and potassium. The advantage of copper carbonate was that it raised pH, but it was not readily available on the market.

Resistance of Maize to Aluminium Toxicity

Maize yields on acid tropical soils in humid regions are limited mainly by aluminium toxicity. Liming is not an economical solution because large quantities would be needed to compensate for the high buffer capacity of the soils. Application of organic matter is also not possible because it is often not available.

One option is to use acidity-tolerant varieties but breeding programmes take several years. We worked with maize breeders from CIRAD-CA to develop methods for testing resistance to aluminium toxicity at an early stage. Field observations already showed that Brazilian varieties are tolerant. In a novel approach, we grew the varieties on nutrient solutions having the same composition as soil solutions. Growth of root systems was related to toxicity resistance in the field. In the next stage, we shall attempt to identify the physiological mechanisms that cause varieties to respond differently. The universities of Hannover, Barcelona, Rennes, and Montpellier were also involved in the project.

Computer-Assisted Training

In collaboration with the Centre national universitaire sud de calcul (CNUSC), France, we prepared a 2-hour course on soil dynamics of potassium. For this purpose we used DRUID software developed by Université Paris VII. The course was intended for Chinese agricultural technicians and formed part of a development project in the Jiangsu province. In this individualized computer-aided course, a trainee's progress is judged from the results obtained in the exercises. The answers are accurately analyzed by techniques closely related to artificial intelligence. Various supports are used including text, graphics, animation, sound, and photographs.

The technique requires extensive preparation—1 h of the course represents 200 h of preliminary work. But it contributes effectively to the use and dissemination of information. The technique will be tested in China in 1993.

Training

We have two target groups for our services. For CIRAD staff we organize in-service training programmes. For scientists from partner organizations, we plan training schedules, organize short-term professional training programmes, and arrange for diploma courses.

In 1992 a total of 502 CIRAD staff attended training courses. The principal sectors included laboratory techniques, computer science, biometrics, remote sensing, and languages.

We assisted in efforts to modernize training projects at: Institut de la recherche agronomique (IRA) and Institut de recherche zootechnique et vétérinaire (IRZV), Cameroon; Centre national de la recherche appliquée au développement rural (FOFIFA), Madagascar; and Institut d'études et de recherches agricoles (INERA), Burkina Faso. The programmes involved approximately 100 scientists, 25% of whom attended diploma courses and 75%, short-term programmes. We were requested by the Institut agronomique de Guinée (IRAG), Guinea, to design and implement a multiannual training schedule. The programmes were organized for about 120 scientists and they were held mostly in Guinea.

We organized a total of 600 courses for these and other partner organizations. They were conducted either at CIRAD or at other research organizations, industrial establishments, or farmers' associations. A total of 275 foreign scientists spent an average of 1½ months in CIRAD laboratories.

Scientific and Technical Information

Our services focus on publication and documentation support to scientists.

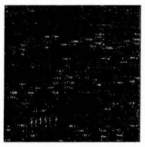
Scientific and technical publications by the departments were evaluated. CIRAD's editorial policy was defined in liaison with the Scientific Advisory Committee. It was based on evaluation of the impact of these publications and available human and financial resources.
The policy encourages publication in international journals; adjustment of the departmental journals to meet the needs of professionals and development agents; and establishment of a series of collections (working documents, research publications, research reviews, bibliographies, conference proceedings).

In the documentation sector, we further developed selective dissemination of information (SDI). In 1992 more than 800 SDI profiles were sent to scientists in more than 50 countries. We provide documentation support to national scientists of western, central, eastern, and southern Africa; and the Indian Ocean region on

behalf of the Technical Centre for Agricultural and Rural Cooperation (CTA), The Netherlands.

We enhanced our database, AGRITROP, by retrospective data entry, with special emphasis on CIRAD publications. By end 1992 the database contained more than 125 000 references.

The conclusions of the first external review of CIRAD's scientific and technical information services, which took place in the last quarter of 1992, should guide us in defining our objectives and in organizing our services.



Computer Services

In 1992 we drew up a 5-year programme (1993–1997) based on users' needs and available technology. It concentrates on a limited number of basic concepts and it is already being implemented.

We set a high priority on equipment; each scientist should be provided with a sufficiently powerful computer for a graphic interface such as WINDOWS. Hardware selected for expatriate staff should be adapted to local working conditions. For the medium range we selected computers that run on UNIX, which is a recognized standard for most applications.

All scientists should have access to up-to-date techniques (large databases, statistical graphics, image analysis, modelling, expert systems, geographic information systems) to process, use, and store data and documents. We work with the different research programmes to design specific PC-compatible software, for example, the expert system for diagnosing sugarcane diseases and the program for graphic and statistical analysis of data. The second program, which was intended for expatriate staff, formed part of an interorganization thematic project in collaboration with the Institut technique des céréales et des fourrages (ITCF) and the Institut national agronomique, Paris-Grignon (INA-PG).

The computer network links all workstations at CIRAD and allows them access to different discipline-specific UNIX computers. A large part of the network (1000 terminals) has already been installed at the Montpellier Research Centre.

Our expatriate scientists should also benefit from networking. We teamed up with ORSTOM to use the intertropical computer network RIO, which allows us to communicate with the international scientific community.

We also set up harmonized and computerized procedures for internal management. The data system respects autonomy of the departments and the administration's need for general information. Our accounting system is capable of monitoring research operations on the fly and retrieving the information needed for establishing financial statements.

Theses Completed in 1992

CIRAD Scientists

Surplus agricoles et stratégies de production [Agricultural surplus and production strategies] by Marc Roesch; Université Montpellier I.

CIRAD Trainees

Etude de la transplantation de boutures de *Posidonia oceanica* (L.) Delile, phanérogames marines ; modélisation de l'architecture et du mode de croissance [Study on transplantation of cuttings of *Posidonia oceania* (L.) Delile, marine phanerogams: Modelling of plant architecture and growth pattern] by Heika Molenaar (France); Université de Nice-Sophia Antipolis.

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Congo	**Olivier Hamel,** Correspondent
Costa Rica	**Jean Laboucheix,** Representative for Latin America and the Caribbean
Côte d'Ivoire	**Jacques Teissier,** Representative
Gabon	**Patrice de Vernou,** Correspondent
Guatemala	**Jean Laboucheix,** Representative (based in Costa Rica)
Guinea	**Edmond Viricelle,** Correspondent
Honduras	**Jean Laboucheix,** Representative (based in Costa Rica)
Indonesia	**Pierre Rondot,** Representative
Madagascar	**Jean-Louis Reboul,** Representative
Malaysia	**Patrick Durand,** Correspondent (based in Singapore)
Mali	**Jean Charoy,** Representative
Mauritius	**Michel Hoarau,** Representative (based in Réunion)
Morocco	**François Bertin,** Correspondent
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Panama	**Jean Laboucheix,** Representative (based in Costa Rica)
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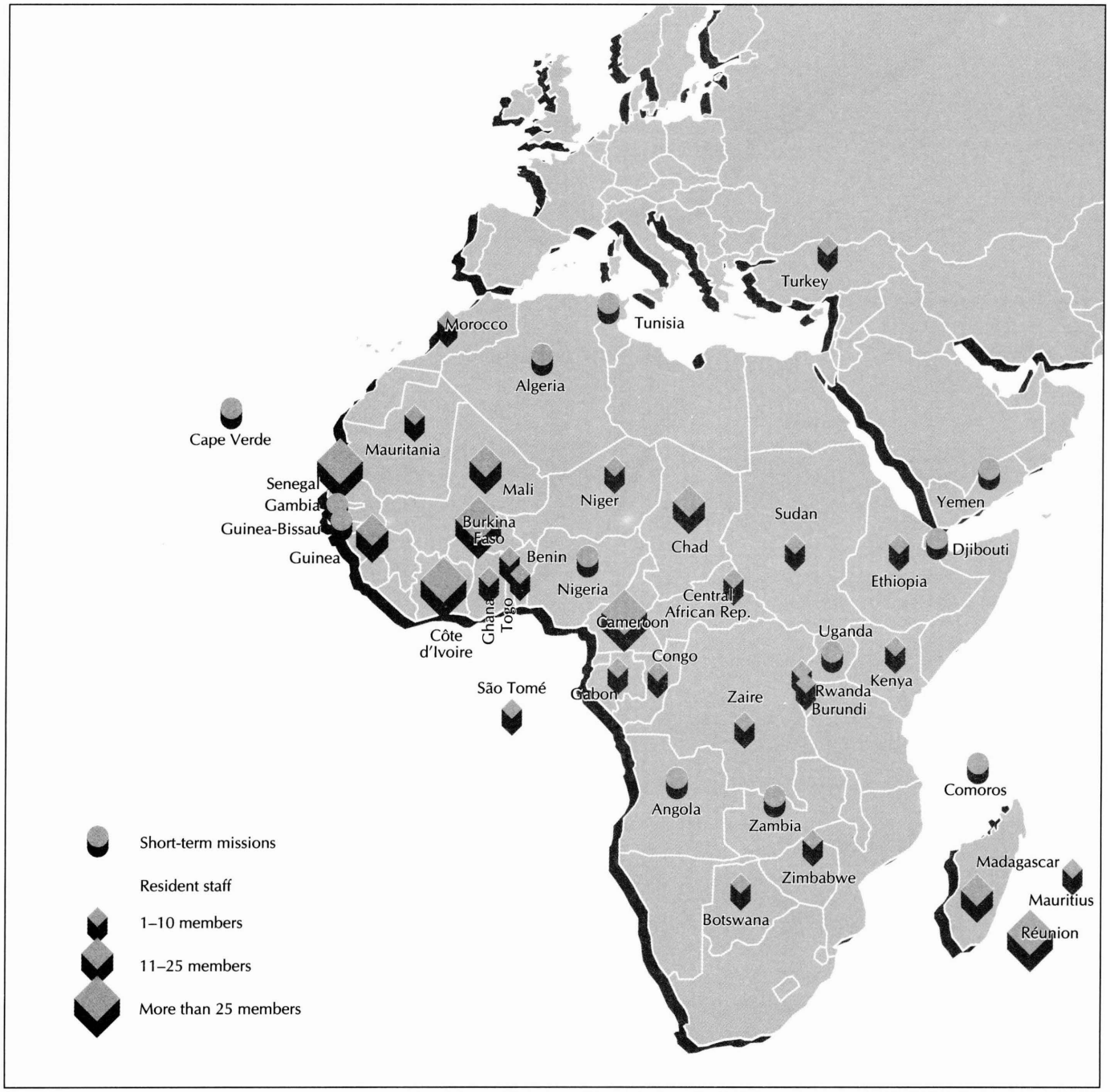
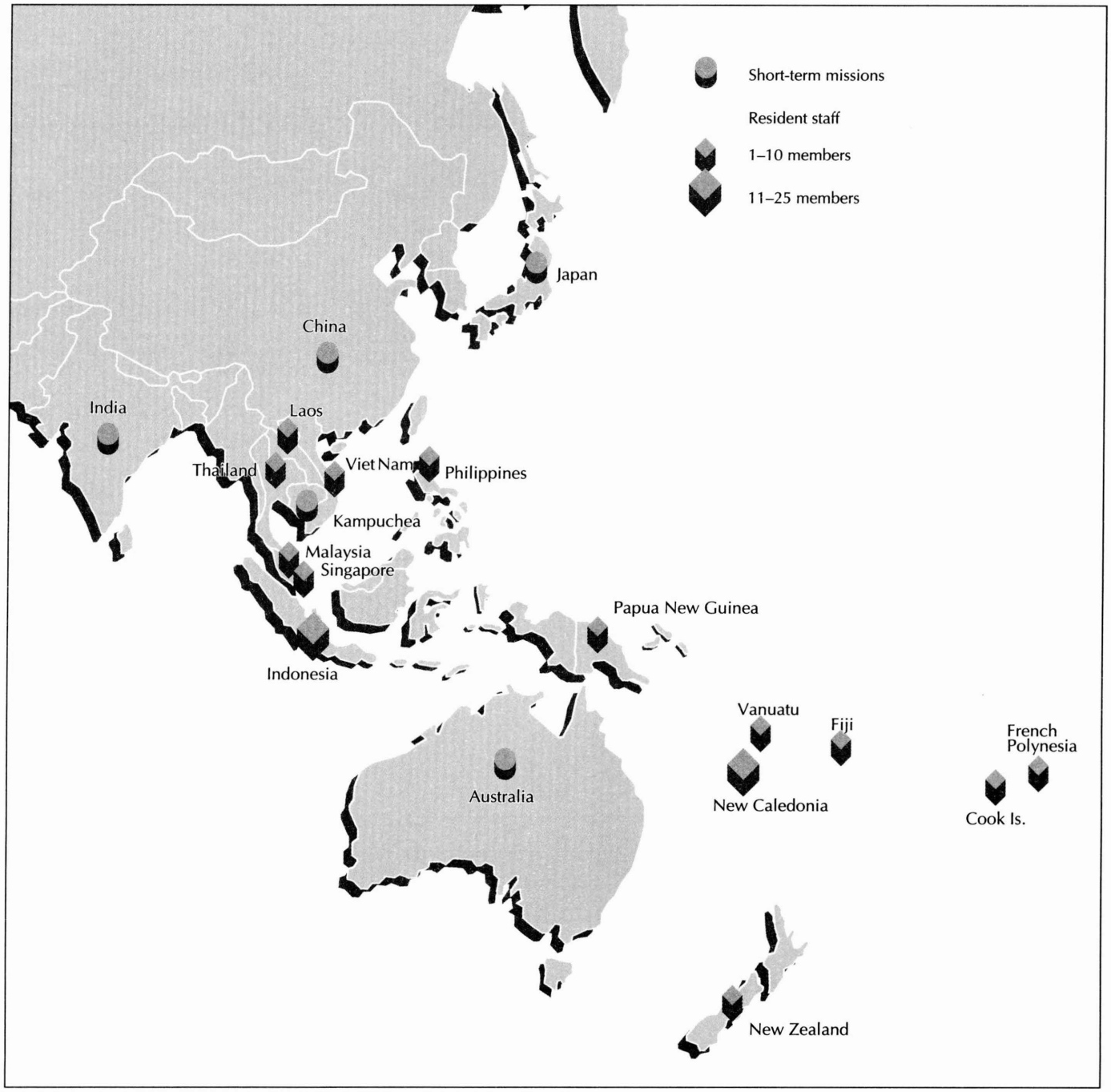
Thailand	**Jean-Claude Vincent,** Representative
United States	**Jill Barr,** Correspondent
Vanuatu	**Guy Mossu,** Representative

CIRAD in Africa and the Indian Ocean Region



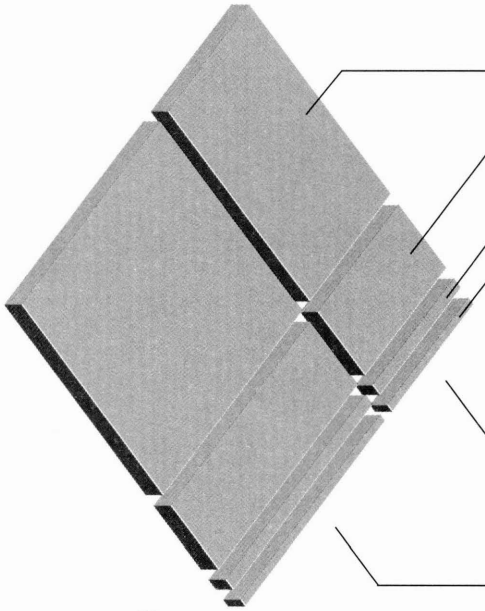
CIRAD in Latin America and the Caribbean

CIRAD in Asia and the South Pacific



1992 Budget: FFr945.3 Million

Income and Expenditure



Expenditure
(FFr million)

Personnel exp.	642.4
Operating exp.	250.5
Other exp.	30.5
Investments	21.9
	945.3

Income

Self-generated income	37%
BCRD subsidy	63%

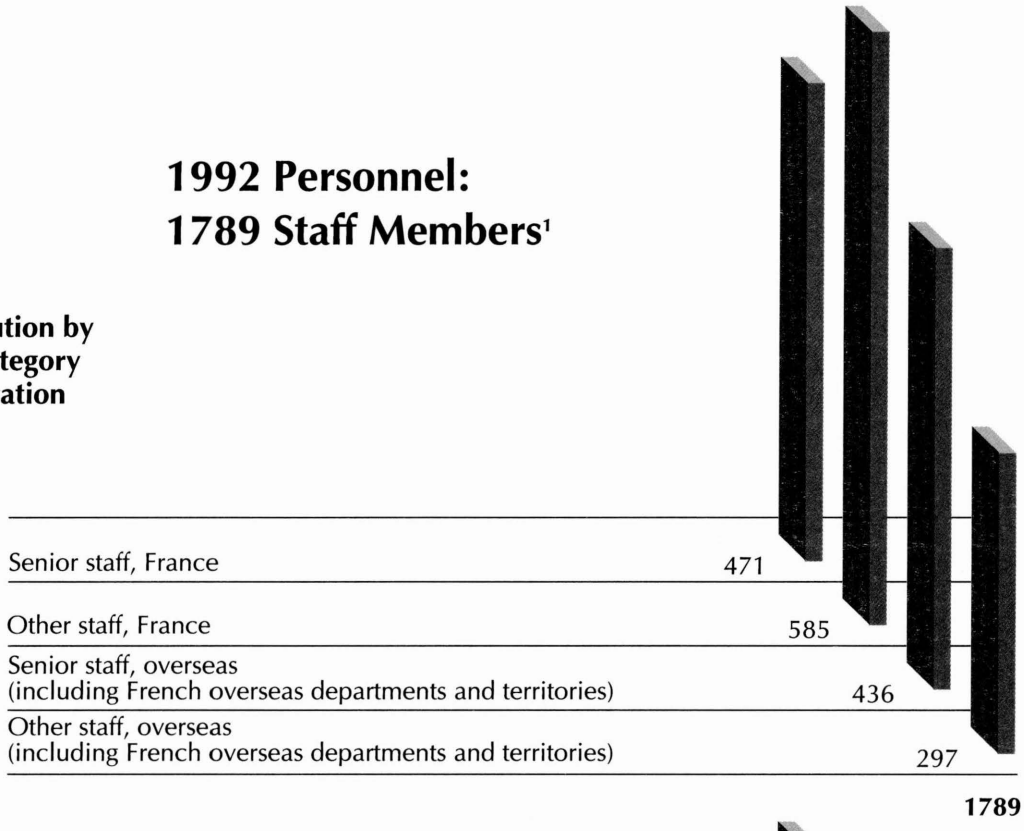
Distribution and Source of Funds by Department

	BCRD subsidy (%)	Self-generated income (%)	FFr million
CIRAD-CA	70	30	212.7
CIRAD-CP	59	41	178.4
CIRAD-IRFA[1]	57	43	91.0
CIRAD-EMVT	65	35	85.4
CIRAD-Forêt	68	32	83.2
CIRAD-SAR	53	47	67.5
CIRAD-GERDAT	64	36	227.1
			945.3

1. CIRAD-FLHOR since 1 March 1993.

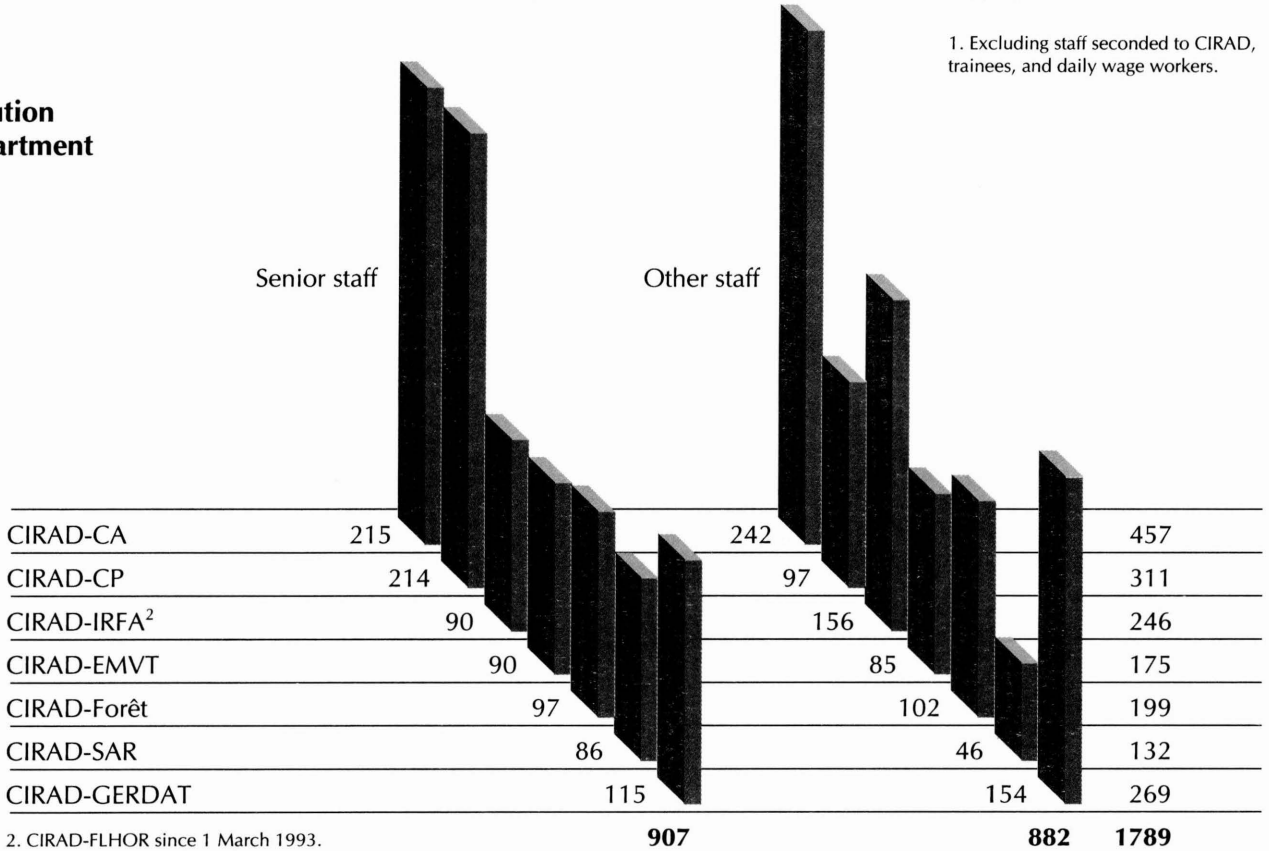
1992 Personnel: 1789 Staff Members[1]

Distribution by Staff Category and Location



1. Excluding staff seconded to CIRAD, trainees, and daily wage workers.

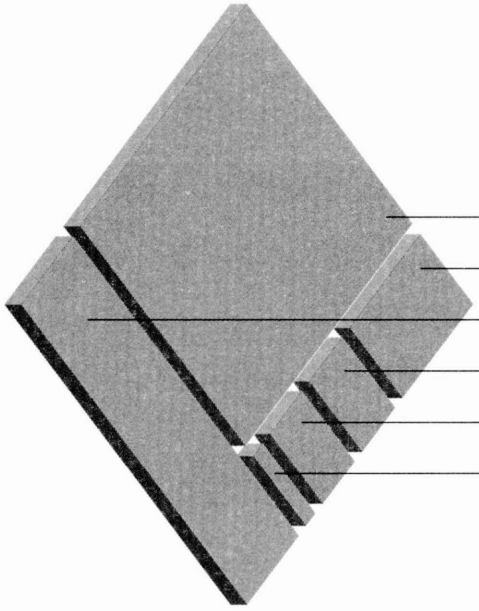
Distribution by Department



2. CIRAD-FLHOR since 1 March 1993.

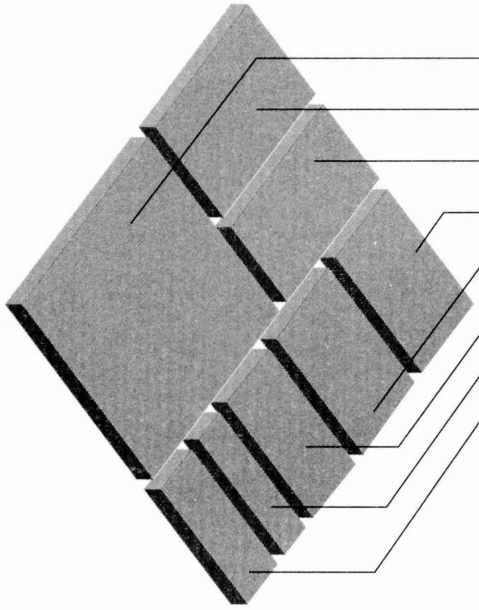
Senior Staff: 907 Members

Geographic Distribution



471	France
88	French overseas dept. and terr.
259	Africa, Indian Ocean region
40	Latin America
43	Asia, South Pacific
6	Others
907	

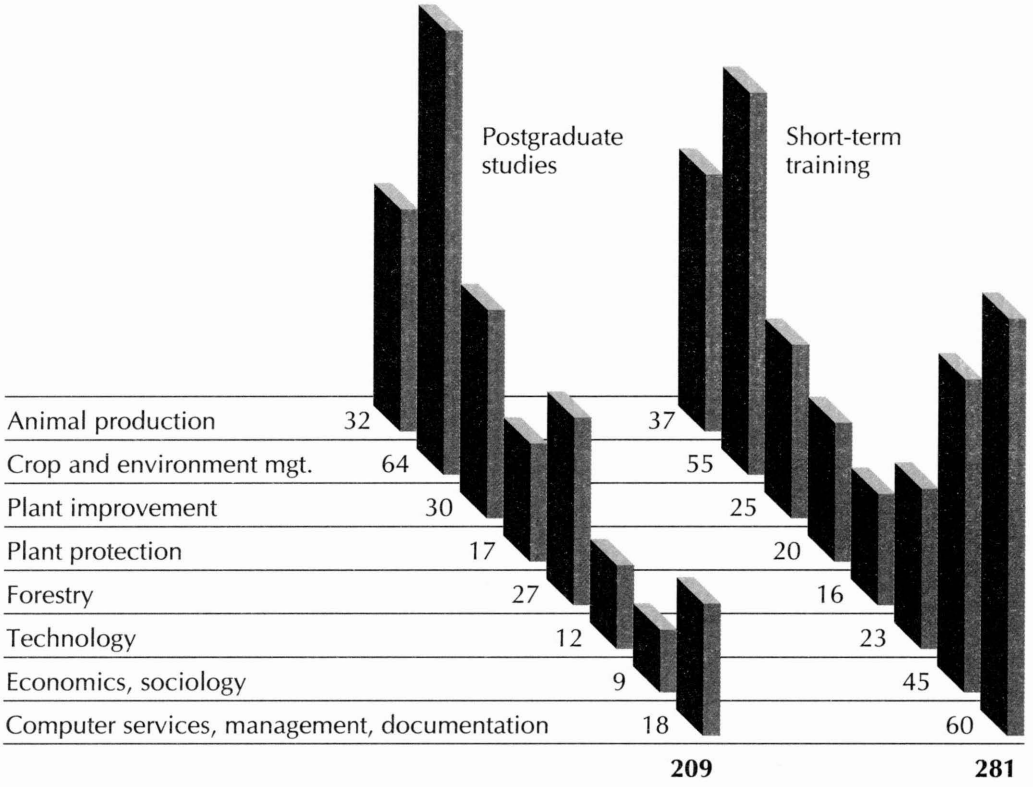
Distribution by Discipline



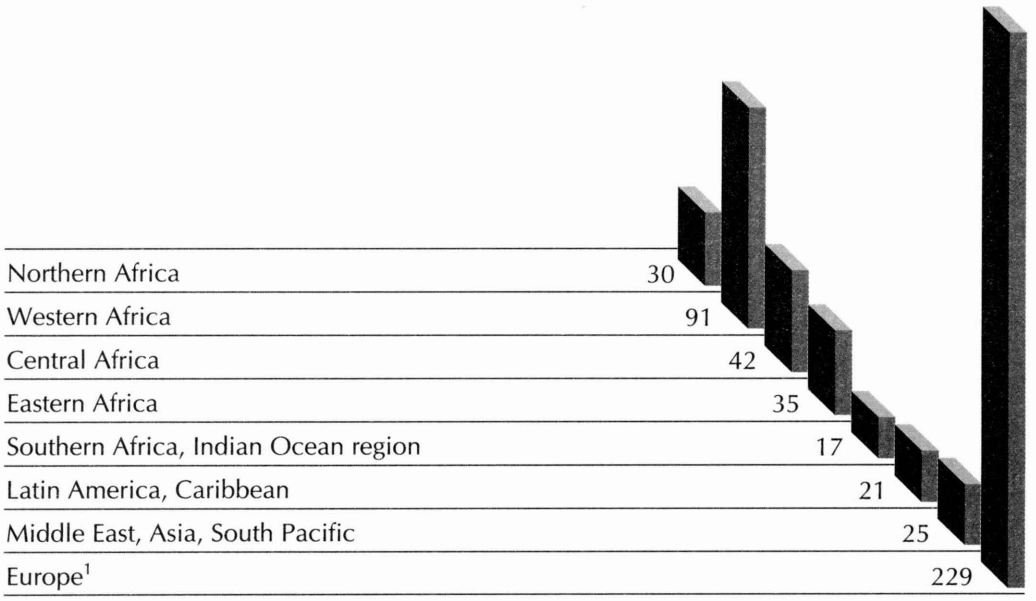
35.9%	Crop and environment management
14.0%	Plant improvement
10.8%	Plant protection
9.0%	Animal production
10.1%	Technology
8.8%	Rural systems, economics, sociology
5.2%	Biometrics, remote sensing
6.2%	Scientific and technical information

Training

Distribution by Discipline and Type of Training



Distribution by Geographic Origin



1. Including 215 from France.

Annexes

Interorganization
thematic research projects

List of acronyms

CIRAD addresses

Interorganization Thematic Research Projects Financed in 1992

Work area	Theme	Partners
Crop Management, Environment		
Water-soil-plant	*Growth of and water uptake by roots in degraded soils*	Universität Hohenheim (Germany); INRA (France) CIRAD-GERDAT, CIRAD-CA, CIRAD-CP
Environment studies and remote sensing	*Survey of plant covers and analysis of surface states*	SOCFINDO (Indonesia) CIRAD-Forêt, CIRAD-CP
	Integration of data from maps and a numeric ground truth model with SPOT satellite data (Madagascar)	FOFIFA (Madagascar); ORSTOM (France) CIRAD-SAR, CIRAD-GERDAT, CIRAD-CA
Soil fertility	*Potassium fertilization and potassium supply modelling*	DRA, IFDC (Togo); IDESSA (Côte d'Ivoire); INERA (Burkina Faso); IMG, INRA (France) CIRAD-GERDAT, CIRAD-CA
	Effect of integrated land development on water and mineral balances in a watershed	CEMAGREF, ENSAM, IMG, ORSTOM (France) CIRAD-CA
Intercropping	*Coffee - pulse intercropping systems*	ISABU (Burundi) CIRAD-CA, CIRAD-CP
	Radiation transfer in coconut - cocoa intercrops. Simulation of optimum spatial arrangements by crop architecture modelling. Influence of the arrangements on the microclimate	IDESSA (Côte d'Ivoire); INRA (France) CIRAD-CP, CIRAD-GERDAT
Ecophysiology	*Growth and development models for annual crops. Evaluation of existing solutions and applications*	INRA (France) CIRAD-CA, CIRAD-CP, CIRAD-FLHOR, CIRAD-GERDAT
Plant Improvement		
Plant breeding	*Strategies for tree crop improvement*	INRA (France); CIRAD-Forêt, CIRAD-CP
Biotechnology	*Study of the genetic diversity of tropical plants and their parasites by RFLP*	INRA, CNRS, Limagrain (France) CIRAD-GERDAT, CIRAD-CP, CIRAD-FLHOR
	Use of RFLP for analyzing plant fungi and trypanosomes	Institut G. Roussy, Université Paris XI (France) CIRAD-CA, CIRAD-CP, CIRAD-FLHOR

Work area	Theme	Partners
	*Somatic embryogenesis and cell culture in liquid medium (*Hevea*, oil palm, rice)*	ORSTOM (France) CIRAD-GERDAT, CIRAD-CA, CIRAD-CP, CIRAD-FLHOR
	Genetic transformation of cotton and coffee for developing pest-resistant plants	PSG (Belgium); INRA (France) CIRAD-GERDAT
	Application of PCR techniques for genetic studies of tropical crops. Objectives and advantages	CIMMYT (Mexico); INRA, CNRS (France) CIRAD-GERDAT, CIRAD-CA, CIRAD-CP, CIRAD-FLHOR
Plant Protection		
Pathology	*Study of the groundnut clump virus in western Africa*	CNRS, ORSTOM (France) CIRAD-CA, CIRAD-CP
	Analysis of plant resistance components and application to plant breeding	INERA (Burkina Faso); CRBP (Cameroon) CIRAD-CA, CIRAD-FLHOR, CIRAD-CP
Entomology	*Early warning system using pheromones*	INRA (France) CIRAD-CP
	Development of tests for early detection of nematode-resistant plants	INRA, ENSA Rennes, ORSTOM (France) CIRAD-CP, CIRAD-FLHOR
Animal Production and Health		
Aquaculture	*Feed value of agricultural by-products for tropical fish farming*	INRA, ORSTOM, IFREMER (France) CIRAD-Forêt, CIRAD-EMVT
	Correlation analysis of the appearance of growth dimorphism in male Oreochromis niloticus *(Cichlidae) and gonadic differentiation of sex and puberty. Role of steroid and growth hormones (GH)*	INRA, ORSTOM (France) CIRAD-EMVT
Animal health	*Genetic study of cowdriosis resistance in Creole goats in Guadeloupe*	Universität Bern (Switzerland); INRA (France) CIRAD-EMVT
	Strengthening CIRDES' capacity for diagnosing blood parasites, using biotechnology	ILRAD (Kenya); GTZ (Germany); CIRDES (Burkina Faso); Université Bordeaux II (France) CIRAD-EMVT

Work area	Theme	Partners
Technology		
Commodity chains	*Innovative technology for food production (short-cycle chains)*	ENSIAAC (Cameroon); ENEA, ISRA, CIEPAC (Senegal); ENSIA, ORSTOM (France) CIRAD-SAR, CIRAD-CA
	Conditions for the emergence and operation of rural food enterprises	Oxford University (United Kingdom); Universidad de Córdoba (Spain); IICA (Costa Rica); DIMAC (Mexico); CEC (Belgium); Université Lyon II, Université Montpellier I, ENSIA (France) CIRAD-SAR, CIRAD-CA, CIRAD-CP
Processes	*Adding value to food products of animal origin through stabilization*	ENSAIA, GRET, IFREMER, INRA, Université de Clermont-Ferrand, Université Montpellier II (France) CIRAD-SAR, CIRAD-Forêt, CIRAD-EMVT
Rural Systems, Socioeconomics		
	Economics of production on the Madagascar highlands	FOFIFA, Ecole normale (Madagascar); INRA, Université Paris I (France) CIRAD-Forêt
	Response of farmers' organizations to state disengagement	ISRA, SAED, IRAM, CIEPAC (Senegal) CIRAD-SAR, CIRAD-EMVT, CIRAD-CA
	Towards the year 2010 in Réunion: Possible scenarios for planning agricultural research	INRA, Ministry of Agriculture, CAH, SUAD, Université de la Réunion (France) CIRAD-CA, CIRAD-SAR, CIRAD-Forêt, CIRAD-EMVT, CIRAD-FLHOR
Biometrics		
	Development of a statistical software package combining CSTAT and LISA	ITCF, ORSTOM (France) CIRAD-GERDAT, CIRAD-CA, CIRAD-CP, CIRAD-FLHOR, CIRAD-EMVT, CIRAD-Forêt, CIRAD-SAR

List of Acronyms

ACSAD, Arab Center for the Study of Arid Zones and Dry Lands

ADAN, Association des aquaculteurs du Niger, Niger

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

AEC, Asiatique européenne de commerce, France

AFDI, Agriculteurs français et développement international, France

AFRD, Agency for Forestry Research and Development, Indonesia

AGRHYMET, Centre régional de formation et d'application en agrométéorologie et hydrologie opérationnelle

AITVM, Association of Institutions for Tropical Veterinary Medicine

AMIFEL, Association méditerranéenne des régions productrices de fruits et légumes

ANDE, Agence nationale de développement de l'élevage, Central African Republic

ANVAR, Agence nationale de valorisation de la recherche, France

BCRD, Budget civil de la recherche et développement, France

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

BRGM, Bureau de recherches géologiques et minières, France

BSN, Boussois-Souchon-Neuvesel, France

CACS, Coopérative agricole des champignonnistes du Saumurois, France

CADEF, Comité d'action pour le développement du Fogny, Senegal

CAH, Commissariat à l'aménagement des Hauts, France

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

CEC, Commission of the European Communities

CECURI, Centre cunicole de recherche et d'information du Bénin, Benin

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

CENIPALMA, Centro de Investigación en Palma de Aceite, Colombia

CEPGL, Communauté économique des pays des Grands Lacs

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

CFCS, Centre français de la canne et du sucre, France

CFD, Caisse française de développement, France

CGIAR, Consultative Group on International Agricultural Research

CGPRT, Regional Co-ordination Centre for Coarse Grains, Pulses, Roots and Tuber Crops in the Humid Tropics of Asia and the Pacific

CIAT, Centro Internacional de Agricultura Tropical

CIDT, Compagnie ivoirienne pour le développement des textiles, Côte d'Ivoire

CIEPAC, Centre international pour l'éducation permanente et l'aménagement concerté

CIFOR, Centre for International Forestry Research

CIHEAM, Centre international des hautes études agronomiques méditerranéennes

CIMMYT, Centro Internacional de Mejoramiento de Maíz y Trigo

CIP, Centro Internacional de la Papa

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

CMDT, Compagnie malienne pour le développement des textiles, Mali

CNES, Centre national d'études spatiales, France

CNRS, Centre national de la recherche scientifique, France

CNRST, Centre national de la recherche scientifique et technique, Burkina Faso

CNUSC, Centre national universitaire sud de calcul, France

COLEACP, Comité de liaison Europe-Afrique-Caraïbes-Pacifique, France

COM, Common Organization of the Market (EC)

CORAF, Conférence des responsables de la recherche agronomique africains

CORDET, Commission de coordination de la recherche dans les départements et territoires d'outre-mer, France

CRBP, Centre régional bananiers et plantains

CREPAG, Coordination régionale et politiques agroalimentaires

CRETF, Centre régional d'enseignement technique féminin

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

CTIFL, Centre technique interprofessionnel des fruits et des légumes, France

DIMAC, Diversification et intensification dans la marge de l'aire caféière, Mexico

DRA, Direction de la recherche agronomique, Togo

EC, European Community

ECART, European Consortium for Agricultural Research in the Tropics

EDF, European Development Fund

EMBRAPA, Empresa Brasileira de Pesquisa Agropecuária, Brazil

ENEA, Ecole nationale d'économie appliquée, Senegal

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

ENSA, Ecole nationale supérieure agronomique, France

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

ENSAM, Ecole nationale supérieure agronomique de Montpellier, France

ENSC, Ecole nationale supérieure de chimie, France

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

ENSIAAC, Ecole nationale supérieure des industries agricoles et alimentaires du Cameroun, Cameroon

ENVA, Ecole nationale vétérinaire d'Alfort, France

ESEM, Ecole supérieure de l'énergie et des matériaux, France

FAC, Fonds d'aide et de coopération, France

FAO, Food and Agriculture Organization of the United Nations

FIC, Fonds interministériel pour la Caraïbe, France

FOFIFA, Centre national de la recherche appliquée au développement rural, Madagascar

GEVES, Groupement d'étude et de contrôle des variétés et des semences, France

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

GTZ, Deutsche Gesellschaft für technische Zusammenarbeit, Germany

IAEA, International Atomic Energy Agency

IARC, international agricultural research centre

IBPGR, International Board for Plant Genetic Resources

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

ICSB, Innoprise Corporation Sdn. Bhd., Malaysia

IDEFOR, Institut des forêts, Côte d'Ivoire

IDESSA, Institut des savanes, Côte d'Ivoire

IDF, Institut de développement forestier, France

IER, Institut d'économie rurale, Mali

IFDC, International Fertilizer Development Center

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

IGN, Institut géographique national, France

IICA, Instituto Interamericano de Cooperación para la Agricultura

IICT, Instituto de Investigação Científica Tropical, Portugal

IITA, International Institute of Tropical Agriculture

ILCA, International Livestock Center for Africa

ILRAD, International Laboratory for Research on Animal Diseases

IMBB, Institute of Molecular Biology and Biotechnology (Insect Group), Greece

IMG, Institut de mécanique de Grenoble, France

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

INCAP, Instituto de Nutrición de Centro América y Panamá

INERA, Institut d'études et de recherches agricoles, Burkina Faso

INIAA, Instituto Nacional de Investigación agraria y agroindustrial, Peru

INIBAP, International Network for the Improvement of Banana and Plantain

INRA, Institut national de la recherche agronomique, France

INTA, Instituto Nacional de Tecnología Agropecuária, Argentina

IOE, International Office of Epizootics

IRA, Institut de la recherche agronomique, Cameroon

IRAG, Institut agronomique de Guinée, Guinea

IRAM, Institut de recherches et d'applications des méthodes de développement, France

IRAP, Institut de recherches appliquées sur les polymères, France

IRBET, Institut de recherches en biologie et écologie tropicale, Burkina Faso

IRRDB, International Rubber Research and Development Board

IRRI, International Rice Research Institute

IRAZ, Institut de recherche agronomique et zootechnique, Burundi

IRZV, Institut de recherche zootechnique et vétérinaire, Cameroon

ISABU, Institut des sciences agronomiques du Burundi, Burundi

ISHS, International Society for Horticultural Science

ISOPB, International Society of Oil Palm Breeders

ISRA, Institut sénégalais de recherches agricoles, Senegal

ITB, Institut du tabac de Bergerac, France

ITCF, Institut technique des céréales et des fourrages, France

IVIA, Instituto Valenciano de Investigaciones Agrarias, Spain

KIT, Koninklijk Instituut voor de Tropen, The Netherlands

NOAA, National Oceanographic and Atmospheric Administration, United States

NRI, Natural Resources Institute, United Kingdom

OCLALAV, Organisation commune de lutte antiacridienne et de lutte antiaviaire

ODR, Office de développement rizicole, Madagascar

OFI, Oxford Forestry Institute, United Kingdom

OIAC, Organisation interafricaine du café

ONADEF, Office national du développement des forêts, Cameroon

ONF, Office national des forêts, France

ORRAF, Office of the Rubber Replanting Aid Fund, Thailand

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

PGS, Plant Genetic Systems, Belgium

PIRFAG, Programme interrégional de recherche forestière Amazonie-Guyane

PORIM, Palm Oil Research Institute of Malaysia, Malaysia

PROMECAFE, Programa Cooperativo Regional para la Protección y Modernización de la Caficultura (IICA)

RRIT, Rubber Research Institute of Thailand, Thailand

SAED, Société d'aménagement et d'étude du delta et des vallées du fleuve Sénégal et de la Falémé, Senegal

SAPH, Société africaine de plantations d'hévéas, Côte d'Ivoire

SEAMEO, Southeast Asian Ministers of Education Organization

SEITA, Société d'exploitation industrielle des tabacs et allumettes, France

SIAL, Salon international de l'alimentation, France

Socapalm, Société camerounaise de palmeraies, Cameroon

Socfindo, Société financière indonésienne, Indonesia

SOFITEX, Société burkinabé des fibres textiles, Burkina Faso

SPAAR, Special Program for African Agricultural Research (World Bank)

SUAD, Service d'utilité agricole de développement, France

UAIC, Unité d'afforestation industrielle du Congo, Congo

UNIDO, United Nations Industrial Development Organization

USDA, United States Department of Agriculture, United States

WARDA, West African Rice Development Association

WINBAN, Windward Islands Banana Growers' Association, Trinidad and Tobago

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