CIRAD 1991

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 that 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 development of these regions through research, experimentation, training, and dissemination of scientific and technical information.

The Centre employs about 1850 persons, including 920 senior staff, who work in some 50 countries. Its budget amounts to approximately FFr1 billion, half of which is derived from public funds.

CIRAD is made up of 10 departments: IRAT (food crops); IRFA (fruit); IRHO (perennial oil crops); IRCC (coffee, cocoa); IRCT (cotton); IRCA (rubber); CTFT (wood and forestry); IEMVT (livestock production, veterinary medicine); CIRAD-SAR (rural systems, food technology), which was created by merging CEEMAT (farm mechanization, technology) and DSA (rural systems); and GERDAT (management, common services and laboratories, documentation). The staff work at CIRAD's own research centres or within national agricultural research organizations, or they work on-site in development projects.

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CIRAD
1991

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The Strength of Commitment

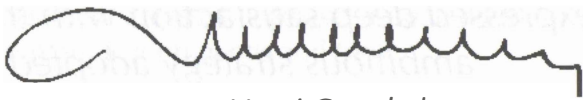
1991 was not only a year of intense research activity, but also a year of rethinking and strategic decisions. The strategy plan, which is the result of across-the-board participation, was adopted by the Board and staff. The document was disseminated throughout the international community to create awareness of CIRAD's new image.

The problems of increasing food requirements and environmental degradation persist. The issues before agricultural research organizations have never been so crucial. They are compelled to provide a coherent response at a time when the international community, confronted with recent disquieting developments in the world, turns its attention away from the South.

But we have to address these issues, despite the current difficulties. In 1991, they attained serious proportions at CIRAD, with cutbacks in funds and personnel and discontinuation of long-standing cooperation contracts. These difficulties have in no way affected CIRAD's commitment, which is now firmly based on its collectively adopted strategy.

I gratefully acknowledge the tireless efforts of the staff in the formulation of the strategy. Their work is proof of the commitment which links all CIRAD staff, even if they are scattered throughout world.

The international scope of CIRAD's work is now firmly anchored in its new approach to cooperation. In 1991, significant progress was made jointly with colleagues in France, and partners in the North and South. The Centre also works closely with professionals and private-sector enterprises who convert its research results into end products. Together with our partners we shall open new horizons and break new ground.



Henri Carsalade
Director General

Rethinking Cooperation in a Changing World

1991 will be a landmark in the history of CIRAD. On 12-13 September in Montpellier, the strategy plan prepared after 2 years of study and discussion was presented to the Minister for Research and Technology and representatives of the Ministers for Cooperation and Development, and for Agriculture and Forestry. At the meeting, Minister Hubert Curien stressed the importance of CIRAD in international agricultural research for the tropics and subtropics and expressed deep satisfaction with the realistic and ambitious strategy adopted by the Centre.

CIRAD's Strategy Plan: Across-the-Board Participation

Two principles guided the preparatory work for the strategy plan. The brief before the working group was to define a forward-looking strategy that reflects the aspirations and experience of the Centre's staff.

Looking Ahead

In the first phase, the working group analyzed the transformation of the agricultural sector worldwide and its impact on agricultural research, as well as changes in international aid. The analysis was carried out in collaboration with the centre for long-term forecasting and evaluation of the Ministry of Research and Technology. The group also examined CIRAD's structure and capacity, based on the reports of the external reviews of the departments.

The report of the working group was discussed with staff and partners. A total of 400 staff members participated in the second phase either individually or in groups. Their comments were summed up by a second working group and submitted to the statutory bodies of CIRAD. The final document is therefore the result of across-the-board participation. It was adopted by the Board of Trustees on 18 June.

The strategy plan expresses the need to adjust the Centre's activities to a rapidly changing world. It provides the guidelines for determining strategic and scientific priorities, cooperative activities, and internal adjustments.

At the September 1991 workshop, the final strategy document was presented to the ministries that sponsor CIRAD and 300 staff representatives. Six staff groups discussed the implications of the recommendations. They studied the main programmes for the different geoeconomic zones, research strategy, conditions for overseas research, career development and staff appraisal, research products and industrial applications, and communication needs and tools.

The recommendations of the six staff groups are the driving force behind changes on three fronts: modernization of research, renewal of cooperation, and reorganization of the internal structure.

Modernization of Research

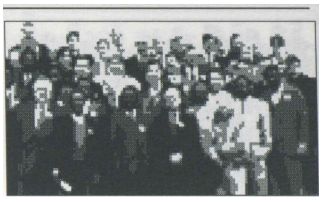
CIRAD's research strategy is oriented towards economic and social development. The Centre's commitment to its goal remains unchanged. The new strategy is based on the needs identified by CIRAD and those expressed by users. It corresponds to the research capacity of the Centre and that of its partners.

CIRAD's mandate is to conduct applications-oriented research. It is also adequately equipped for fundamental research, which it undertakes depending on the need and its capacity. This work is supplemented by applied research, technology development, and participation in economic and social development operations.

To fulfill these tasks, CIRAD has adopted a double-axis matrix structure for its internal organization. The objective is to combine scientific and operational (end use) aspects in a given research project. The new structure is being gradually established under the guidance of the Scientific Advisory Committee.

The operational project axis is formed by research projects for development. Their objectives are derived from a strategic analysis undertaken by each department for its long-term plan. Objectives, output, time frame, and resources are determined for each project. Implementation is based on an operational analysis and involves collaboration with partners from the South. The scientific support axis is formed by research units grouped according to major disciplines.

CIRAD's *missions* coordinate the work of the departmental research units for different work areas. In addition, they advise the administration and are responsible for establishing links with national and international organizations. These links are consolidated into networks of partners. The scientific committees of the *missions* are a forum for exchange of ideas and information; external members are selected from research organizations such as the Institut national de la recherche agronomique (INRA) and Institut français de recherche scientifique pour le développement en coopération (ORSTOM), French universities, and private-sector enterprises. The coordinators are thus well informed about the current status of research, capacity of different research teams, and possibilities of cooperation. These links are leading to the establishment of an increasing number of joint projects with French and foreign partners, as evidenced by the 30 interorganization thematic research projects (ATP) funded in 1991.



The success of CIRAD's research depends on efficient human resource management. Its staff needs to keep pace with scientific developments and research requirements. Recruitment of scientists depends on research priorities and may vary according to discipline. Within each discipline a balance is maintained between field and laboratory specialists. In certain work areas such as technology and socioeconomics, staff strength will be increased depending on available funds. CIRAD will focus on career development, training, and staff appraisal as some of the means for matching human resources to the overall research strategy. The new staff appraisal system centres on three criteria: homogeneity, equity, and dynamism. CIRAD's new human resources policy will be launched in 1992 in keeping with its new strategy.

From 1993, continuing education for scientists, particularly doctoral studies, will be the focal point of this policy. Already, about 20 doctoral theses are completed each year. These studies are conducted in collaboration with training institutions and supported by the Ministry of Research and Technology.

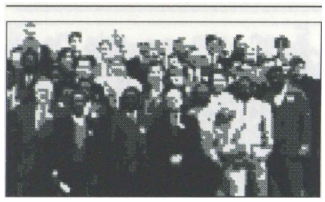
Renewal of Cooperation

CIRAD focuses on bilateral and regional cooperation for its outreach activities. Memoranda of understanding signed with host governments for bilateral cooperation are followed up by detailed agreements with partner organizations that serve as a framework for work contracts for expatriate scientists. The aim of regional cooperation is to widen the scope of exchange and overcome management difficulties often faced by national organizations.

Working conditions for expatriate staff were discussed during the preparation of the strategy plan and at the September 1991 workshop. Optimum working and living conditions are prerequisites. A favourable environment implies stability, which ensures continuity and efficient management of on-going work, and maintenance of adequately sized teams. These conditions determine the assignment of scientists overseas.

Renewal of cooperation at CIRAD implies concentration of its overseas research capacity, strengthening of its efforts in Latin America and Asia; and reorganization of its operations in Africa, particularly in Côte d'Ivoire. These are the trends that emerge following the adoption of the strategy plan in 1991.

Another thrust recommended by the new strategy is the establishment of links with development agencies and research organizations other than those in



the traditional cooperation sector. These include professional agricultural organizations and nongovernmental organizations.

Reorganization of the Internal Structure

The rethinking on CIRAD's identity, mission, research strategy, and activities in a changing world is reflected in recent changes in its organization structure. In December 1991, the Board of Trustees approved the reorganization recommendations based on the external reviews of the departments. The process of change, which was outlined in the strategy plan, was immediately put into effect.

The original 11 departments of CIRAD are too small to assume the task of simultaneously widening and intensifying their research operations and extending their geographic coverage. The creation of larger departments will promote the establishment of solid research units, foster a cohesive structure, and streamline administration work. It will also facilitate the adoption of common management procedures.

The changes will be introduced in phases without disrupting the Centre's work.

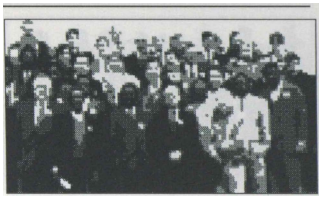
The first step is the creation on 1 January 1992 of Systèmes agroalimentaires et ruraux (CIRAD-SAR), the department for rural systems and food technology, which was formed by merging DSA and CEEMAT. Its work concerns farming systems and rural societies. CIRAD-SAR is also responsible for the common food technology laboratory for process engineering and food science.

The annual crops department will be established on 1 July 1992 by merging IRAT, IRCT, and the annual oil crops division of IRHO. Its mandate covers annual crops as components of both farming systems and commodity chains (*filières*).

The perennial crops department, which will be established in early 1993, will be made up of IRCA, IRCC, and IRHO's oil palm and coconut divisions.

The livestock production and veterinary department, IEMVT, and the forestry department, CTFT, were already reorganized after their external reviews in 1988 and 1989, respectively. The only change is the transfer of the aquaculture and fisheries division from CTFT to IEMVT.

The external review of IRFA, the fruit crop department, is scheduled for early 1992. A review will also be conducted for GERDAT, which is responsible



for management, common services and laboratories, and documentation. Reorganization of these departments will be undertaken after completion of the reviews.

Communication

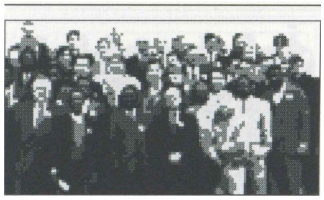
An organization like CIRAD, with its complex structure and large number of staff and partners, needs an overall policy for internal and external communication to effectively disseminate information on its research and organization. The guidelines were set in the strategy plan. A staff group elaborated them and submitted a communication strategy and a 3-year plan in November 1991

Internal communication aims to promote dynamism and quality. Corporate culture and identity take on an added significance at CIRAD because of the geographic spread of its research teams. A major effort needs to be made to overcome isolation of expatriate staff and to integrate nonmanagerial staff through better access to information. Modern telecommunications will play an important role in this effort.

The general public in France and other European countries, and decision-makers are the main target groups of CIRAD's external communication efforts. A greater awareness of CIRAD's work among the French public will help establish the Centre's reputation, and dissemination of its results will promote its image among its partners and clients. CIRAD's integration in the national and international scientific communities will depend on these efforts.

Strengthening International Cooperation

Despite the unstable international context, CIRAD's cooperative activities with a wide range of partners were intensified in 1991. Visits and information exchange between CIRAD and its partners increased. Internationalization of research and increased collaboration with European organizations have stimulated exchange of ideas.



An Unstable World

The world in which CIRAD operates was shaken by violence and civic strife. During the Gulf crisis all missions to Islamic countries in Africa, Middle East, and Asia were blocked for 3 months. Work in certain African countries (Ethiopia, Zaire, and Chad) was interrupted when scientists were evacuated because of uprisings. Social agitations created an atmosphere of insecurity in Mali, Togo, Cameroon, Congo, and Madagascar where work was disrupted.

All these circumstances had a disastrous impact on on-going research. Programmes fell behind schedule and scientists were demoralized; the inability of national organizations to function normally further paralyzed operations. Such conditions are not conducive to research. CIRAD needs to work in stable environments; new agreements are being negotiated with national partners.

New Agreements and Follow-Up

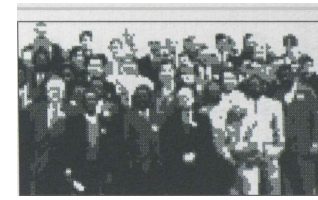
On 25 February 1991, the French Ministry of Cooperation and Development and the Chadian Ministry of Planning and Technical Cooperation signed an agreement for a veterinary and livestock production programme for the Sahel. This regional programme will be conducted by IEMVT.

Memoranda of understanding for scientific cooperation with national agricultural research systems (NARSs) were signed by CIRAD with: Centre national de recherche agronomique et de développement agricole (CNRADA), Mauritania; Institut national de recherches agronomiques du Niger (INRAN); and Fundación Hondureña de Investigación Agricola (FHIA), Honduras.

CIRAD also signed memoranda of understanding with regional and international organizations: Centre régional de formation et d'application en agrométéorologie et hydrologie opérationnelle (AGRHYMET), International Institute of Tropical Agriculture (IITA), and International Board for Plant Genetic Resources (IBPGR).

Cornell University, USA, and CIRAD signed a cooperation agreement in October 1991 for research on tropical soil management.

Annual meetings for programme evaluation and planning are held regularly with certain partners, as stipulated in the memoranda of understanding. Meetings were held with: Institut sénégalais de recherches agricoles (ISRA) in Dakar (February); the Malagasy Ministry of Scientific and Technological Research for Development (MRSTD) in Paris (September); the Cameroonian Ministry for Higher Education, Information Technology, and Scientific Research



in Garoua, Cameroon (October); Centro Agronómico Tropical de Investigación y Ensenañza (CATIE) in Turrialba, Costa Rica (November); and Empresa Brasileira de Pesquisa Agropecuária (EMBRAPA) in Brasilia (November). As a member of the Conférence des responsables de la recherche agronomique africains (CORAF), CIRAD participated in the plenary meeting from 24 to 29 June in Yaoundé.

Stability and Quality for Outreach Programmes

The strategy plan stressed the importance of stability and quality as prerequisites for CIRAD's outreach programmes in the tropics and subtropics.

The idea of regional cooperative research bases (*pôles de recherches en coopération*) was proposed to meet these two requirements. Each base is formed by a sufficiently large team of scientists. Responsibility is shared with other partners so that stability and efficient management ensure favourable working conditions. Each base focuses on a major research issue that affects the country or region where it is located; its work therefore has a regional scope. Compared with the CORAF *bases-centres*, the regional cooperative research bases involve a wider group of partners, including private-sector enterprises and professional agricultural organizations from one or several countries.

The bases will undertake research, training, and information dissemination operations; they will also support related projects and networks. Guidelines for organization, management, and evaluation are set down in a report by CIRAD's External Relations Directorate dated December 1991 and entitled *Les pôles de recherche en coopération : la responsabilité partagée d'implantations stables et de qualité*. The report serves as a base for negotiations to establish jointly managed centres.

End of the Research Management Contract in Côte d'Ivoire

Management of research on forestry, and fruit and tree crops in southern Côte d'Ivoire had been entrusted to CIRAD. But its work was beset by cutbacks in research funds and rising staff expenditure. CIRAD's supervising ministries and Board of Trustees therefore authorized contract termination. It was a difficult decision for both partners who have long-standing cooperative relations. CIRAD is, however, prepared to negotiate a new arrangement for scientific cooperation on a different basis.

Responsibility for research management was transferred to the Ivoirien Ministry of Higher Education and Scientific Research in December 1991. CIRAD will

withdraw its staff leaving a small team so that the work continues uninterrupted by the changes. The number of CIRAD staff working in southern Côte d'Ivoire was 67 in early 1991; of these 46 remained at the end of the year.

Visits and Information Exchange

CIRAD's scientists work in 54 countries, including 26 in Africa, 11 in Asia, and 11 in Latin America. A comparison of these figures with those of previous years shows a trend towards expansion outside Africa.

There was a significant increase (+25) in the number of staff assigned to Cameroon, Madagascar, Thailand, Togo, and Vanuatu. Staff were reduced in Brazil, Chad, and Congo in addition to the 21 scientists withdrawn from Côte d'Ivoire.

The number of high-ranking visitors to CIRAD, particularly the Montpellier Research Centre, has increased as CIRAD's reputation spreads throughout the international community.

More than 100 ministers, university rectors, directors of research organizations and development agencies from 35 partner countries, and directors of 7 international agricultural research centres (IARCs) visited CIRAD in 1991. Visits by high-ranking officials from Angola, Cambodia, China, Iran, Mozambique, Uzbekistan, and Viet Nam open possibilities for cooperation with new partners.

CIRAD's work in food technology is gaining recognition. Several entrepreneurs from Mexico, Thailand, and the USA also visited CIRAD.

National Partners and Expatriate Staff

The CIRAD administration is committed to close interaction with partner organizations and its expatriate scientists for acquiring a better understanding of the situation and a clear perception of problems. Several members of the administration travelled to partner countries in 1991: the Chairman of the Board to Burkina Faso in February, the Director General to Congo and Côte d'Ivoire in April and to Mali in December, and the Director of Research to Senegal in November.

Members of the CIRAD management also accompanied the French Minister for Research and Technology to New Caledonia and the Director General for Research and Technology from the Ministry to French Guiana.

Expansion of Programmes in the French Overseas Territories

CIRAD's centres in the French overseas departments and territories (DOM-TOM) have 400 staff members, a budget of FFr150 million, and 27 research stations. These centres have stability and quality, the prerequisites stressed in the strategy plan. The research programmes are established in collaboration with partner organizations and respond to local development needs. But they are not confined to the DOM-TOM and often extend beyond these areas.

The CIRAD regional centre in Réunion participated in two workshops organized in 1991: one in Comoros on soil protection and restoration and the other in Madagascar on endemic vegetation. It also participates in the environmental programme of the Indian Ocean Commission. The Commission met in Comoros and Mauritius to develop an ambitious programme in collaboration with experts from the Commission of the European Communities (CEC). The programme focuses on rational soil management, preservation of natural vegetation, control of adventitious species, coastal environment management, prevention of accidents caused by toxic wastes, and legal aspects related to these issues.

The Réunion centre provides technical support to agricultural development projects in Comoros. The modalities of a scientific monitoring programme suited to local conditions were defined. The programme concerns soil conservation, rangeland and forage crops, food crops, agroforestry, and sylviculture.

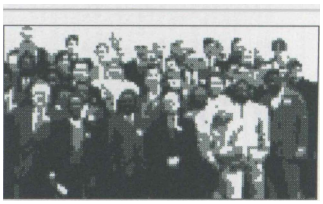
The Director of the Réunion centre visited the Republic of South Africa to establish links and study the possibilities of scientific cooperation with the Agricultural Research Council (ARC). The Council—like CIRAD—was formed recently by grouping national agricultural research organizations.

In Réunion, the Centre français de la canne et du sucre (CFCS) was founded following an initiative taken jointly by the local sugar industry (including CERF), the Chamber of Agriculture, and CIRAD. The new Centre thus benefits from the combined resources and scientific, technical, and training programmes of the three partners. Its mandate extends beyond the island as it covers all areas where sugarcane production and sugar technology are being developed, mainly in Martinique and Guadeloupe.

In New Caledonia, a memorandum of understanding was signed with three provinces. It entrusts CIRAD with the management of local agricultural, livestock, and forestry research centres. Their research covers animal production (cattle, deer), forestry, food crops, fruit crops, and coffee.

CIRAD works with the South Pacific Commission through its centre in New Caledonia. A CIRAD scientist is responsible for the rural technology sector. Several studies, mainly on the cattle sector, and development aid missions were conducted by CIRAD for the Commission.

CIRAD also cooperates directly with other South Pacific countries. In Vanuatu, several CIRAD scientists work on coffee, and coconut-based cropping and livestock systems. Livestock research will be extended to other parts of the region, with technical support from New Caledonia. In the Cook Islands, CTFT is conducting a long-term programme for conservation and use of the islands' forests. CTFT also carried out a preliminary study for the reforestation project in an old mine area in Nauru. The Director of the CIRAD New Caledonia centre undertook a mission to Australia following a visit by an adviser from the Australian Ministry of Research to New Caledonia. The possibilities of strengthening cooperation for livestock and forestry research were discussed.



The number of preliminary and support missions and participation in conferences also increased to 800. Africa (32 countries) was the main destination; Cameroon and Côte d'Ivoire accounted for more than 100 visits. CIRAD scientists also travelled to 60 countries outside Africa.

Internationalization of Research

CIRAD's active participation in major operations has confirmed its international role. The Council of Ministers of the western African Communauté économique du bétail et de la viande (CEBV) approved the establishment of the Centre international de recherche-développement sur l'élevage en zone subhumide (CIRDES) at a special meeting held on 12 December. CIRDES will replace the Centre de recherches sur les trypanosomoses animales (CRTA) in Bobo Dioulasso, Burkina Faso. IEMVT played a decisive role in the creation of CIRDES and its Director was elected Chairman of the Board.

CIRAD took several initiatives for promoting international forestry research. CTFT actively participated in the Tenth World Forestry Congress, which was organized in Paris from 17 to 26 September. It presented more than 30 papers and organized media contacts. The department also participated in discussions on the creation of an international forestry research centre. At the request of CEC, it contributed to the establishment of an international programme on the Amazonian forest system, located in French Guiana. Research on productivity of commercial forest plantations was resumed in Congo through a programme jointly conducted by the Unité d'afforestation industrielle du Congo (UAIC), the Congolese government, and CIRAD.

CIRAD is strengthening its ties with international development agencies. During their discussions on development problems with directors of the Food and Agricultural Organization of the United Nations (FAO), the Chairman and Director General of CIRAD reiterated the attributes of CIRAD's research capacity. The visits of the Director General to the International Fund for Agricultural Development (IFAD) and the World Bank had the same objective.

Collaboration with European Organizations

The Natural Resources Institute (NRI), UK; Koninklijk Instituut voor de Tropen (KIT), The Netherlands; Instituto de Investigeção Científica Tropical (IICT), Portugal; and CIRAD plan to form a European association for tropical agricultural research. Meetings were held in the UK, France (Montpellier), and Portugal to discuss the project. They were accompanied by visits of scientists

to the different institutes to promote mutual understanding. Nine areas of common interest were identified for collaboration. The European Consortium for Agricultural Research in the Tropics (ECART), as the association is called, will offer its combined research capacity to the South for development efforts. The Consortium will be officially established in 1992.

Exchange of Ideas

The promotion of CIRAD as a forum of exchange for agricultural research is one of the themes of the strategy plan. In 1991, CIRAD participated in more than 20 important meetings.

Among the meetings organized or coorganized by CIRAD in 1991, the four most important related to: Science and Technology for Development (STD) programme of the CEC (in Bangkok); funding and rural development in Burkina Faso (in Ouagadougou); quality of food products of animal origin (in Paris); and rice cultivation in the lowlands (in Antananarivo).

CIRAD hosted a meeting of the Board of Trustees of the International Food Policy Research Institute (IFPRI) in May; the Director General of CIRAD is a member of the Board. It also hosted the international workshop on IFPRI's 10-year strategy. During the same month, CIRAD received the Board Chair Group of the Consultative Group on International Agricultural Research (CGIAR) when it attended a CGIAR meeting in Paris.

CIRAD participated in a large number of conferences: for instance, the 10th anniversary meeting of the French Ministry of Research and Technology, forum of the partners of ORSTOM, forum of biology students, Franco-Brazilian workshop on agricultural cooperation at Belo Horizonte, plenary meeting of the Special Program for African Agricultural Research (SPAAR), and international workshop on rainfall management for agriculture of the R3S network of CORAF at Bamako.

CIRAD's efforts to adapt, enhance, and expand its cooperative activities give substance to its commitment to promote more efficient interaction with its partners.

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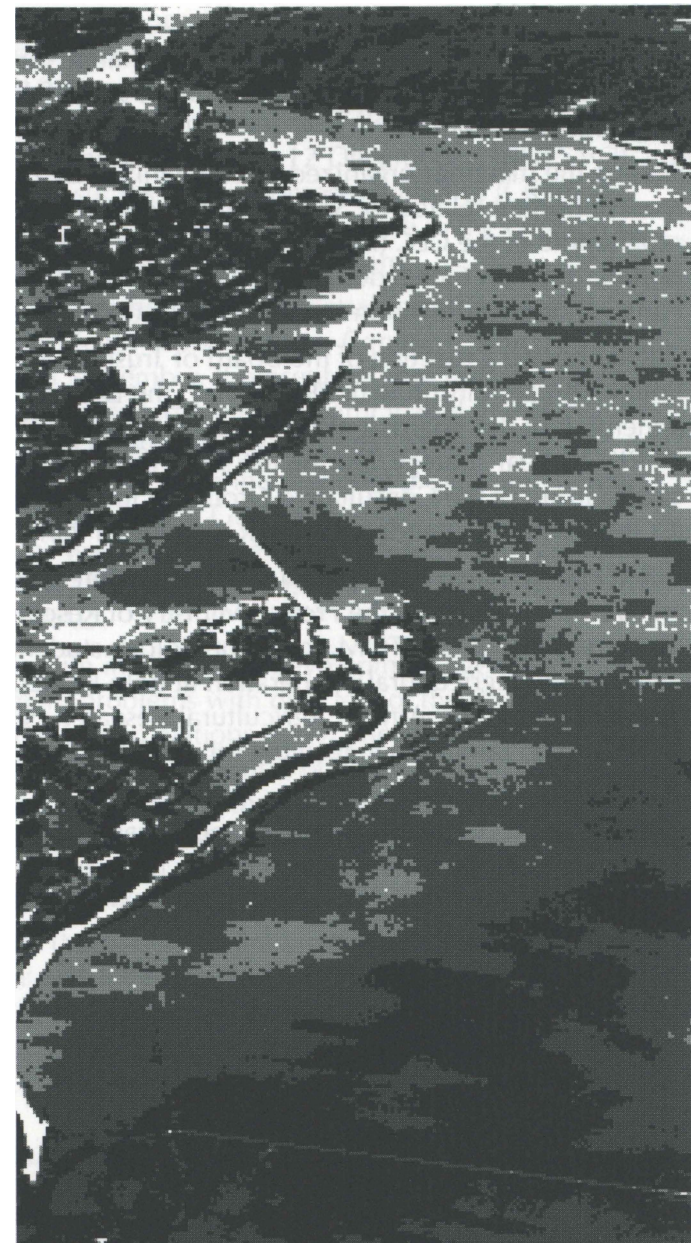
CIRAD's efforts to adapt, enhance, and expand its cooperative activities give substance to its commitment to promote more efficient interaction with its partners.

Agronomists must think in wider ecological terms to ensure rational use of natural resources. For this they must consider the entire agroecosystem and the interrelatedness of its different components: climate, soil, crop, and cultural practices. Successful integration of agriculture in the environment implies the re-establishment of biological balances. Farmer participation is a crucial factor in this effort. Local effects of phenomena such as depletion of soil fertility and deforestation can yield lessons for controlling these processes on a wider, even global, scale. CIRAD has adopted an interdisciplinary approach to respond to the challenge of development based on sound ecological principles.



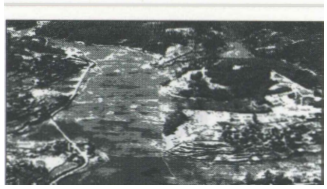
Environment and Agronomy

Evaluation and Management of Natural Resources

Management of Rainfall

Agroclimatology research at IRAT draws on various disciplines to widen its scope beyond water balance at field level. It now focuses on the water cycle to cover water reserves and fluxes at watershed and regional levels. Management of the components of this cycle is one way of reducing the gap between potential and farmers' yields.

In the Dogon region of Mali, the Institut d'économie rurale (IER) and IRAT identified local pearl millet cultivars (NKK and M9D3) that can be adapted to the local rainfall pattern and are therefore drought-tolerant. In Senegal, IRAT's work with the Institut sénégalais de recherches agricoles (ISRA) showed that a top dressing with farmyard manure caused concentration of roots near the surface and intense vegetative growth within a



short period. Water supply was depleted prematurely, reducing availability at the grain-filling stage. This was observed in a pearl millet–groundnut rotation. In Côte d'Ivoire, a similar condition was observed in a maize crop during the first cropping season. In this case the cause was linked to tillage operations. Cultural techniques should be adapted to the rainfall pattern to conserve water for the reproductive phase.

Climatic risk should also be considered in profitability assessments of commercial input use. A model based on 15 years of experimental data from a representative location in the 600-mm/year rainfall zone predicted a twofold increase in yields with the recommended fertilizer dose. But the actual gross margin did not exceed 20%.

Recommendations by regional organizations should integrate factors involved in improved rainfall management so that they respond more effectively to farmers' needs.

Nitrogen Supply in Cotton Crops

Rational fertilizer management is based on soil nitrogen availability (linked to rainfall distribution before planting) and nitrogen mineralization. A joint study by IRCT, Institut de la recherche agronomique (IRA, Cameroon), and Institut national de la recherche agronomique (INRA, France) aimed to develop methods for diagnosing nitrogen supply in a cotton crop. The information will be useful for matching nitrogen fertilizer application to crop requirements. Data series on nitrate concentration at the petiole of the fourth leaf of the cotton plant indicate nitrogen intake by the plant. Low nitrate levels in the petiole can be caused by either low nitrogen supply in the soil, a dry spell, or other nutrient deficiencies. Nitrate reductase activity in the leaf blade is a reliable indicator of petiole nitrate. High enzyme activity but low nitrate content signifies nitrogen deficiency in the soil. Low enzyme activity can be induced by a dry spell or high temperature. Nitrogen deficiency and the necessary input to correct this deficiency can be assessed from these indicators.

Soil Fertility in the Savanna Zone

The impact of mineral fertilizer application in cotton and sorghum crops was studied to determine soil productivity. Two parameters were used to characterize this response: maximum yield (production potential) and fertilizer-use efficiency (response curve). The crop environments fall into three categories: recently cultivated environments showing low response and high potential; environments with nutrient depletion showing high response and high potential; and degraded environments showing low response and low potential. The method used for this type of evaluation considers the particular cropping conditions for a given year. The method was developed during a survey of 150 farmers' fields in northern Cameroon.

Soil productivity evaluations were made in Mali by IER and IRCT for comparing different cotton systems in long-term trials, some of which were established more than 25 years ago. The role of potassium and phosphorus is often underestimated in soil fertility changes in the Sudano-Sahelian zone. Cotton yield potential mainly depends on the status of soil potassium which in turn is linked to the potassium balance for the cropping system (rotation crops, crop residue management, mineral and organic fertilizers, etc.). Fertilizer-use efficiency is closely linked to the status of soil potassium and phosphorus in the soil. Cropping practices in this region are conditioned by a chronic negative potassium balance which occurs in phosphorus-poor soils. This explains the stagnating and, sometimes reduced, cotton yields in the region.

Weed Control in Cotton Crops

Vegetation regrowth in land cleared for cotton cultivation is a serious constraint to productivity. The impact of herbicides, apart from their cost and adverse environmental effect, should be assessed at crop level by considering the cropping system and cultural practices (manual, mechanical). This assessment also requires accurate knowledge of weed population dynamics.

For the past 3 years IRCT has studied weed growth in the cotton crops of northern Cameroon. In newly established cotton fields there were few weeds but

several species. Under the impact of cultural practices and fertilization, the flora changed and in the 3rd year, although the number of species decreased considerably, growth of those that remained was abundant. These weeds were mainly short-duration grasses. Plants that propagate vegetatively through rhizomes or underground bulbs also appeared; they were very difficult to eradicate. For example, *Cyperus rotondus* which did not occur in traditional crops was commonly found in intensive crops.

IRCT's work demonstrates the importance of weed ecology and biology studies for adjusting herbicide treatments, particularly the time of application. For example, *Commelina benghalensis* germinates massively when the soil is prepared at the start of the rainy season. As conventional herbicides are ineffective in this case, the best control method consists in ploughing the soil after the first rains and applying a contact herbicide as soon as the weed emerges. Cotton can be planted as usual after these operations.

A combination of mineral fertilizer and kraal manure is recommended for cotton crops in Mali. But kraal manure encourages development of *Ipomoea* sp. (morning glory). Herbicides for cotton crops have no effect on this weed. Experiments in Benin showed that a weed control strategy that embraces the entire crop rotation system can be effective. Cotton is followed by maize with an input of mineral fertilizer and the herbicide used for maize can destroy *Ipomoea*. The solution was to use kraal manure for maize and only mineral fertilizer for cotton. The solution is simple and yet covers the overall fertilizer requirements of the rotation crops. This is an efficient approach because weed control is integrated in the technical itinerary for the entire crop rotation system. The concept has been assimilated in northern Cameroon, but it will take longer in other situations where it implies a modification of the established practices.

Improvement of Coffee Productivity

Smallholders in the Xalapa-Coatepec region in Mexico needed advice on fertilizing their coffee crops in an effort to innovate cultural techniques. IRCC's studies conducted with their participation showed that efficient fertilizer use should be accompanied by a coherent set of improvements that are based on a prior evaluation of available natural resources. Altitude, shadow intensity, plant density, and physical properties of the soil are determining factors. Soils most suited to coffee crops are Andosols and ferrallitic soils on volcanic ash. Ratooning, which is not practised in the region, can also raise yields. However, crop response to nitrogen fertilizer is low because of high soil acidity and exchangeable aluminium saturation. A production component analysis stresses that plantation management and tillage are more important priorities than fertilization for increasing yield.

Soil Structure and Oil Palm Yields

On certain sandy ferrallitic soils in Côte d'Ivoire, yield reduction is observed in second-generation oil palm plantations. In a preliminary study, the presence of a compacted horizon was found to obstruct root penetration. IRHO, in collaboration with INRA, studied pore space in clod samples from different representative sites in a plantation to understand the structural degradation process.

In samples from first-generation palm groves, the clay soil was made up of small juxtaposed aggregates and coarse pores (>50 µm) that represented 30% of total pore space. But in replanted groves the clay was compacted and without any coarse pores. The main causes of compacting are frequent use of heavy equipment and probably the cumulative effect of high potassium chloride application. Deterioration of soil structure is a gradual and inconspicuous process, but it can reduce yields by 25%. Planters are therefore

■ INTERNATIONAL MEETINGS

Antananarivo Workshop on Lowlands

The Malagasy rural development research institute, FOFIFA, and CIRAD organized a workshop on rice cultivation in the lowlands at Antananarivo from 9 to 14 December 1991. It was cofinanced by the French Agence de coopération culturelle et technique (ACCT) and ORSTOM. A total of 110 participants from different countries and representing various disciplines met to review information and experience on tropical lowlands. Different regional situations and disciplinary approaches were compared with the ultimate objective of increasing productivity of these lowlands. Useful conclusions were drawn on scientific, methodological, and practical aspects.

Workshop Recommends Extension of CORAF Network

An international workshop on rainfall management in agriculture was held in December 1991 at Bamako. It was organized by the Institut du Sahel and CIRAD for the R3S drought resistance network of the Conférence des responsables de la recherche agronomique africains (CORAF) and Comité permanent inter-Etats de lutte contre la sécheresse dans le Sahel (CILSS). The sponsoring agencies included the Commission of the European Communities (CEC), Technical Centre for Agricultural and Rural Cooperation (CTA), and Canadian International Development Agency (CIDA). Eighty participants representing various disciplines attended the workshop. One of the recommendations was to extend the network to the anglophone countries in western Africa.

cautioned to pay more attention to long-term conservation of soil productivity. Subsoiling and alkaline inputs are recommended in replantations because they can increase yields appreciably by 15%.

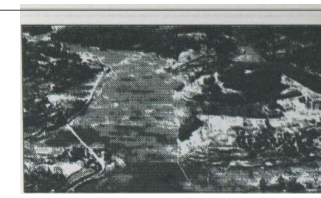
Evaluation of Plantation Status

Oil palm and rubber planters need a tool to assess the nutrient and disease status of their crops. IRHO, IRCA, and the CIRAD Remote Sensing Unit worked in collaboration with several Indonesian partners on SPOT images of plantations in northern Sumatra taken in June 1991. Certain patterns revealed by numeric analysis will be characterized using data from ground surveys. For oil palm, 67 test areas were selected for soil sampling and studies on leaves and palm height. For rubber, because data were already available from previous studies the number of test areas was limited to 15 for evaluation of nutrient content in soil and leaves. Meanwhile, radiometric data were analyzed to distinguish soil types in palm groves and different clones in rubber plantations.

Coconut on Peat Soils

The project for coconut cultivation on peat soils, which was launched in 1987 in Sumatra, neared the completion of its first phase. To date, 18 000 ha have been planted. Other plantation projects are under consideration.

IRHO, which has technical responsibility for the project, was confronted by an unexpected situation in 1991. Although the plantation was progressing well, fruit set was not uniform in plots that had reached production stage (500 ha). Flowering had been early and abundant with good pollination, and no pest or disease incidence had been observed. Palms with good fruit set, particularly those near deposits of clay along the secondary drains, were compared with coconuts with poor fruit set. The hypothesis of a silica deficiency was proposed. Applications of sodium silicate had a positive effect on fruit set; further studies are under way to confirm the hypothesis. Locally available slag from heavy industries or other easily accessible sources could be applied to rectify the deficiency.



More information is needed on the properties and processes of peat soils to forestall such problems. Two seed gardens of 200 ha each were established to produce plant material selected according to IRHO's techniques. Establishment of a 500-ha experimental area is under way. The two main factors that still need to be optimized are fertilization and the water table level, which can be adjusted by means of the drainage system. Intercropping will be studied for a project aimed at the establishment of smallholdings. The development of oil palm on peat soils will also be studied to design cultural techniques suited to these soils.

■ Crop Yield Modelling

Yield Formation Models for Oil Palm

IRHO studied yield formation in oil palm by examining net photosynthesis in a canopy and distribution of assimilates in the palm.

Calculation of net photosynthesis of a canopy is based on radiation measurements and light interception by the foliage. Conventional mathematical models cannot be used for this purpose because of the aggregate structure of the oil palm canopy. CIRAD's Plant Architecture Modelling Laboratory created computed oil palms that were arranged in "scenes" to study this phenomenon. Field observations were converted into parameter files that accurately described the position and angle of the leaves forming the canopy. The result was an almost exact reproduction of plant diversity in a palm grove. Light transfer was studied on the basis of the scenes. The shade model reconstructed incident solar radiation at soil level, without including light scattering within the canopy. The radiation balance model simulated radiation transfers within the canopy. And the ray-tracing model described the trajectory of a ray and its possible scattering, up to its absorption or exit from the cover. Although this model exactly reproduces radiation exchange within the vegetation, the calculations are time-consuming and should be limited to more fundamental studies.

In normal water supply conditions, annual biomass production in an oil palm crop is high, up to 105 t/ha in Côte d'Ivoire. Vegetative growth (leaves, stem, roots) consumes 80% of the assimilates, half of which are directed to the roots. The rest is available for yield production. Respiration and development of male flowers take up 11%; only 9% remains for the bunches, which amounts to 9.2 t of dry matter or the equivalent of 23 t of harvested yield.

The work on photosynthesis and assimilate distribution is useful for modelling harvestable yield production in oil palm. A preliminary model considers climatic factors (radiation, temperature), stand structure (leaf area index), and physiological parameters.

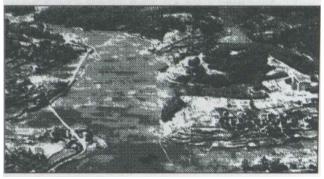
Root System of Oil Palm

Research on the root system of oil palm aims to improve drought tolerance, and to enhance understanding of water and mineral supply and of competition in intercropping systems. It also contributes to the study of harvestable yield production.

In a study conducted for the Institut des forêts (IDEFOR) at La Mé, Côte d'Ivoire, the root system of oil palm was examined in sandy sediment soils that offer little resistance. The large primary roots can be very long, but they do not penetrate beyond 20 cm in depth. Half the secondary roots are located within 1.30 m from the soil surface and can penetrate up to 4.80 m in depth. The tertiary and absorbent quaternary roots colonize the rhizosphere up to 4.80 m in depth, although half of them are found in the top 50 cm. These data on rooting depth in the absence of soil resistance will modify assessments of soil depth and water reserves that can be used during the dry season.

Estimation of Cereal Yields

Research on the use of satellite data (NOAA) for estimating cereal yields in the Sahel was conducted from 1985 to 1991 by the Centre national d'études spatiales (CNES), INRA, and IRAT, with support from CEC. Radiation, radiometric, and biological measurements from field experiments in Niger were used to adjust a production model. It was applied to satellite image data



for mapping pearl millet yields in the Niamey region. The results were then used in a pilot project for yield prediction in the Sahel, in collaboration with the Institut national de la recherche agronomique du Niger (INRAN); the Nigerien Ministry of Agriculture and meteorological services; the regional centre, Agrhymet; and the Sysame company. A software package installed at Agrhymet will assess the cropped area and yields up to arrondissement level.

Adaptation of the GOSSYM Model

IRCT is developing agricultural diagnostics tools for its scientists in the field that will enable them to propose more relevant recommendations. GOSSYM, a cotton growth model from the USA, was tested by IRCT for a year at the Starkville laboratory of the United States Department of Agriculture (USDA). The model contains data on plant-environment interactions. The current model is conceived for regions where the limiting factor is temperature and not water, which is the case in the semiarid tropics. Moreover, it is based on the hypothesis of uniform soils, whereas the soils in Africa are heterogeneous, particularly their physical characteristics. The model therefore needs to be "tropicalized" by introducing data on photosynthesis, and relations between soil and crop growth and development. Further research is needed to supplement available information, particularly on the distribution of assimilates and mechanisms involved in boll fall.

Sustainable Development of Land Use Systems

Strategies for sustainable development of natural resources should be designed according to the physical conditions and farming situations that combine to form land use systems, each of which has its particular set of development issues.

Agroforestry in Réunion

CTFT, IEMVT, and the Office national des forêts are studying possibilities for introducing woody forage plants in the different land use systems of Réunion. The idea is to use bushes as erosion checks, wind-breaks, and sources of forage.

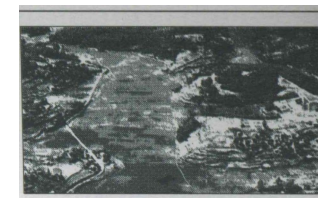
One of the systems combines vegetable and tree crops with goat production. Three bush legumes were proposed for different altitudes: *Leucaena diversifolia* (1300 m), *Calliandra calothyrsus* (100 m), and *Glyricidia sepium* (600 m). The trials aim to identify suitable zones for each of the species; to determine dry matter production and feed value; and to compare performance in cutting and grazing systems. Recent incidence of psyllids calls for caution. *L. diversifolia* has not yet been affected at 1300 m. *C. calothyrsus* did not appear to be susceptible and yielded 4.5 t of dry matter per cutting of leaves. It is an excellent forage crop with a high total nitrogen content, but it is low in phosphorus. The three species were also studied in a goat production system in the more tropical eastern part of the island.

Lowland Systems

In the tropics, lowlands are small valleys where a high water table and temporary streams ensure good water supply. In Africa, despite their high potential, lowlands are not adequately exploited. The highlands of Madagascar have an extremely dense network of lowlands at altitudes between 900 m and 1800 m. Farmers grow aquatic rice in these areas, but yields are low. To help them optimize this potential, studies were undertaken to gain a better understanding of these environments.

A detailed interdisciplinary study was conducted in a lowland 25 km to the north of Antananarivo. It was a collaborative project involving the participation of organizations from Madagascar (FOFIFA; University of Antananarivo; and the Ministry of Industry, Energy, and Mining) and France (IRAT, ORSTOM, Universities of Avignon and Montpellier). Valuable information was obtained for technical recommendations and research methodology.

The complex water system of a lowland is made up of surface flows and groundwater flow from the interfluvial uplands to the shallow water table in the lowland. Water supply from these two sources varies with the season.



The physico-chemical features were studied by measuring parameters related to the rice rhizosphere (pH, oxidation-reduction potential, water temperature, and cation exchange capacity). The problem of iron toxicity in lowland rice is caused by the release of ferrous iron in the waterlogged soils. Toxicity is higher in the hydromorphic organic and peat soils on the upper part of the catena than in the mineral and well-drained soils on the lower part.

Crop yields were found to be related to the position of the crop in the catena. Per hectare yields were higher at the valley bottom (1.4 t) than at the ridge top (2 t) because of toxicity.

The results of this collaborative research should indicate certain modifications in cultural practices that avoid toxicity by stimulating reoxidization.

Small-Scale Water Management Structure

Efficient water management is based on knowledge of the physical environment and farmers' practices. High soil permeability in the lowlands and small plains in the Sikasso region, Mali, is the main cause of ineffectiveness of the water control structures. IER and IRAT tested an overflow bank with a cutoff trench that checked flow from the water table; the design was based on detailed morphopedological observations of the lowlands. Water flow readings, crop monitoring, and socioeconomic surveys over 4 years confirmed that the structure successfully regulated water flow and that it was cost-effective even for nonintensive crops. This is significant because rice is mainly cultivated by women who have practically no access to inputs. Without any other modification of cultural practices, per hectare yields increased from 1.4 t to 2 t in fields with such structures. In addition, the basic principles for modelling water management in lowlands and for simulations of hydrological processes in lowlands with or without banks were derived from this research.

Irrigation Systems

The irrigation system of the Office du Niger in Mali, which was established in the 1930s, needs to be rehabilitated. The Bureau pour le développement de la production agricole (BDPA), Institut de recherches et d'applications de méthodes de développement (IRAM), and DSA participated in a CEC-funded project, Retail. It covers 500 farms spread over 2500 ha. The project area serves as a field laboratory for the entire irrigation system.

Renovation of the hydraulic system will facilitate efficient water management for intensive rice cultivation. Recommendations for the system included transplanting instead of the earlier practice of broadcasting; use of short-duration, nonphotosensitive cultivars; and introduction of double cropping. It was accepted by farmers. Double cropping has been adopted in one-quarter of the project area and transplanting has spread beyond the project area. In 1991, distribution of the cultivars identified by the IER for double cropping was undertaken on a massive scale.

Fields located outside the official system used to benefit from the sometimes deliberate leakage of drains; remodelling of the hydraulic structures has curbed this practice. For the farmers of these fields the consequences were disastrous. A proposal for partial and controlled irrigation was put forward. A satisfactory solution for all concerned is being negotiated. It should allow farmers to resume cultivation of their lands and assure irrigation authorities that there will be no further disruption of the drainage system. Scientists will also be satisfied that appropriate measures will be taken to check alkalinization and excess sodium due to poor drainage.

Other options for crop intensification were tested. Some fields were converted for growing vegetable crops. Farmers showed keen interest in this change because the nearby city of Niono offers an excellent market. The establishment of forage crops around the villages also received a good response. It answers the need for a new source of feed for draught animals as the grazing area has been reduced by double cropping. Annual feed legumes and forage trees (on slopes) are being tested.

Ecological Agriculture in Oases

The traditional oasis has three strata of vegetation: annual (vegetables, cereals) and forage crops, fruit trees,

■ PRODUCTS FOR DEVELOPMENT

Processing Satellite Imagery in Burkina Faso

CIRAD's remote sensing studies conducted since 1986 for the rainfed crop programmes of the Institut d'études et de recherches agricoles (INERA), Burkina Faso, have attracted the attention of the national agricultural development authorities. The statistical results and maps for the western region show rapid land transformation following a high influx of farmers from other regions. The resulting agricultural expansion and intensive cultivation have placed heavy pressure on natural resources. Such information is indispensable for the implementation of sustainable land use management strategies. The national research authorities therefore decided to establish a remote sensing unit at INERA with funds from the French agency Fonds d'aide et de coopération (FAC) and technical support from CIRAD. Certain processing operations on satellite imagery can now be undertaken locally; the unit will also develop new applications. Equipment was acquired in 1991 and several studies were commissioned. Training programmes were also organized on site and at the CIRAD Remote Sensing Unit in Montpellier.

Review of Timber Plantations

CTFT completed and published a review, sponsored by FAO, on cultivation of timber species in the African rain forests. Wood from these trees is used for furniture, panels, and as structural material. Twenty-one species were studied, including teak, framire, limba, ayous, cedro, gmelina, and okoume. Plantation establishment, sylvicultural techniques, growth patterns, and yield potential are described for each of them. The publication serves as a useful handbook for foresters and sylviculturalists. It is the result of 25 years of work in five African countries, but the techniques and basic elements can be extrapolated to other ecologically similar regions.

and date palms. This sophisticated agroecosystem with its favourable microclimate works well as long as the balance is maintained.

A Franco-Tunisian project involving the Institut national de la recherche agronomique de Tunisie (INRAT), International Research and Training Institute for Education and Development (IRFED), INRA, and CIRAD focuses on research for developing oasis agriculture in southern Tunisia. In the Tozeur oases, the trend toward date palm monoculture based on a single variety, Deglet Nour, decreases biodiversity and weakens the agroecosystem. Monoculture also removes the microclimate and its buffer effect. Moreover, reduction in the forage crop area and livestock decreases organic matter production, and manure for maintaining soil fertility has to be acquired externally. The oasis is no longer self-sufficient in food.

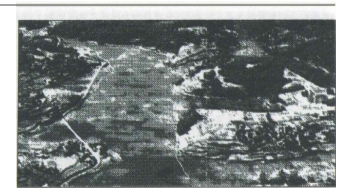
Until now, the high demand for Deglet Nour dates on the international market ensured a high income to farmers. But this newly acquired wealth is being threatened by competition from Algerian products.

With growing labour shortage, artificial pollination may soon become a problem. Unfavourable sharecropping contracts may be prompting workers to seek more lucrative activities in the tourist trade or to migrate to neighbouring countries.

The recommendations attempt to increase efficiency in the use of critical resources, particularly irrigation water. The introduction of other date palm cultivars is stressed as well as the restoration of at least one more vegetation stratum. An inventory of oasis germplasm by the date palm department of INRAT will lead to the establishment of accessions collections for use in breeding programmes. Integrated pest management is proposed for controlling pyralids and white scale insects. Measures are also needed for possible incidence of vascular wilt. Date technology focuses on harvest conditions, fruit quality, and handling.

Ecological Development

Through its recommendations and operations, CIRAD promotes new ways of managing land use systems. Any



modification implies changes in the basic balance and these need to be carefully considered.

The Food and Agriculture Organization of the United Nations (FAO) called upon DSA to participate in an integrated development project in southern Angola. The existing system is characterized by a close integration of crop and livestock production. The area has a high cattle population, particularly of draught animals. Cereals are grown on smallholdings where labourers work on less than 2 ha each. All the fields are tilled and most are weeded. Soil fertility is maintained by applying kraal manure.

With the end of the war in the country, markets have started emerging. The project aims to develop cash crops such as castor, sunflower, and cotton. DSA cautioned decision-makers on the serious consequences of these major changes on sustainable development. The introduction of cash crops would lead to an expansion of the cropped area to the detriment of soil fertility. The reduction of forage crops would reduce the cattle herd and manure production. At the same time nutrient uptake would increase with the use of more productive crops.

All these factors need to be considered before altering the existing systems. Future strategies should determine the yield level that is compatible with fertility maintenance in each ecological development area.

Environment and Agriculture

Inventory of Pasture Resources

A land use inventory method that combines remote sensing and ground surveys was developed by IEMVT for mapping pasture resources. It includes statistical analyses for a more efficient use of satellite image data and assessment of the accuracy rate. Survey units were identified through systematic and random selection. Remote sensing techniques increased the average accuracy of land use data from 34.5% to 85.5% for two test areas located in southern Mauritania.

Mission télédétection

Scientific Coordinator
Jacques Imbernon

Scientific Committee

• External Members

Jean-Paul Cheylan, CNRS *Michel Deshaves,* CEMAGREF *Christine King,* BRGM *Claude Klapisz,* Université Paris VII *Hervé Le Men,* IGN *Jacques Noël,* ORSTOM *Gilbert Saint,* CNES *Bernard Seguin,* INRA

• CIRAD Members

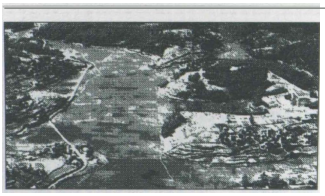
One representative from each department

Improved Methodology for Interpreting Radiometric Data

Results obtained by the CIRAD Remote Sensing Unit demonstrate the importance of satellite image data for establishing maps to be used for rural development. The output serves as an analytical tool for land use management and execution of agricultural projects. However, interpretation of radiometric data may contain confusions in which different surface states are represented in the same class. To avoid such errors, external data were introduced for a prior segmentation of the satellite image. The method was applied for the first time while mapping the Taravao peninsula in Tahiti where the location of human settlements and natural vegetation are closely linked to slope and altitude. The image was segmented according to these parameters and the results showed that the main confusions were eliminated. Work on methodology continues with a study on the Imamba and Ivakata watersheds in Madagascar. The objective of the project is to provide planners with maps for land and water management.

Advance of Desertification

IEMVT compared aerial photographs of the Sahelian zone in Burkina Faso that were taken at an interval of 20 years to determine the spread of desertificaton. The affected area increased from 5% in 1955 to 27% in 1974. Supplementary analyses used multiple-date Landsat and SPOT images of a test area (60 000 ha) to ascertain whether the process continues. Vegetation population dynamics varied according to the nature of the soil and substrata. On sandy soils, denudation was reversed during years with favourable rainfall, whereas



regeneration was extremely limited on low-gradient slopes with silt soils. In general, desertification is spreading further; compared with 1972, the condition in 38% of the test area is good, stable, or improving, while soils in 21% of the area are degraded or steadily deteriorating.

Agricultural Expansion and Parasite Pressure

The surge in the demand for agricultural products owing to population growth in a large number of countries has led to increased agrosylvopastoral activities. The resulting transformation of natural and settled environments has aggravated pest and disease incidence. One of the most striking effects is the rise in locust and grasshopper outbreaks. In 1991, two studies were undertaken by PRIFAS in collaboration with the CEC on outbreaks due to land transformation.

In the study conducted in the Brazilian states of Mato Grosso and Rondonia by the environment monitoring cell of the Empresa Brasileira de Pesquisa Agropecuária (NMA-EMBRAPA) and PRIFAS, it appears that forest clearing for cash crop cultivation has led to the emergence of the grasshopper *Rhammatocerus schistocercoides* as a serious pest. The biology and ecology of the species were studied. The results will be compared with observations on the changing environment based on satellite images taken over the past 15 years.

In China, the construction of the dam for the hydroelectric power project on the river Hwang at Shanmexia has affected cultivated lands. Salinity and changes in the amplitude of flood levels have made them unproductive. Locust and grasshopper incidence has increased, particularly of *Locusta migratoria manilensis* and *Oedaleus infernalis*. Studies on the biology and ecology of the two species were undertaken in collaboration with the University of Shansi.

On the basis of these studies recommendations will be made for curbing outbreaks in the short term. Rational control measures for the long term will include modifications of land management practices.

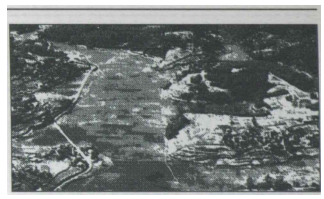
Monitoring Deforestation

Biological imbalances in the environment and expansion of cropped areas are largely responsible for deforestation. In Southeast Asia, where it has increased at an alarming rate since the 1970s, deforestation will figure as a priority issue for environment protection and socioeconomic development. Six countries (Brunei, Indonesia, Malaysia, Philippines, Singapore, Thailand) are participating in the deforestation project of the Southeast Asian Ministers of Education Organization (SEAMEO). CTFT provided technical support for a two-level study of the situation. At the macro level, NOAA data were used to assess the extent of change in the overall forest cover. The data were compared with previous information (maps, statistics, etc.) when it was available. At a more specific level, high-resolution SPOT data were acquired for two selected test areas in each country. This detailed analysis will enhance understanding of deforestation processes.

Forests of Central Africa

The past few decades have witnessed the vanishing of a large part of the tropical rain forests in certain countries. The remaining natural forests need to be protected and managed so that logging does not affect regeneration. More intensive reforestation is needed to reduce pressure on this valuable resource.

In December 1991, the CEC decided to fund a large-scale project for conservation and rational exploitation of the central African forests. It was commissioned to a consortium formed by CTFT, the Universities of Rennes and Louvain, and two consulting firms, Agrer (Brussels) and Agriconsulting (Rome). The project covers seven countries: Cameroon, Central African Republic, Congo, Gabon, Equatorial Guinea, São Tomé and Principe, and Zaire. A forest area between 10 000 ha and 100 000 ha was selected in each of the countries to study forest resources, flora, and fauna for formulating sustainable management strategies. CTFT provides overall scientific support and is responsible for studies on the N'Gotto forest in the Central African Republic. This is the only location where the three operations of the project are carried out simultaneously. They concern forest



management for timber production (20 000 ha), conservation of biodiversity (20 000 ha), and rural development based on agroforestry (about 8000 ha). This project will serve as a model for work on tropical rain forests in other regions.

Forest Management in the Amazon Region

FAO commissioned CTFT to prepare a report on rain forest management and conservation in the Amazon region for the 1992 United Nations Conference on Environment and Development in Rio de Janeiro. The document drew on various national and project reports to elucidate the current situation. In most countries, forest management has hardly progressed beyond the concept stage despite proposed legislation for integrating forest management and availability of technical know-how.

Deforestation is directly linked to population growth. In countries with a pressing demand for food and wood, conservation of the forest ecosystems is clearly less important than forest clearing.

Three types of situations exist in tropical America. The Central American and Caribbean countries have high population growth, land shortage, and soil erosion. In these countries, a policy based on protected areas should be combined with rational forest exploitation and agroforestry. In the Amazon countries, population density is low in the forest areas. Ecological zoning based on scientific parameters will lead to rational land use. Consequently, agriculture will be shifted to the best soils, exploitation will be restricted to the permanent forest, and the ecologically and biologically rich areas will come under special protection. In the Guiana forest, which is sparsely populated, forest management is concerned more with technical problems than with forest clearing.

Firewood and the Environment

Urban populations in developing countries consume vast quantities of firewood, mainly for cooking. Supply of firewood is a common activity in the informal sector. Uncontrolled firewood collection from areas surrounding the villages not only depletes the resource, it is also responsible for dry spells, wind erosion, and parasite incidence.

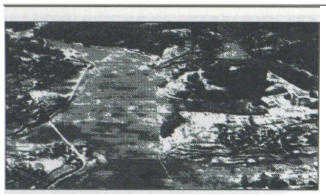
A World Bank project funded by Denmark focused on the four main cities in Niger. It was jointly implemented by the Ministry of Water Supply and Environment and the Ministry of Mining and Energy, with technical support from CTFT and the consulting firm, Seed. The objective was to guarantee regular supply of firewood for household needs and to ensure conservation and rational management of bush vegetation, in an attempt to check desertification. For each city, plans were drawn up to reorganize the supply system and to indicate priority areas. Work was completed for Niamey and it is under way for the three other cities. In addition, an amendment of current regulations was prepared for promulgation in 1992. It involves the imposition of a forest tax to fund the management of natural resources. Rural firewood markets were established and agroforestry initiatives were taken at village level to enhance the role of farmers in the firewood sector.

Waste Water for Agricultural Use

Waste water from agroindustries and cities raises serious problems of water pollution and other harmful effects (toxicity, health hazard, stench). Current laws in tropical countries cannot tackle this problem. The development of vegetable cultivation on city outskirts could offer an opportunity to initiate antipollution measures. Waste water could be recycled after treatment to provide energy or be used for fertilizing fields.

Research on waste water treatment was undertaken at Montpellier by IRAT in collaboration with the Université Montpellier II, and the regional centre for innovation and technology transfer, Verseau. The process is based on the principle of separation of solid and liquid fractions. Almost 90% of solid suspended matter is fixed by cereal straw. Compost produced with this straw is used to provide energy and plant nutrients for vegetable crops. The remaining water is filtered and recycled for use in irrigation or agroindustry.

The process was patented under the name Transfiltre; it is now in the final development stage. It can be used, for example, to treat waste water after extraction of starch



from cassava by fixing solids on bamboo chips; residual water from sugar refineries can also be treated the same way by using cane trash.

Agriforce, a subsidiary of CIRAD, specializes in waste water recycling. A major operation concerns treatment of waste from slaughterhouses in the Sudano-Sahelian zone, tests for which are run at a pilot unit in Thiès, Senegal.

A workshop was organized in November 1991 for slaughterhouse managers from the eight Sudano-Sahelian countries. They recognized the extent of pollution and harmful effects caused by the slaughterhouses and the need to reduce their high water and energy consumption. Waste from the slaughterhouses is mostly made up of stercoral matter, which is deposited outside the slaughterhouses. It amounts to a total of 15 000 t per year for the eight countries. An estimated total of 400 000 m^3 of methane is produced by anaerobic fermentation. In terms of the greenhouse effect this represents the equivalent of burning 5700 ha of savanna. About 780 000 kWh of electricity and 2500 t of compost could be recovered. This was successfully tested on a pilot scale in Thiès. Water from the slaughterhouses could be treated before recycling by adapting the lagooning process.

Cadmium Hazard in African Rock Phosphates

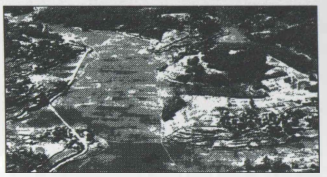
Certain African rock phosphates contain cadmium, a highly toxic heavy metal that is a serious health hazard. Northern European countries have stopped buying these phosphates. This is a serious setback to producer countries, mainly Senegal and Togo. The western African association for the promotion of phosphate products requested CIRAD to study the behaviour of cadmium in the soil and its possible introduction in the food chain.

In acid soils, cadmium is readily available for uptake by plants. But in other soils (e.g., calcareous or clayey) it combines with insoluble chemicals and, as it is fixed almost irreversibly, it cannot be absorbed by plants. Cadmium availability in soils fertilized with phosphate products is not linked to total cadmium content in the phosphates. Extracted cadmium may divide into fractions—generally two—with different extraction rates. These factors should be considered in toxicity risk analyses.

■ TRAINING

Assessment of Deforestation in Southeast Asia

The SEAMEO project for monitoring deforestation in six Southeast Asian countries includes a training component for participants from each country. In 1991, 21 participants attended two training programmes conducted in Thailand at the Asian Institute of Technology (AIT) and Tropical Biology Centre of SEAMEO. Another programme on interpretation of NOAA data is being prepared for smaller groups. The participants also contribute to studies of the test areas in their respective countries.



▼ *Theses Completed in 1991*

Les "sols rouges" de l'Inde péninsulaire méridionale : pédogenèse fersiallitique sur socle cristallin en milieu tropical [The red soils in southern peninsular India: fersiallitic pedogenesis on crystalline shield in the tropics] by Gérard Bourgeon (France); Université Paris VI; IRAT staff member.

Evolution et comportement de sols sablo-argileux ferallitiques sous culture de palmiers à huile [Changes in and behaviour of ferrallitic sandy clay soils under oil palm] by Christian Hartmann (France); Université Paris VI; IRHO trainee.

Caractérisation de la fragilité écologique et des potentialités agronomiques de la région de Houndé au Burkina Faso : utilisation de différentes techniques de diagnostic [Characterization of the ecological fragility and agronomic potential of the Houndé region in Burkina Faso: use of different diagnostic techniques] by Philippe Morant (France); Institut national polytechnique de Lorraine; IRAT staff member.

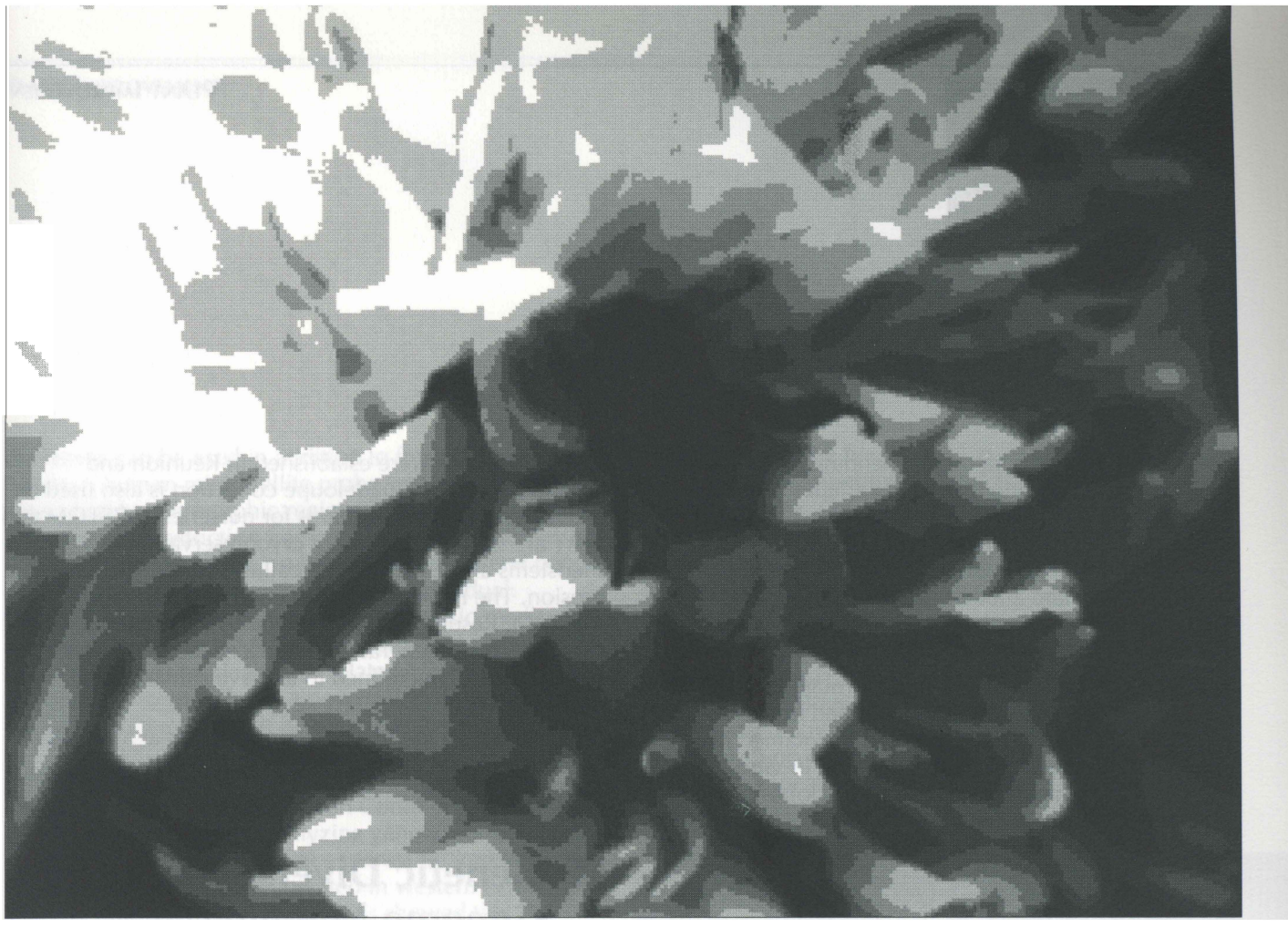
Estimation de la production primaire en zone sahélienne à partir de données radiométriques. Cas d'un couvert discontinu [Estimation of primary production in the Sahel using radiometric data. Case of a discontinuous cover] by Agnès Beque (France); Université Paris VII; IRAT trainee.

Pluviosité et nutrition azotée du cotonnier (*Gossypium hirsutum *L.) : validité du diagnostic pétiolaire [Rainfall and nitrogen nutrition of cotton (*Gossypium hirsutum* L.): validity of petiole diagnosis] by Joseph Ekorong (Cameroon); Ecole nationale supérieure agronomique de Montpellier; IRCT trainee.

Fermentation méthanique des épluchures de manioc. Influence et dégradation du cyanure [Methane fermentation of cassava peels. Influence and break-down of cyanide] by Nadine Cuzin (France); Université Provence, Aix-Marseille I; IRAT trainee.

Plant improvement has been steadily contributing to agricultural development through the reation of modern cultiars, multiplicatio of true-to-type and disease-free plant material, and design of techniques for field screening of enotypes. These achievements are supported by continual progress in genome studies, cellular biology, and plant genetics. Cirad uses state-of-the-art equipment and technology to keep pace with this progress. In 1991 it created Biotrop, a unit of common laboratories for the application of biotechnology to tropical plant improvement.

PLANT IMPROVEMENT



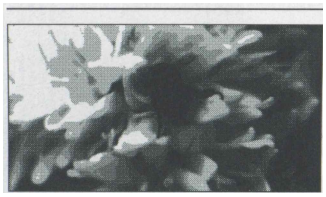
■ Germplasm Collection and Conservation

CTFT identified new sources for *Eucalyptus pellita* and *Acacia aulacocarpa* in Papua New Guinea. The discovery of these new sources enhanced current knowledge of the natural habitats of these species. The genetic base of breeding programmes was widened because these ecotypes possess particular characteristics.

Intense exploitation is depleting natural populations of rattan in Southeast Asia. Certain large forest enterprises are considering the establishment of commercial plantations in an attempt to replenish supply. One of them, Innoprise in Malaysia, launched a programme for analyzing genetic diversity and developing varieties either from seed or in vitro-cultured cuttings. The programme is conducted in collaboration with CTFT.

An international coconut germplasm network that will link 24 countries was created following a meeting organized in 1991 by the International Board for Plant Genetic Resources (IBPGR) in Indonesia. IRHO was given the responsibility of setting up the germplasm database. It will receive input from the 18 countries of the network that operate coconut research programmes. The importance of zygotic embryo culture and cryopreservation of this material was stressed at the meeting. These techniques were first developed jointly by the Institut français de recherche scientifique pour le développement en coopération (ORSTOM) and CIRAD.

The IRAT and IRCT working collections in Montpellier are maintained in the form of seed to ensure conservation and facilitate germplasm exchange. At present, there are 4830 pure lines and populations in the rice collection, 720 in the maize collection, and 1600 in the sorghum collection. The cotton collection comprises 1300 cultivars. In addition, seed samples (2300 for rice and 1500 for cotton) collected during surveys are conserved in accessions collections. The main cultivars (193 rice, 50 maize, and 52 sorghum cultivars) developed and distributed by IRAT are also maintained



by the IRAT Seed Laboratory. Depending on the crop, the base material for multiplication of varieties or hybrid development is produced in Montpellier, Guadeloupe (rice and maize), or Senegal (sorghum). IRHO maintains two collections of groundnut accessions: one in Senegal (1300 cultivars) and another in Burkina Faso (600 cultivars). All the germplasm is conserved in cold chambers or in cold storage (–18°C).

Sugarcane germplasm is preserved through in-vitro cultures to save space. Plantlets obtained from bud cultures are placed in test-tubes and maintained in a slow-growing state at 18°C. In 1991, the in-vitro collection at Montpellier included 550 clones; partial in-vitro collections were established in Réunion and Guadeloupe. The Guadeloupe collection is also used for producing disease-free plants for nurseries. ORSTOM and IRAT are studying the use of cryopreservation of meristems and embryogenic calluses to reduce genetic erosion. The material is maintained in liquid nitrogen (–196°C). Results vary with the cultivar; in the case of Co 64-15 the regeneration rate exceeded 90%. The technique is being refined to achieve similar results with other cultivars.

IRCC started an in-vitro culture collection at Montpellier for coffee clones. It currently holds 150 lines from individual plants.

MEMORANDUM OF UNDERSTANDING

Pooling Know-How on Genetic Resources

The Mission connaissance et amélioration des plantes, which is concerned with plant improvement at CIRAD, organized a seminar on genetic resources in May 1991. It was attended by about 30 scientists from IBPGR, INRA (Institut national de la recherche agronomique, France), ORSTOM, and CIRAD. Discussions focused on five topics: types of biodiversity in wild species; establishment and management of core collections; in-vitro conservation of germplasm, mainly somatic embryos; virus diseases in germplasm; and mechanisms governing seed recalcitrance to conservation.

The seminar led to the proposal of joint research projects including comparison of different methods for evaluating biodiversity in cocoa and sugarcane.

In December 1991, IBPGR signed a memorandum of understanding with INRA, ORSTOM, and CIRAD to pool their know-how and resources.

Genetic Diversity and Genome Mapping

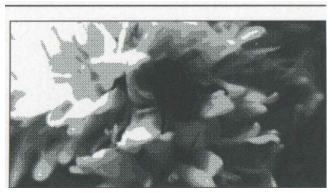
Genetic Potential of Criollo Cocoa

Theobroma cacao diversified from its centre of origin in the upper Amazon basin into two main genetic groups, Forastero and Criollo. The Criollo cocoas were domesticated by the Mayas; today, they are in demand because they produce the finest chocolate, although acreage is very limited. The Forastero cocoas, which are more hardy, have spread throughout the world over the past century. Until now, genetic research at IRCC has mainly focused on the Forastero group and its wide diversity has been established by isozyme electrophoresis.

Genetic variability was analyzed by studying the cytoplasmic DNA of 150 cocoa clones, using heterologous cytoplasmic probes. Wide diversity was observed in the Criollo group. This should encourage breeders to exploit the genetic potential of the group, which is threatened with extinction. Diversity is further studied by using nuclear DNA probes.

Molecular Fingerprints of *Hevea*

A molecular fingerprinting method was developed to determine the identity of cultivated *Hevea* clones. The advantage of this method over isozyme methods is that



dry leaves can be used in addition to fresh or freeze-dried leaves. A human minisatellite probe was used as it can detect highly polymorphic regions in the *Hevea* genome. The pattern of restriction fragment length polymorphisms (RFLPs) produced by the probes comprises several bands, which constitute the fingerprint of the individual. (Minisatellite probes are also used in forensic medicine and for paternity tests.) A single probe and a single enzyme sufficed to identify 73 related *Hevea* clones. Molecular fingerprinting is a powerful tool that can be used in combination with isozyme electrophoresis.

Three Groups of Guinea Sorghums

The Commission of the European Communities (CEC) cofinanced a project for analyzing genetic variability in sorghum. It focused on the race guinea of *Sorghum bicolor* which is widely cultivated in western Africa. Isozyme analysis of 168 individuals showed that the guinea sorghums are organized into three groups. The first group from central and western Africa comprises the subraces gambicum and guineense. The second group from southern Africa and Asia (India, Nepal) comprises the subraces conspicuum and roxburghii. The third group, margaritiferum, does not correspond to a geographic area but to a particular type. This type is characterized by earliness, small and hard grain, and well-developed spikelet characters in contrast to primitive vegetative characters. In western Africa, margaritiferum sorghums are grown in high-rainfall areas and the grains are cooked and eaten as rice.

The existence of these three groups was confirmed by an evaluation of genetic distance based on isozyme analyses (at Montpellier) and morphophysiological classification (in Burkina Faso). The conclusion is that guinea sorghums have two independent centres of domestication: one in western Africa and another in southern Africa. The Indian guinea sorghums probably originated in southern Africa. The origin of margaritiferum has yet to be determined.

Tagging Favourable Traits from Wild Sugarcane

The genetic base of sugarcane cultivars is made up of only a few clones of two species, *Saccharum officinarum* and *S. spontaneum*. Fifty wild *S. spontaneum* clones were analyzed using molecular markers to determine the organization of the two species in an effort to identify new sources of variability. About 30 heterologous nuclear and cytoplasmic probes from maize—a related species—were used; they proved to be a powerful tool that could be used for accurate characterization of a wider sample of clones from the genus *Saccharum*.

Genome mapping of sugarcane was undertaken in a comparative study with maize. Twenty-eight maize probes fell into six linkage groups in the sugarcane genome. Homology was observed between large portions of the genomes of the two crops. Therefore, information on the location of useful genes in maize could serve to indicate the location of similar genes in sugarcane.

As there is little recombination in sugarcane, only a limited number of probes are needed to tag an entire chromosome. *S. spontaneum* chromosomes were tagged with markers to identify their phenotypic effects so that they can be combined more effectively in breeding material.

Molecular Markers for Banana

Three molecular marking techniques were used to establish a database on the genetic diversity of the genus *Musa* and to construct its genetic map. The techniques included isozyme electrophoresis, RFLP analysis, and random amplified polymorphic DNA (RAPD) analysis. The genetic map currently comprises 32 markers, of which 20 fall into 6 linkage groups. The map will be used to mark segregation of agronomic traits such as resistance to black Sigatoka (*Mycosphaerella fijiensis*). Genetic mapping will also provide a basis for the manipulation of sterility in breeding programmes that use wild and cultivated diploid material.

The size of the banana genome was determined by flow cytometry. It is interesting to note that this is a small genome comparable to that of tomato or rice.

New Guidelines for Citrus Breeders

IRFA's citrus research is aimed at the development of material that combines high yields and resistance to local diseases, particularly for small orchards in the tropics.

Polyembryony is a significant factor in citrus breeding programmes. IRFA scientists used RAPDs to distinguish

■ PRODUCTS FOR DEVELOPMENT

A Laboratory Kit for Hevea

Biotrop designed a field-usable isozyme electrophoresis kit for Hevea *clones in plantations. The technique was simplified so that it does not require a centrifuge. The kit was successfully tested on two occasions in Côte d'Ivoire in 1991. At the Institut des forêts (IDEFOR), it detected 5% off-types in the budwood gardens of a widely distributed clone. As these gardens are a source of plant material that is multiplied and distributed to plantations, even small errors can have serious consequences.*

In a commercial plantation, of the 31 clones that were analyzed, 2 were not true-breeding and 3 were heterogeneous. Annual economic losses due to such errors can amount to hundreds of thousands of dollars in a medium-size plantation.

Seed and Cuttings from Trees

*The commercial tree plantation in Côte d'Ivoire made remarkable progress. The seed orchard with 100 selected clones of teak (*Tectona grandis*) attained full yield potential.*

The seed—obtained through open pollination between clones—is used for planting 700-1000 ha annually. In 1991, cuttings of 115 Triplochiton scleroxylon *clones selected and supplied by CTFT were used by the national forest development corporation, Sodefor, to produce 280 000 cuttings of a multiclonal variety. A similar operation for* Gmelina arborea *led to the production of 250 000 cuttings from about 60 selected trees.*

accurately between plants obtained through normal sexual propagation (zygotic plants) and those from the nucellar tissue of the maternal parent (nucellar plants). This distinction is useful for selecting and mass-propagating elite rootstock. RAPDs were also used to fingerprint varieties belonging to the genus *Citrus*. For this purpose 16 RFLP nuclear probes with single-copy genes were applied to 29 varieties of different *Citrus* species.

Six *Citrus* hybrid progenies were specially bred at the INRA-IRFA station in San Giuliano, Corsica, for genome mapping. A comparison of parent and progeny genomes using RFLPs revealed an abnormal transfer of certain genes linked to desirable agronomic characters. These observations are useful for designing appropriate variety development strategies.

Flow cytometry provided additional information on the genome. The genome size in diploid plants varies for the six major *Citrus* species. Citron has the largest genome followed by pomelo; the smallest is that of mandarin. The results were confirmed by RFLP analysis. The genome architecture suggests a trend towards the formation of three major groups: mandarin, pomelo, and citron. This explains problems usually faced in interspecific breeding programmes.

■ Development of Varieties

Wide Crosses

Wide crosses in rice were studied in a collaborative project between the International Rice Research Institute (IRRI), ORSTOM, and CIRAD. Progeny of the initial backcrosses used in the study were supplied by IRRI. Introgression of a wild species, *Oryza brachyantha*, in the cultivated species, *O. sativa*, was analyzed. RFLP molecular markers showed the existence of a large number of recombinations despite low chromosome pairing during meiosis. An RFLP method using nonradioactive probes was devised for rice; it is suitable for use in the South.

The western African guinea sorghums have excellent grain quality; they are also suited to local conditions and

widely accepted by farmers. Other races, kafir and caudatum, were screened in Burkina Faso for characters that will raise their yield potential. But recombination of complementary characters through crosses of guinea with kafir and caudatum appeared difficult until now. IRAT crossed a kafir sorghum with a guinea sorghum from each of the three groups (western African, southern African, margaritiferum) and studied 33 morphological characters in the progeny to determine the cause of this difficulty. F_1 lines showed good fertility. From the F_2 lines it could be seen that the characters recombined independently; the parent genotypes were therefore compatible. The morphological variability of the guinea sorghums was fully reproduced in the F_2 populations as a whole. The absence of expected recombinations in the F_2 lines can be attributed to the large number of dominant alleles in the guinea parent rather than cytological phenomena.

The study highlighted the need for methods that increase the number of recombinations. Observations should cover a maximum number of individuals in the early generations to increase the probability of recombination of recessive characters. Parent material from genetically distant groups should be used to create a wide genetic base.

In Brazil, IRAT works with Rhône-Poulenc and Callahan, a seed company from the USA, to acclimatize temperate maize material developed in the USA. The three main characters to be selected from this material are stem quality, earliness, and yield potential. Reciprocally, tropical material with resistance to leaf and virus diseases could be used to improve temperate maize. Progeny from crosses were tested alternately in tropical (Campinas, Brazil) and temperate (Indianapolis, USA) conditions. Promising results obtained in Brazil will lead to the development—in 3 years—of new types of hybrids for the tropics. However, scientists are cautious about accidental introduction of disease susceptibility owing to genetic manipulations. Callahan introduced certain types of resistance in its breeding programmes.

Recurrent Selection in Self-Pollinated Crops

Recurrent selection is applied to populations whose individuals can be cross-pollinated. It is based on alternate cycles of selection and recombination. The improved populations can be used as such or as sources for new cultivars. This method leads to a gradual concentration of favourable genes, which ensures slow but steady progress. In self-pollinated crops—where there is no natural cross-breeding—random mating is achieved through the use of genic male sterility.

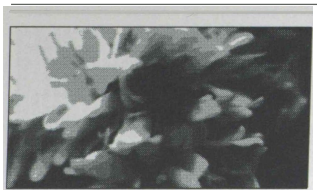
IRAT has done pioneering work in adapting recurrent selection to rice. The method is used in cultivar development programmes that aim to improve a large number of polygenic characters such as resistance to cold, drought, and rice blast. For this work IRAT worked with the Empresa Brasileira de Pesquisa Agropecuária-Centro Nacional de Pesquisa de Arroz e Feijão (EMBRAPA-CNPAF), Brazil, using male-sterile material supplied by IRRI. Twenty-one populations (11 *indica*, 9 *japonica*, 1 *indica* x *japonica*) were developed for various regions. Two other populations (CNA-IRAT 4, CNA-IRAT 5) developed in Brazil are made available to the international scientific community.

CNA-IRAT 4, an *indica* population, is intended for irrigated systems. It is currently undergoing its second selection cycle and is used in crop improvement work at two Brazilian research institutes. Two subpopulations for the hybrid breeding programme were also derived from CNA-IRAT 4.

CNA-IRAT 5, a *japonica* population for upland rice cultivation, is also in the second selection cycle. It is used for developing upland cultivars through selection for multiple characters in Brazil. It also serves as a source of male sterility in Argentina and as a base population for improving polygenic resistance to rice blast in Brazil and Côte d'Ivoire.

The *japonica* population CNA-IRAT 1 MD1 was designed for irrigated systems in the high-altitude areas of Madagascar. It is currently undergoing its first selection cycle. The objective is to develop resistance to low temperatures and local diseases.

The recurrent selection programme on three sorghum populations uses the same source of male sterility, ms3. In Burkina Faso, a composite made up of selected lines of different origin is in the second selection cycle. Each selection cycle increases the probability of extracting elite



lines. In Mali, two populations were developed independently and will be combined to form a single population that will consolidate complementary characters. The first population is made up of local guinea ecotypes selected for hardiness and grain quality. The second is made up of caudatum material with a high yield potential but poor grain quality according to consumers. The two populations will also be used independently for their individual characters.

Haploidy and Mutagenesis

Haploid bananas were developed by IRFA simultaneously by androgenesis (in Guadeloupe) and by induced gynogenesis using irradiated pollen (at the Centro Agronómico Tropical de Investigación y Enseñanza, CATIE, Costa Rica). Preliminary results were confirmed on a larger set of plants in Guadeloupe; they showed the suitability of this method for genetic improvement of banana.

Anther culture was used by IRAT to rapidly fix lines either for irrigated rice in the Mediterranean region or for upland rice in the tropics. In 1991, 323 doubled haploids obtained from five crosses in Guadeloupe were evaluated in southern France in collaboration with the Centre français du riz (CFR). The results showed expected uniformity and 54 lines suited to the Mediterranean region were selected. This was the first time that haploids were used in the Camargue, southern France. The excellent results will lead to a modification of IRAT's rice breeding programme in the Camargue. Doubled haploids from Guadeloupe were also introduced in breeding programmes for tropical upland rice. A doubled haploid line from IRAT 216 x IRAT 177 was included in the IRAT cultivar catalogue. This success confirms the suitability of the haploid method, which can be widely used by breeders in western Africa.

In Côte d'Ivoire, IDEFOR and IRCC continued their work on the identification and use of cocoa haploids. Spontaneous haploids were found in low numbers by screening germinating beans. IRCC used irradiated pollen (50-100 Gy) to increase the number of haploids and that of genotypes producing haploids. F_1 hybrids from doubled haploids were field-tested for uniformity and combining ability.

Consumers prefer seedless mandarins. But this character is seldom obtained through natural hybridization. IRFA aims to increase the propensity of the plant material to express this character. It developed isomutants by irradiating nucellar calluses for greater control over the process and for reducing the risk of chimera trees. The appropriate gamma ray dose as established through experiments ranges from 160 to 180 Gy.

Networks for Variety Development

IRAT coordinates a variety development programme for upland and aquatic rice; eight western African countries of the Conférence des responsables de la recherche agronomique africains (CORAF) participate in this programme. National organizations benefit from the pooling of plant material and the synergy created by the regional thrust. Collaborative work between the Institut des savanes (IDESSA) and IRAT in Côte d'Ivoire is now part of the regional programme. Ten new cultivars were developed during the year through this collaborative effort and added to the IRAT catalogue. One new cultivar was developed in Togo and two each in Benin and Burkina Faso.

IRCC launched a *Coffea arabica* hybrid development programme within the Promecafé network in Central America. The hybrids will be screened for yield and resistance to nematodes, rust, and coffee berry disease.

True-to-Type Material with In-Vitro Culture

Microcutting and Meristem Culture

Hevea microcutting technology was applied to 10 commercial clones and multiplication rates were increased. The work was carried out as part of an agreement between IRCA and the Société de microbouturage de l'hévéa (SMH), France. More than 30 000 plantlets, including 3000 of the cultivar IRCA 18, were produced and dispatched to acclimatization units in

Côte d'Ivoire and Gabon for testing. The unit in Gabon was established in 1991 at the Hévégab commercial plantation and a team of trained staff was formed.

After 4 years of production, arabica plants obtained from in-vitro culture continued to give excellent results. The plants were true-to-type and material produced from microcuttings was satisfactory.

Banana is a widely grown crop for which commercial-scale production of plantlets is developing rapidly. Faced with an increasing demand for plant material, Vitropic, a subsidiary of CIRAD, produced more than 1 million plantlets in 1991; they were mainly distributed in Latin America and Africa. The only difficultly is the appearance of variants. IRFA developed a strategy to reduce this risk in commercial production and a method for eliminating variants at an early stage. Further improvements are under way.

Somatic Embryogenesis

IRHO and ORSTOM have adapted vegetative propagation processes for mass production of oil palm plant material. Somatic embryogenesis on solid medium advanced to pilot production stage. More than 1 million ramets were produced for Côte d'Ivoire, Malaysia, and Indonesia. Field observations on the regenerated plants provide valuable information that will serve to refine the method. For most clones, all individuals produced by this method were normal. Scientists now seek an early marker to indicate true-to-type multiplication at laboratory stage for those clones that show variations.

Mission connaissance et amélioration des plantes

Scientific Coordinator
Jacques Meunier (until 28 Feb 1992) *Michel Jacquot* (from 1 Mar 1992)

Deputy Coordinator
Jacques Schwendiman

Scientific Committee

- **Chairperson**

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- **External Members**

André Charrier, ORSTOM and ENSA Montpellier

Alain Deshayes, INRA

Yves Hervé, ENSA Rennes

- **CIRAD Members**

One representative from each department

Somatic embryogenesis in shaken liquid medium was successfully attempted on six oil palm clones. This technique will help to reduce production costs, increase in-vitro proliferation rates, and improve output quality. Moreover, the embryos are not densely packed and their development is synchronous. Field observations are under way in Côte d'Ivoire to check whether they are true-to-type.

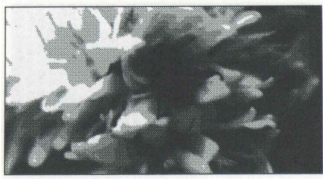
The results were achieved through the joint efforts of ORSTOM, IRHO, several university laboratories, and planters. This type of adaptation of laboratory techniques to commercial production can serve as a model for other crops.

For coconut, IRHO succeeded in obtaining embryos and plantlets of five genotypes through somatic embryogenesis. The method is reproducible. Efforts will now concentrate on the regeneration phase and then on embryo multiplication for mass production.

IRCA's work on somatic embryogenesis of *Hevea* led to significant progress in understanding the metabolism of water and endogenous growth regulators in relation to carbon and mineral nutrients. Embryo production, germination, and maintenance of embryogenic capacity through cultures were thus improved. The influence of genotype and culture conditions on callus friability was determined. Genotype and composition of the nutrient medium (particularly calcium content) determine whether somatic embryos are formed from single or multiple cells.

Research on somatic embryogenesis from leaf explants of coffee is under way for *Coffea arabica* and *C. canephora*. The advantage of such calluses is that they can be cultured in liquid medium for either mass production of somatic embryos or genetic transformation. High-frequency or prolific embryogenic calluses were easily produced with *C. canephora*, but the method was less successful with *C. arabica*. Investigations are under way on plant and cell mechanisms that prevent embryogenesis.

IRFA developed new approaches to mandarin in-vitro cultures. Mandarin ovules collected 3 weeks after flowering were cultured on solid media. Special techniques were developed to control callogenic and embryogenic potential. Callogenic potential is used to



enhance a collection of 25 stabilized lines in the form of calluses. Embryogenic potential is used in liquid medium for commercial production of true-to-type rootstocks.

Somatic embryos of cocoa were obtained for the first time by IRCC from petals.

Somatic embryogenesis in banana was first applied to seeded diploids and the triploid cultivar, Bluggoe. It is now applied to the Cavendish subgroups (mainly cv Grande Naine) and plantain (cv Curraré), and the first somatic embryos were obtained at Montpellier and CATIE, Costa Rica. After germination, certain somatic embryos developed into hardening plantlets. Triploidy in these plantlets was checked by flow cytometry.

Genetic Transformation

Genetic transformation programmes at CIRAD currently concentrate on a limited number of crops. In addition to the use of *Agrobacterium tumefaciens* as vector, the Biotrop laboratory tested physical methods of transformation. In 1991, the laboratory acquired a particle gun and an electroporator.

Somatic embryogenesis research on banana aims at the successful regeneration of plants from transformed in-vitro material. Cell suspensions were prepared for introducing genes that provide resistance to the cucumber mosaic virus (CMV), which mainly attacks plantain.

Genetic transformation of coffee aims to incorporate resistance to leaf miners and leaf-feeding caterpillars (*Epicampoptera* sp.). The first phase of obtaining protoplasts from calluses and cell suspensions raises no further problems and these protoplasts can now be developed into microcalluses. But at the genetic engineering stage, initial electroporation treatments led to high protoplast mortality. The technique needs to be refined. Promising preliminary results were obtained with the particle gun tested on leaf explants and embryogenic cell suspensions. The potential of genes from *Bacillus thuringiensis* that code for insecticidal toxins was evaluated. About 10 toxins were laboratory tested; of these 3 proved to be effective against the leaf miner.

The progress made in rice plant regeneration, particularly during 1991, enables IRAT to undertake genetic transformation. The regeneration process is now routinely carried out through the different stages: establishment of cell suspensions from zygotic embryo calluses and anther microspores, production of protoplasts, and regeneration of embryos (0.6% frequency) and of plantlets (50% success rate). The three *japonica* used for these experiments are well known cultivars; IRAT 177 is a tropical upland cultivar, and Pygmalion and Miara are Mediterranean cultivars. A total of 750 plants were obtained from Miara, which flowered normally in greenhouse grow-outs. Plantlet diploidy was ascertained by flow cytometry. The transfer of male-sterile cytoplasm for hybrid development is under way in collaboration with the University of Nottingham, UK. Transfer of a *Bacillus thuringiensis* gene that codes for a toxin against stem borers is under way.

The same *B. thuringiensis* gene was introduced in cotton using *A. tumefaciens* as the vector. IRCT, in collaboration with INRA, identified a particularly active *A. tumefaciens* strain, determined the conditions for cocultivation of the vector with embryo calluses, and developed a transfer efficiency test. The elimination of the vector by using kanamycin or a herbicide after the gene transfer is being studied.

Variety Testing Networks

African and Mediterranean Networks for Rice

IRAT's rice breeding programme participates in several networks for evaluating newly developed varieties.

CORAF's rice network, of which CIRAD is a member, developed common descriptors and experimental designs for evaluation. These facilitate statistical interpretation of test results from 15 member countries. The methods were applied in several countries and will ensure a better evaluation of yield stability across locations. The results will also indicate the optimum cropping intensity for each cultivar.

IRAT also participates in the International Network for Genetic Evaluation in Rice (INGER) coordinated by the international agricultural research centres. Cultivars developed by IRAT are evaluated throughout the network. In 1991, among the superior cultivars identified by the African section of INGER for upland rice, five were developed by IRAT; these are medium-duration IRAT 161 and IRAT 170, and short- duration IRAT 144, IRAT 262, and IRAT 268.

In 1990, at the initiative of the Food and Agriculture Organization of the United Nations (FAO), a network was created to link the rice-growing countries in the Mediterranean region and Eastern Europe. Joint trials were organized in 1991 to test a set of 24 cultivars and 36 potential parents in local conditions. IRAT participated in this operation through CFR.

Stability of Maize Varieties

Fifteen hybrids developed by IRAT in Burkina Faso and Brazil (in collaboration with Rhône-Poulenc) were tested across IRAT's multilocational maize network in 1989 and 1990. The trials were conducted at 55 locations in 17 countries of Latin America, western and central Africa, Oceania, and the Indian Ocean region. Compared with the best hybrids from other breeding institutions, certain hybrids developed in Brazil performed well at all locations. IRAT 354 (named IR 30 in Brazil), a superior performer, is already marketed.

A modified statistical analysis of yield stability involves weighting of trial results. It allows a more reliable evaluation of stability parameters. According to this analysis, certain cultivars—including IRAT 354—show high stability. Other cultivars, such as IRAT 355, need specific cropping conditions despite their high yield potential.

African Sorghums

New sorghum lines developed by IRAT are tested through the network of the Semi-Arid Food Grain Research and Development (SAFGRAD), Burkina Faso. Seventeen countries in western and central Africa are linked through this network. Cultivars are screened for yield performance, and resistance to *Striga* and diseases.

■ PRODUCTS FOR DEVELOPMENT

Adoption of Rice Cultivars

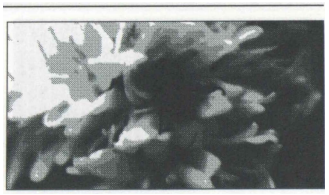
In tropical Africa, after 30 years of cooperative work, the area planted to IRAT cultivars reached 50 000 ha, which accounts for 5% of the total upland rice-growing area. In Brazil, where cooperative activities are more recent—for only 10 years—900 000 ha are already sown to cultivars developed jointly by EMBRAPA-CNPAF and IRAT; this corresponds to 20% of the total upland rice-growing area in Brazil. Rio Verde (IRAT 216), the most recent product, already covers 50 000 ha.

IRAT 112, IRAT 144, IRAT 216, and some others are modern upland rice cultivars that have already entered local farming systems. Average paddy yields in farmers' fields attain 4-5 t/ha; these cultivars also have wide adaptability. Others require more specific conditions; IRAT 351, for example, is intended for high-altitude areas.

This difference in the adoption rate for material of the same quality shows that transfer of research results to farmers' fields depends on the level of agricultural development.

Certified Disease-Free Citrus Plant Material

In 1991, the INRA-IRFA station in San Giuliano was nominated by IBPGR as one of the five centres in the world for distributing material that is certified free of virus and virus-like diseases. It delivered 400 000 buds of elite cultivars of mandarin, orange, grapefruit, lemon, and lime.



The best cultivars are then selected by the Institut du Sahel for trials in farmers' fields in a subnetwork of seven countries. In 1991, one of the cultivars recommended to farmers was CE 180-33, an early and drought-resistant cultivar that was jointly developed by IRAT and the Institut sénégalais de recherches agricoles (ISRA).

Citrus in the Tropics

Over the past 10-15 years, certified disease-free citrus material from the INRA-IRFA station in San Giuliano has been acclimatized to tropical conditions.

In Martinique, a set of eight cultivars of mandarin, pomelo, and lime and hybrids of mandarin and orange were selected for monsoon areas after a performance study of 160 cultivars. In Réunion, which has a similar climate, 150 cultivars were tested under high pest and disease pressure. About 10 cultivars are already grown by local farmers and produce high yields. These include Beauty (mandarin), Orlando (tangelo, which is a hybrid between mandarin and pomelo), and Ortanique (tangor, which is a hybrid between mandarin and orange). In New Caledonia, the collection of 150 cultivars arrived at production stage only in 1991; further studies over another three or four cropping seasons are needed before recommendations can be made on cultivars suited to South Pacific conditions.

The objective for the Sudano-Sahelian regions is to improve vitamin content in the human diet. In addition, cultivars with adequate sugar and low acid contents are sought for on-farm consumption, and rural and urban markets. Trials were conducted in northern Côte d'Ivoire and northern Cameroon. A collection of 120 cultivars was tested and 10 mandarin and orange cultivars, including hybrids, were selected. They gained wide acceptance among villagers because of their taste, yield, and profit potential and are already grown in village orchards.

Evaluation of Oil Palm Clones

The first 40 oil palm clones produced through somatic embryogenesis by ORSTOM and IRHO have been planted over about 100 ha in Côte d'Ivoire, Indonesia, and Malaysia since 1984. Preliminary results were obtained with 14 oil palm clones between 3 and 6 years after planting. Oil yield increased by an average of 11%—up to 25% in the case of the four best clones—compared with oil palms from commercial seed. This yield gain was confirmed over the 2500 ha of plantations in the world that use in-vitro plant material.

The trials provided valuable information on heritability of certain characters. Phenotypic and genotypic effects can be separated by using genotypically uniform material derived from in-vitro cultures. Heritability of bunch production and oil yield characters was higher than expected. As there is no antagonism between the two characters, any progress in improving one of them finally leads to higher oil yield.

■ PRODUCTS FOR DEVELOPMENT

Eucalyptus in Industrial Plantations

In Congo, new eucalyptus clones for commercial plantations were distributed and field-tested. These include the first clones from Eucalyptus urophylla x E. grandis *and* E. urophylla x E. pellita *crosses. Production exceeded that of current varieties by at least 30%.*

▼ *Theses Completed in 1991*

Variabilité des descendances de trois croisements de riz (*Oryza sativa *L.) fixées par haplodiploïdisation et par filiation unipare [Variability in progeny of three crosses of rice (*Oryza sativa* L.) fixed by diploidization of haploids and single-seed descent] by Brigitte Courtois (France); Ecole nationale supérieure agronomique, Montpellier; IRAT staff.

***Mise en œuvre d'une méthode de marquage non radioactif de l'ADN pour l'étude des RFLP chez le riz : cartographie du génome et suivi des introgressions entre* Oryza sativa *et* O. brachyantha** [Application of a method for nonradioactive DNA markers to study RFLP in rice: genome mapping and monitoring of introgressions between *Oryza sativa* and *O. brachyantha*] by Olivier Panaud (France); Université Paris XI, Centre d'Orsay; trainee at IRRI, ORSTOM, and IRAT.

***Contribution à la recherche d'haploïdes de* Sorghum bicolor *(L.) Moench par gynogenèse* in-situ *après croisement intergénérique, pollinisation avec du pollen irradié et par androgenèse* in vitro** [Contribution to the identification of *Sorghum bicolor* (L.) Moench haploids by in situ gynogenesis after intergeneric crossings, pollination with irradiated pollen, and anther culture] by Aurélio O. Virgo-Brown (Panama), Université Montpellier II; IRAT trainee.

Maturation et sénescence de l'ananas (*Ananas comosus *[L.] Merr.) en Côte-d'Ivoire [Maturation and senescence in pineapple (*Ananas comosus* [L.] Merr.) in Côte d'Ivoire] by Alain Cellar; Université Montpellier II; IRFA trainee.

Contribution à l'étude de l'origine, la domestication et la dispersion de l'espèce* Gossypium barbadense *L. : polymorphisme enzymatique, morphologique et agronomique des populations sauvages, subspontanées et cultivées [Contribution to the study of the origin, domestication, and spread of the species *Gossypium barbadense* L.: enzyme, morphological, and agronomic polymorphism in wild, subspontaneous, and cultivated populations] by Juan Lazo Alvarez (Peru), Université Paris XI, Centre d'Orsay; IRCT trainee.

Micropropagation du palmier à huile (*Elaeis guineensis *Jacq.) en milieu liquide [Micropropagation of oil palm (*Elaeis guineensis* Jacq.) in liquid medium] by Blandine de Touchet (France); Université Paris XI, Centre d'Orsay; trainee at ORSTOM and IRHO.

Connaissance de la morphogenèse du palmier dattier (*Phoenix dactylifera *L.). Etude* in situ *et* in vitro *du développement morphogénétique des appareils végétatif et reproducteur [Morphogenesis of date palm (*Phoenix dactylifera* L.). In-vitro and in-situ study of morphogenetic development of vegetative and reproductive systems] by Nadia Bouguedoura-Keddad (Algeria); Université des sciences et de la technologie Houari Boumediene, Algiers; GERDAT trainee.

***Influence des caractéristiques de l'atmosphère (gaz carbonique, éthylène, eau) et de la disponibilité en eau du milieu sur les cultures* in vitro *d'*Hevea brasiliensis** [Influence of atmosphere parameters (carbon dioxide, ethylene, water) and water supply in the medium on in-vitro cultures of *Hevea brasiliensis*] by Eric Auboiron (France); Université Montpellier II; IRCA trainee.

***Recherche de marqueurs de la juvénilité-maturité et de la réactivité* in vitro *lors du microbouturage chez* Hevea brasiliensis. *Relation entre la juvénilité et la réactivité* in vitro** [Identification of juvenility-maturity markers and in-vitro reactivity during microcutting of *Hevea brasiliensis*. Relationship between juvenility and in-vitro reactivity] by Valérie Haffner (France); Université Paris VI; IRCA trainee.

Etude des relations entre la teneur en sucres du latex et la production. Approche des mécanismes du chargement en saccharose des laticifères d'*Hevea brasiliensis *Muell. Arg. [Study of the relationship between latex sugar content and latex production. Approach based on sucrose loading mechanisms in laticifers of *Hevea brasiliensis* Muell. Arg.] by Régis Lacrotte (France); Université Montpellier II; IRCA staff member.

Facteurs de la fructification chez le cacaoyer (*Theobroma cacao *L.). Influence sur le nombre de graines par fruit [Fruiting factors in cocoa (*Theobroma cacao* L.), with special reference to number of beans per pod] by Philippe Lachenaud (France); Institut national agronomique, Paris-Grignon; IRCC staff member.

Contribution à l'étude de l'embryogenèse somatique chez le cacaoyer (*Theobroma cacao *L.) [Contribution to the study of somatic embryogenesis in cocoa (*Theobroma cacao* L.)] by Philippe Chatelet (France); Université Paris XI, Centre d'Orsay; IRCC trainee.

Diversité génétique de* Frankia, *symbiote de* Casuarina equisetifolia *L. Johnson en Afrique de l'Ouest [Genetic diversity of *Frankia*, a symbiont of *Casuarina equisetifolia* (L.) Johnson in western Africa] by Laurent Maggia (France); Université Paris VII; trainee at ORSTOM and CTFT.

PLANT PROTECTION

Integrated pest management (IPM) has now become a universal strategy. It combines various complementary methods to maintain crop pest and parasite levels within economically acceptable limits. Pesticide use is reduced in an attempt to protect the environment. In 1991, after extensive consultation, the international agricultural research centres adopted a general policy to promote IPM. CIRAD's research is in line with this policy. New approaches to IPM are devised through collaboration with a large number of partners. Research is leading to a more accurate understanding of pests and parasites. Various methods are integrated for crop-specific control; the resulting strategies offer tropical countries more effective, easier, and environment-friendly solutions for pest and parasite control.

Diagnosis and Variability

The Canopy Raft Mission

CIRAD has been actively involved in the canopy raft[1] operation since the first mission in 1989 in French Guiana. It was also on the team with members from 13 countries that undertook the second mission in southwestern Cameroon from October to December 1991. The mission was coordinated by the Université Montpellier II and sponsored by Fondation Elf, France. The objective was to study the biology of a tropical rain forest canopy. Methods for sampling forest flora and fauna were developed by the CIRAD Weed Research Laboratory.

Leaf samples—total area 117 m^2—were taken from the ground and canopy to study the density and vertical distribution of insects. A paradoxical find was that although the insect population in the canopy was three times that at ground level and mainly consisted of leaf feeders, the canopy samples were less damaged (2.5-5.5%) than those taken from the ground (10%). This is probably because, in the canopy, ants protect the vegetation against many insects and foliage is replaced faster. Both explanations need to be examined during subsequent missions.

The insect traps yielded 10 000 specimens, which is enough material for extensive studies. The quantity and diversity of the catch increased fivefold with improved traps compared with conventional traps.

One thousand scanned images of leaves and stem sections were taken; these will be integrated in the expert systems PANTROP and AFLANE for identifying botanical species.

CIRAD with its know-how in scientific information technology was asked to provide computer support for the entire operation.

Remote Sensing for Locust and Grasshopper Studies

Prevention of locust and grasshopper outbreaks is a major concern for the Sahelian countries. Remote sensing can be an effective monitoring tool but the data need to be checked against ground truth. In 1991, satellite image data (Landsat, Météosat, NOAA, SPOT) covering 300 km^2 of dry-season vegetation in Tamesna, northern Niger, were interpreted and evaluated. The results will be compared with 800 photographs taken during airborne surveys by plane (6000 km of flights, 30 h of flying time) and with support data from ground surveys (300 sites, 80 h of helicopter flying time). The operation was conducted by a team from CIRAD's locust and grasshopper studies unit, PRIFAS, in collaboration with the Bureau pour le développement de la production agricole (BDPA), France; it was funded by the French Ministry of Cooperation and Development.

Population Analysis of Parasitic Fungi

Phytophthora is a parasitic fungus that attacks perennial tropical crops such as coconut and cocoa. Population analysis of the parasite is useful for developing resistant varieties and chemical control treatments.

1. A canopy raft is a 600-m^2 platform that is transported by a hot-air airship and deposited on the tree tops. Scientific observations and experiments on canopy biology are conducted from the platform, while the airship returns to base.

Recent studies implicated several *Phytophthora* species, which show wide variability. *P. palmivora* is therefore not the only parasitic species. The *Phytophthora* genome was analyzed through protein isozyme and restriction fragment length polymorphism (RFLP) studies to indicate the origin and relationship between species for a more accurate taxonomic classification.

Isozyme profiles established by IRHO and IRCC revealed three new species (*P. arecae*, *P. nicotianae* var. *parasitica*, and *P. katsurae*) on coconut and three others (*P. megakarya* made up of 3 populations, *P. capsici*, *P. citrophthora*) on cocoa. It is often difficult to distinguish between *P. capsici* and *P. citrophthora* because they show strong morphological variation, even if it is known that *P. citrophthora* occurs only in Latin America. The isozyme study results were confirmed by RFLP analysis.

Mycosphaerella fijiensis causes black Sigatoka of banana and plantain. IRFA established a gene bank based on a type isolate of this fungus to analyze its diversity. The bank is made up of large DNA fragments. A large number of these probes corresponding to unique sequences were isolated for rapid analysis of population structure. Mitochondria DNA was purified recently to identify additional probes.

A homologous probe of *Fusarium oxysporum*, the fungus that parasitizes oil palm, enabled IRHO to identify *Fusarium oxysporum* f. sp. *elaeidis.* Further studies led to the identification of four African groups and one South American group (related to one of the African groups) within this pathotype.

RFLP analysis was used to distinguish between rice-pathogenic strains of *Magnaporthe grisea* and those of other Gramineae. This indicates parasite specificity. Polymorphism in the African population of rice-pathogenic strains is being analyzed using molecular probes. This research, together with that on *Fusarium*, was conducted by IRAT in collaboration with the Université Paris XI.

Virus Genome Studies

The obvious symptom of peanut clump virus (PCV) infection is severe stunting. In samples from various African countries, IRHO identified rod-shaped virus particles similar to PCV particles, but the plants showed different symptoms.

Preliminary mechanical inoculation tests on *Chenopodium amaranticolor* plants also produced variable symptoms.

Forty-four PCV isolates were identified in this material. Enzyme-linked immunosorbant assay (ELISA) tests using polyclonal and monoclonal antibodies were carried out on the isolates. Differences in their reactions showed that they belonged to five serogroups. Identification of PCV disease is therefore not as simple as it was once believed because the virus causes variable symptoms in the field.

The virus genome was studied as serological tests are not always conclusive. Two RNAs were identified, one of which is shorter in certain isolates. cDNA and cRNA (complementary DNA and RNA) probes were prepared to determine sequence homology among isolates.

A collaborative project between the Institut national de la recherche agronomique (INRA) and IRCC led to further progress in the study of the cocoa swollen shoot virus. It showed that the virus genome is made up of DNA and that it belongs to the badnavirus group. Sequencing is under way. Sequence amplification by polymerase chain reaction (PCR) can be used for wider applications such as epidemiological studies and development of resistant cocoa varieties.

Biomodel of the Desert Locust

The project for developing a biomodel of the desert locust (*Schistocerca gregaria*) was jointly financed by the European Development Fund (EDF) and the French Ministry of Cooperation and Development, and carried out by Prifas. The SGR biomodel, as it is called, is a descriptive tool for forecasting outbreaks. It is intended for use in about 60 countries affected by this serious problem. The biomodel was tested using 1985-1990 data from the European Centre for Mid-term Weather Forecasts (ECMWF), UK, and Météo France. Reports published by the Food and Agriculture Organization of the United Nations (FAO) on grasshopper and locust activity during the same period were used to verify the accuracy of the SGR output. There was 80% agreement between the SGR predictions and the FAO reports for the hot season and 68% agreement for the cool season.

Expert Systems for Diagnosis

Two expert systems, DIACOT and DIANA, were designed by IRCT and IRFA to enable development corporations and farmers' organizations to detect the cause of abnormal conditions in cotton and pineapple crops. The models integrate pathological, entomological, and agronomic data. The diagnosis is based on symptoms and their interaction. In certain cases several diagnoses are proposed, each with a probability coefficient.

The systems use both plant- and plantation-based approaches but stress one of them. DIACOT, for cotton, has 480 rules and stresses the plant-based approach, whereas DIANA, for pineapple, has 200 rules and stresses the plantation-based approach.

DIACOT was tested in farmers' fields in Togo. The diagnoses proposed by the expert system were compared with those of a specialist. In 82% of the cases the answers were identical, in 9% the specialist was not certain of the diagnosis, and in the remaining 9% the answers were incorrect probably because the questions were not clearly stated by the expert system. On balance, DIACOT appears to be a good system. It will be made more user-friendly by simplifying the questions; images will also be added as they are preferred by users. It will be offered complete with recommendations for better crop management. DIANA will be tested according to the same procedure.

DIACOT and DIANA will be ready for field use in 1992. They will serve as diagnostic and training tools.

Diverse Control Techniques

Detection of Citrus Viroids

Among the 12 viroids currently identified for citrus, 3 cause serious diseases (exocortis and cachexia-xyloporosis) worldwide.

The INRA-IRFA station at San Giuliano, Corsica, produces large quantities of plant material for the Mediterranean countries, Latin America, and China. The material has to be free of contaminants, particularly viroids. Until recently, it could be indexed for safety only through observation of symptoms on indicator plants, a

INTERNATIONAL COOPERATION

ICRISAT and CIRAD Collaborate on Groundnut Disease Research

*An advantage of the Montpellier Research Centre for groundnut pathogen studies is that it is safely located outside the groundnut-growing zone. The joint projects by the International Crops Research Institute for the Semi-Arid Tropics (ICRISAT), India, and CIRAD focus on studies of pathogen variability. An ICRISAT scientist is studying PCV variability at the tropical and subtropical plant virology laboratory in Montpellier. Another ICRISAT scientist is working on the early leaf spot fungus (*Cercospora arachidicola*). Fungal isolates from most groundnut-growing areas in the world were collected at Montpellier. They were tested on a set of groundnut genotypes to detect possible host-parasite interactions and to compare pathogenicity.*

CIRAD Participates in the African Plant Virology Network

In recognition of the need for a structure to enable African scientists to pool their efforts and results, the Inter-African Phytosanitary Council of the Organization of African Unity (OAU) arranged a meeting of virologists. Eight African scientists and one CIRAD scientist met in Yaoundé in August 1991 to prepare the ground for the African plant virology network, RAVI. The General Secretariat of the network is based in Congo.

CEC Sponsors International Meetings

Two international seminars were organized by CIRAD in 1991. They were part of two projects financed by the Commission of the European Communities (CEC): one on vascular wilt of oil palm and the other on Phytophthora *diseases of coconut. The seminars were attended by scientists from Belgium, Côte d'Ivoire, Indonesia, Nigeria, the Philippines, Spain, the UK, and France.*

process which took 1-2 years. Other indexation methods are now being used to accelerate the process.

Viroid detection by electrophoresis proved to be reliable and efficient; it also reduced the observation period by 6 months. A bark fragment from a vitroplant was grafted to an Etrog citron. The viroids multiply rapidly because citron is highly susceptible. Six months later a fraction of nucleic acid extracted from young shoots was subjected to successive electrophoresis runs that revealed the presence of circular viroids. The test is highly sensitive and can detect up to nanogram quantities of viroids. It is now routinely used in Corsica. Current efforts focus on reducing the viroid multiplication period in citron.

Determination of Thresholds for Chemical Treatments

The occurrence of a pathogenic fungus in an agricultural zone or plantation does not necessarily signify the need for treatment. The fears of coffee planters in southeastern Mexico about epidemics of leaf rust (*Hemileia vastatrix*) in plantations undergoing modernization proved to be unjustified. According to an IRCC study, the disease becomes epidemic only late in the season and has little effect on production. This is because the inoculum reserve at the start of the growing period is depleted as the infected leaves fall during the dry season that follows coffee picking. Coffee planters can thus avoid unnecessary chemical treatments. The study also provided information on the epidemiology of leaf rust and offered an opportunity to test current methodology.

Similar epidemiological studies are under way in Guatemala and Costa Rica in cooperation with regional and national organizations (Promecafé, Anacafé, and Icafé), and in Papua New Guinea in collaboration with the PNG Coffee Research Institute. Each study seeks to establish the actual impact of the disease, including crop loss, to determine the need for chemical treatments, which are cost- and labor-intensive, and therefore should be used judiciously.

Plant physiology studies on coffee were carried out with the Centre d'études nucléaires (CEN) in Cadarache, France, to obtain more information on host-*H. vastatrix* relations. Light intensity and nutrient stress, mainly nitrogen deficiency, have an important effect.

Chemical control of *Phytophthora* pod rot of cocoa by injecting fosetyl-Al in the tree trunks gave disappointing results. The study, which was carried out in collaboration with the Institut de la recherche agronomique (IRA), Cameroon, showed the improbability of developing a promising method for chemical control of *Phytophthora megakarya*. Efforts should therefore focus on the development of resistant varieties. Clones with a high general combining ability for characters that reduce contamination were identified.

New Method for Protecting Cotton Crops

Pest control in cotton crops normally involves four to six treatments. In 15 years, average yields increased from 0.35 to 1 t/ha over 1 million ha in francophone Africa. Recent concern over costs and pollution has led to the adjustment of treatments according to the level of pest incidence.

Farmers need to be trained to adopt this approach. An intermediate method called *lutte étagée* was conceived by IRCT, IRA, and the Cameroon cotton development corporation, Sodecoton. The principle is to apply half the dose as scheduled and to use the other half only if pest incidence exceeds a predetermined level. The spraying technique is changed from ultra-low volume to low volume at 10 litre/ha so that different active ingredients can be mixed with water for pest-specific control.

The new method was tested at village level in almost all the countries where IRCT works. It has since been adopted over 3000 ha in Cameroon. The efforts resulted in substantial gains. In villages near Guider in the northern province, the method was adopted over 700 ha. In 1991, farmers spent only CFAfr6500/ha instead of CFAfr18 000/ha for conventional methods and obtained the same results. The establishment of farmers' organizations and self-motivation of farmers are the key factors of success for this method. Group leaders are responsible for operations such as insect counts and for decisions on treatments.

Farmers' Practices

The Compagnie française pour le développement des fibres textiles (CFDT), France, and IRCT launched a study

on farmers' use of inputs in cotton-growing areas. The study was financed by the French Ministry of Cooperation and Development. The preliminary survey conducted in Burkina Faso and Cameroon included a research methodology component. In Burkina Faso, the survey across 450 farms revealed that recommendations were not followed irrespective of the type of technology (manual, animal-powered, or motorized).

A difference in seed cotton yield of 600 kg/ha was observed between the farmers' crop and correctly treated plots established in the centre of the surveyed fields. Lower yields can be imputed to particularly high incidence of *Helicoverpa armigera* in 1991 and inadequate control of the pest. Farmers constantly apply less than the recommended dose. One of the reasons is that the cropped area is larger than that declared. The other is that inputs are diverted to the other crops, mainly cowpea.

Similar surveys will be carried out in Benin, Côte d'Ivoire, Mali, and Senegal in 1992. They will then be extended to all the countries of the network of the Conférence des responsables de la recherche agronomique africains (CORAF).

Resistance to Insect Pests

Among the IPM methods, cultivation of resistant varieties is suited to countries where farmers do not have the resources to pay for chemical treatments. Another advantage of this method is that it protects the ecosystem.

INRA and IRAT have been working together on tomato resistance to the leaf miner (*Liriomyza trifolii*) right from the initial stage. A wild tomato, *Lycopersicon cheesmanii*, was identified because of its complete resistance. It was crossed with tomato cultivars to produce a "tropical" population. Parent lines that combine useful agronomic traits with resistance to *L. trifolii* were laboratory- and field-tested in Senegal, in collaboration with the Institut sénégalais de recherches agricoles (ISRA). The seeds are now available for commercial production. This success has prompted IRAT to undertake a similar programme on melon.

Crops in the maize-growing areas of Latin America are attacked by the fall armyworm (*Spodoptera frugiperda*). IRAT used certain resistant maize populations from Guadeloupe and other material supplied by the Centro Internacional de Mejoramiento de Maíz y Trigo (CIMMYT), Mexico, to develop resistant varieties for the Caribbean region. Field trials were carried out under artificial and natural infestation. The material was scored for damage intensity; results from controlled treatments were more reliable. Selected resistant lines will be used in the variety development programme.

Field trials were conducted under artificial and natural infestation at the ICRISAT-CIRAD centre in Samanko, Mali, to test resistance of sorghum grain to the head bug *Eurystylus immaculatus*. Of the 12 western African sorghums selected from breeding trials by ICRISAT, 2 showed superior resistance in multilocational trials over the past 2 years. Further studies at the CIRAD Cereal Technology Laboratory showed that this resistance is apparently linked to physiological characters, mainly grain hardening during maturation. These characters will be integrated in the sorghum breeding program for the Sahel.

The maize stripe virus (MStpV) and maize mosaic virus (MMV) are both transmitted by the shoot bug *Peregrinus maidis*. IRAT's work in Réunion demonstrated that maize resistance to the diseases was directed against the vector, virus, and transmission. When maize genotypes were screened under artificial infestation, some were found to possess one form of resistance; rare cases possessed two. Honeydew analysis and electronic monitoring of insect behaviour on plants were undertaken for a detailed examination of resistance to *P. maidis*. Feeding habits of the vector were studied to determine transmission conditions.

■ PRODUCTS FOR DEVELOPMENT

Adoption of Biological Control by Coffee Planters

The coffee berry borer, Hypothenemus hampei *(Coleoptera), originated in Africa and was introduced into Central America through Brazil. But its natural enemies are not present in the new environment to control its development. A CEC project coordinated by CIRAD aims to introduce natural enemies from Africa into the coffee-growing countries of Central America.*

The programme initially focused on the introduction of the hymenopteran parasitoid Cephalonomia stephanoderis. *The parasitoids were captured by IRCC in Togo and sent to the quarantine laboratory at the International Institute for Biological Control (IIBC), UK. The parasitoids were then sent to the Centro de Investigaciones Ecológicas del Sureste (CIES), Mexico, for multiplication, and biological and ecological studies. After trial releases, the CIES distributed the parasitoids among research institutes in Guatemala, El Salvador, and Honduras. They were multiplied once again at the institutes.*

Public awareness campaigns were carried out among the coffee planters, who are mostly smallholders. They were trained to rear the parasitoids by simple techniques using locally available means. The results constitute an enormous success for the program. The next objective is to assist the planters in the organization of timely releases of the parasitoids.

Protecting Orchards in Réunion

Fruit flies are a severe problem in citrus and mango orchards in Réunion. Together with the local chamber of agriculture, IRFA developed a rational control strategy based on monitoring and insecticide treatment. Pheromone traps were used to catch male insects for monitoring changes in pest populations. In a scattered application, an insecticide mixed with a food attractant was spread on certain parts of selected trees in the orchards. As the treatments are based on monitoring results they are undertaken only when necessary and insecticide use is reduced. This method is effective, economical, and less polluting than others. It was first tested with a few fruit growers and readily accepted by others.

Nematode Resistance

Rapid screening techniques were developed for nematode resistance breeding programmes. Banana and pineapple in vitro-cultured plants and young coffee seedlings were inoculated with nematodes. Plant damage and changes in nematode populations were observed.

About 40 pineapple varieties belonging to the major species showed variable resistance to *Pratylenchus brachyurus.*

For banana, the technique showed the same range of susceptibility to *Radopholus similis* as observed in plantations. Moreover, the results were obtained within 8-10 weeks instead of 6 months in normal crop conditions.

In certain *Coffea canephora* lines, resistance to *P. loosi* was revealed within 2-3 months. Of the 89 *Coffea arabica* lines collected in Ethiopia, 73 were resistant to *Meloidogyne* sp. This resistance may be monogenic or oligogenic.

Genetic Engineering of *Bacillus thuringiensis*

The use of toxins produced by the bacterium *Bacillus thuringiensis* has opened new possibilities for IPM programs. The genes that code for endotoxin production in the bacterium are engineered into transgenic plants, or genetically modified strains of *B. thuringiensis* are produced for use as biopesticides. These strategies for crop-specific biological control need to be adaptable so that they can respond to changes in the pest complex and to the emergence of resistance in pests.

Toxins that recognize receptors in the coffee pest *Leucoptera* sp. were identified. The programme, which was conducted jointly by Plant Genetic Systems (PGS), Belgium, and IRCC demonstrated the methodology for discovering insect-toxin relations.

Transgenic plants were developed to control the following pests: *Helicoverpa armigera* (cotton), *Chilo supressalis* (rice), and *Leucoptera* sp. and *Hypothenemus hampei* (coffee).

Work on recombination of "customized" *B. thuringiensis* strains is progressing rapidly. Of the 18 genes that code for toxins, 8 can be used to control lepidopteran pests.

The number of possible combinations is so vast that it is difficult to find appropriate strains in natural conditions. The technique consists in isolating the genes, recombining them, and introducing them through a vector into a strain that has been rendered avirulent.

CIRAD biotechnologists have assembled avirulent strains and vectors in addition to the eight genes, which were obtained through collaborators in Canada, the Netherlands, and the USA. Cloning of the genes is under way. The recombined bacteria will be used to study resistance in pests, to produce stronger toxin combinations, and to extend the effect of *B. thuringiensis* to other pests.

Sex and Aggregation Pheromones

A large number of insects produce attractants or sex pheromones. CIRAD collaborates with the INRA Chemical Mediators Laboratory to study ways of using these substances for IPM programmes. Pheromones can be used to study natural population dynamics and for directly controlling pests.

Pheromones of *Setothosea asigna*, a lepidopteran leaf feeder of oil palm in Indonesia, were extracted, isolated, and synthesized. Capsules containing different pheromone mixes were placed in a palm grove. With one of the mixes, 400 males were captured in a single night. Many eggs in the next generation were infertile. Further experiments will be carried out to determine optimum conditions for using this mix.

Rhynchophorus palmarum, the American palm weevil, also transmits red ring disease. When males are near a host plant they produce an aggregation pheromone that attracts both sexes. Trapping efficiency increased fivefold when the synthetic aggregation pheromone was added to pieces of palm stem.

▼ *Theses Completed in 1991*

***Ecologie chimique du charançon des palmiers,* Rhynchophorus palmarum *(L.)* (Coleoptera : Curculionidae)**[Chemical ecology of the American palm weevil *Rhynchophorus palmarum* (L.) (Coleoptera: Curculionidae)] by Didier Rochat (France); Université Paris VI; IRHO trainee.

Les* Pseudococcidae *déprédatrices des racines de caféier (*Coffea arabica *L.) au Guatemala. Cas particulier de* Dysmicoccus cryptus *(Hempel, 1918) [Pseudococcidae root pests of coffee (*Coffea arabica* L.) in Guatemala with special reference to *Dysmicoccus cryptus* (Hempel, 1918)] by Armando Garcia Gonzalez (Guatemala); Université Paul Sabatier, Toulouse III; IRCC trainee.

Animal Production

Animal Nutrition

Pasture Resources

More information is needed on herbage resources to improve rangeland management. A total of 65000 samples of tropical African plants were collected and meticulously examined for the IEMVT herbarium. It is unique in that it also provides ecological information on the species. The information is stored in a databank for easy retrieval and use by specialists for management of pasture resources.

The botanical studies are reported in two publications. The first of the four volumes of *Enumération des plantes à fleurs d'Afrique tropicale* on flowering plants of tropical Africa was published in 1991. *Guide de reconnaissance des principales graminées de Nouvelle-Calédonie* is a

Development of livestock production in the tropics faces several challenges. Animal nutrition needs to be improved, but the new methods should not affect existing land use systems; inadequate knowledge and poor management of resources make this task even more difficult. The technical achievements of countries in the North may influence current thinking, but preservation and use of biodiversity in the tropics are primary concerns. Inventories of animal resources and biological studies are the only suitable means for protecting and optimizing these resources in relation to constraints in the South. Animal diseases seriously hinder development of livestock production in a context where veterinary services are still rudimentary. Development of diagnostic tools and effective preventive measures is an urgent priority. Through its work, CIRAD seeks to help decision-makers and producers respond to these challenges.

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handbook for nonspecialists to assist them in the identification of the main grasses in New Caledonia.

Monitoring of Grass Resources

IEMVT used satellite imagery for evaluating grass resources and monitoring the vegetation cover over a large area in southern Tamesna, Niger.

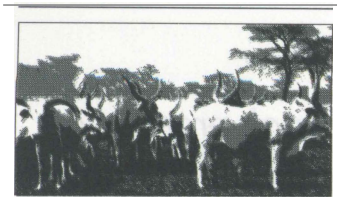
Ground-measured radiometric data were supplemented by grass biomass measurements taken at the same time through a large network. Yields can now be predicted on-site directly from radiometric readings because of good correlation between the normalized vegetation index for each type of vegetation cover and the grass biomass.

This methodological and applied research was jointly conducted by Nigerien and French specialists. It demonstrated that the method can be applied in the Sahel for quantifying and monitoring grass production.

For wider coverage, ground-measured radiometric data were replaced by Landsat and SPOT data. Maps of the grass cover were prepared for each year since 1985. When compared, they revealed a clear increase in pasture production in the Sahelian zone linked to improved rainfall conditions.

In the semihumid tropical zone, production is abundant during the rainy season but the forage rapidly loses its value. Feed reserves (e.g., silage) are needed for the dry season when grass is sparse.

Certain ensilage techniques for prairie grasses were tested in New Caledonia and Réunion. The studies demonstrated that round bales sealed in a plastic cover,



using *Panicum maximum*, were most suited to local conditions.

Pasture Improvement

The objective of the Saharan and Sahelian Observatory, an international initiative proposed by the French government, is to encourage exchange of information on drought and desertification. IEMVT contributed its expertise to the monitoring of development and experimental operations in Algeria, Morocco, and Tunisia. Technical recommendations, such as planting of perennial grasses, were recommended for pastures at village level.

In the Sahelian and sub-Saharan zones, soil degradation due to drought and human intervention has decimated the vegetation. But it can be partially restored and used for livestock production. A technique for restoring productivity was developed through several experiments. It involves recovery of runoff, sowing or planting of local or introduced grass and woody species, and organized management of restored pastures.

Results obtained in experimental fields in Djibouti led to the establishment of several soil management operations in barren depressions. Trenches were dug mechanically to retain water from scarce rainfall. Nursery cuttings of forage grasses with tolerance to salt salinity (*Sporobolus helvolus*) and browse trees (*Acacia nilotica*) were then planted.

A similar operation was jointly carried out in Chad by the Laboratoire de recherches zootechniques et vétérinaires de Farcha and IEMVT. Resources that were readily available to farmers, mainly animal traction, were used for the operation.

For pasture improvement in the Sudanian zone, intercropping of legumes and selected grasses was widely recommended for establishing sown prairies in the semihumid tropics. The most common combination was *Panicum maximum* (cv C1) and *Stylosanthes hamata* (cv Verano). Over the past 7 years, about 1500 ha of pasture were established around villages in northern Côte d'Ivoire; they are directly managed by herders. When the combination was recently used to improve 25 ha of pasture at the Banankélédaga farm in Burkina Faso it yielded 20 t of straw from the first cut.

Several techniques aim to encourage establishment of forage grasses that improve the effect of fallow on soil fertility maintenance and at the same time produce high-quality forage. In a collaborative project with the Institut de recherches zootechniques (IRZ) in the cotton-growing area of Cameroon, legumes were introduced in the crop rotation for forage or incorporation in the soil. With the Institut des savanes (IDESSA), high-quality forage grasses were established and maintained for protection and controlled exploitation of traditional fallow in Bouaké, Côte d'Ivoire.

Animal Nutrition

In Senegal, the Institut sénégalais de recherches agricoles (ISRA) and IEMVT have been working together for several years on animal nutrition in pastoral and agropastoral systems. In 1991, their work focused on the study of the diversity of feed resources in community lands (*terroir*).

Phytosociological profiles based on botanical analyses were used to map plant populations. The study supplemented observations on grazing behaviour, animal selectivity of forage, and herd behaviour. The studies were useful for selecting scales and parameters for subsequent work on extensive livestock systems and for monitoring and evaluating intensification efforts.

In Burkina Faso, observations on forage intake on rangelands were undertaken for a study on the performance of cattle herds.

In villages, single-stomach animals feed mainly on household refuse and plants in fields; commercial feed represents only a small part of the ration. Studies were conducted in Haiti (FAC project) and New Caledonia (Iles province) to determine appropriate feeds for the two regions. Balanced rations were developed for certain animals—for example, piglets in the case of the Haitian project for reintroduction of pig production.

In response to the growing demand in tropical countries for pork and poultry meat, IEMVT undertook a study on the use of crop residues for feed. The material included cereal residue (rice, pearl millet, maize, sorghum), coffee by-products, and oilcake (coconut, oil palm, cottonseed).

The work involved various CIRAD teams and animal nutrition teams from the Institut national de la recherche agronomique (INRA), France.

Animal Resources

Wild Fauna

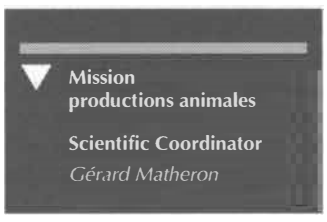
At a workshop organized on the initiative of the French Ministry of Cooperation and Development, about 20 specialists developed a strategy proposal for wildlife management in Africa. IEMVT was assigned a preliminary survey to prepare the base documents for the workshop. The survey was based on information on about 20 African countries, and more than 400 persons were interviewed.

The depletion of African wildlife and its habitats has not prompted adequate action. The strategy proposed by the workshop aims at rational management and controlled use of wildlife.

Another survey revealed that wildlife in the Sud province of New Caledonia contributed more than 10% of the meat requirements of the inhabitants. The main game were the rusa deer, wild pig, and to a lesser extent *notou* (endemic pigeon) and flying fox. This game needs to be protect and managed for more productive use. Tourism for game watching and hunting needs to be developed. For this purpose existing regulations need to be revised and development projects should be proposed.

Genetics of Ruminants

A regional research project on small ruminants involving Cameroon, Chad, and Niger was launched in 1991.



Quantitative genetics, factorial genetics, and herd monitoring were combined for characterizing breeds used by local producers. Observed morphological diversity did not reflect real differences in production. The breeds were probably derived from a relatively reduced population.

In Mali, N'dama cattle were selected on the basis of performance monitoring results. The selection method was originally developed by IEMVT at the Madina-Diassa ranch. The operation led to the development of a new software package called ARAS. Parent animals can now be selected on-site by means of an index based on significant weight increase criteria including weight at birth, and pre- and post-weaning growth.

Molecular methods developed by IEMVT to detect disease genes will also be useful for future work on the establishment of genetic maps for ruminants. The map of the major histocompatibility complex covering 3 million basic pairs was published in 1991 by Marcel Dekker, USA, in *Gene Mapping Techniques and Applications*. A new polymorphic multigenic family was discovered. The genes code for surface proteins of certain lymphocytes involved in the immune response. The addition of the new complex, which is made up of 1 million basic pairs, completes the map of immunity genes.

In collaboration with the International Laboratory for Research on Animal Diseases (ILRAD) and INRA, IEMVT developed new techniques for DNA sequence amplification using the polymerase chain reaction (PCR) to locate polymorphic zones throughout the genome. The study of these zones in goat families with known genealogy and resistance/susceptibility to cowdriosis should be useful for marking the two responses, and to possibly characterize resistance/susceptibility genes. In addition, IEMVT collaborates with ILRAD for work on genetic markers for trypanotolerant animals.

Aquaculture and Fisheries

At present, *Oreochromis niloticus* is the only species of tilapia that is farmed in the inland waters of Côte d'Ivoire. Samples were collected from five farmed populations and compared with two wild populations from the Volta and Niger river basins.

The results revealed homogeneity between the two wild populations. Genetic variability was maintained at the same level in all the farmed populations, which shows that stocks for fish farms were correctly constituted and

NETWORKS

Tropical Rangelands

IEMVT pasture and animal nutrition specialists coordinate tropical rangeland research for the Parcours network of the Association française de pastoralisme (AFP). CIRAD was thus involved in the organization of the Fourth International Rangeland Conference in collaboration with Agropolis, the agricultural research complex in Montpellier. The Congress was held in Montpellier in April 1991. It was attended by 620 participants from 68 countries; of these 143 came from Africa. The 255 papers focused on the study and management of marginal lands in tropical and temperate zones.

Collaboration for Aquaculture and Fisheries

CIRAD, Institut français de recherche scientifique pour le développement en coopération (ORSTOM), and Centre national du machinisme agricole, du génie rural, des eaux et des forêts (CEMAGREF) have formed a group, Groupe Aquaculture, to handle inland aquaculture and fisheries in the tropics and the Mediterranean region. The operational objectives are protection of fish resources, introduction of new species, and integration of aquaculture in river valley development projects. Cooperative programmes were planned for reproduction and fry rearing of catfish and tilapia and study of food webs in fish farms.

managed. Intrapopulation variability in the stocks accounted for 80% of the total; interpopulation variability was very low. Although genetic introgression in crosses was low, its effects on production are not yet clearly known, particularly for *O. aureus* strains that are being tested for brackish water.

Intensification of Production

Animal Physiology

As ovulation in camels is controlled by hormones, the mating period is determined from the physiological status of the female. It is indicated by the level of certain hormones. With the development of a field-usable kit, the camel lutein hormone can now be determined on-site and samples no longer need to be sent to a distant laboratory.

Output of milk cows can be increased considerably by shortening the dry period, particularly the calving interval. The application of modern controlled reproduction techniques (early embryo signal, echography, rectal exploration) in milk herds in Réunion allowed annual savings of FFr1000/cow. These diagnostic methods, which were developed for local producers, were adopted by breeders.

For its artificial insemination and embryo transfer programme, the animal semen laboratory at Port Laguerre in New Caledonia adapted semen collection methods (mainly electro-ejaculators) to local conditions. Superior pure-bred Limousin, Charolais, and Santa Gertrudis, selected according to methods developed by IEMVT, were thus used to introduce new blood in tropical herds.

Herds and Livestock Systems

Results of cattle performance surveys were compiled into a database. The surveys were conducted using KALAO software in several African countries; the most recent were in Cameroon and Djibouti. Herds with similar characteristics according to sociological, economic, and geographic criteria were compared. The

differences in production were found to be closely linked to the livestock management method.

In addition, data on livestock output were collected through an information network operating in several countries including Cameroon, Chad, Djibouti, Senegal, Sudan, and Thailand. The network is also involved in the characterization of various populations of cattle, sheep, goats, and camels.

A survey of livestock systems was conducted by IEMVT among herders in the Nord province of New Caledonia. A sample of 60 farms out of a total of 500 was used to explore their diversity. A study of the structure, behaviour, and performance of the herds revealed high diversity, particularly between the Melanesian and European animals.

Animal Health

Creation of a Regional Research Centre

In 1991, the Council of Ministers of the Communauté économique du bétail et de la viande (CEBV) constituted by the ministries concerned in Benin, Burkina Faso, Côte d'Ivoire, Niger, and Togo signed a convention for the establishment of the Centre international de recherche-développement sur l'élevage en zone subhumide (CIRDES) in Burkina Faso. The Centre is cofinanced by CIRAD. It replaces the Centre de recherches sur les trypanosomoses animales (CRTA) in Bobo-Dioulasso.

The mandate of CIRDES covers animal health and development of livestock production in the subhumid zone of western Africa. Its areas of work are: research and development related to parasitic diseases, mainly animal trypanosomiasis in Africa (tsetse fly control, trypanotolerance studies) and tick-borne diseases; livestock production in experimental and field conditions, with the aim of using local breeds in their environment; and staff training in techniques used for development operations in the area of concern.

Tsetse Fly Control and Trypanosomiasis

Detection of trypanosomes in animals and tsetse flies requires appropriate tools. Methods developed by ILRAD in eastern Africa are being adapted to trypanosome species and strains found in central Africa. They are also being simplified for field use by substituting cold probes for radioactive probes. The new method is used in development projects in the Central African Republic.

Monoclonal antibodies for enzyme-linked immunosorbant assay (ELISA) tests were supplied by ILRAD; other conventional tests were also used. Preliminary results demonstrated that ELISA was more sensitive than conventional methods because it detected a larger number of infections. The assay will be used in the field once its specificity has been confirmed.

Genetic probes were used for detecting and identifying trypanosomes in the tsetse fly by means of the touch blot technique. The tests were carried out on *Glossina fuscipes fuscipes*. The plasmids needed for preparing the probes were supplied by ILRAD. A probe library is being developed in Montpellier.

An antigen protein (69 kilodaltons) found in *Trypanosoma congolense*, *T. vivax*, and *T. brucei* at all stages of the life cycle was isolated to diagnose the type of trypanosome infection. The antigen produces a humoral immune response in all animals but the immunoglobulin rate is lower in trypanosensitive cattle.

Studies on tsetse fly control aim at a better understanding of the insect's perception of the environment. The findings will be useful for improving trapping methods. Research by ORSTOM and IEMVT on tsetse fly receptor systems yielded more information on the sensory organs, mainly the chemoreceptor hairs on the wings, which were described for the first time. Biometric analysis of this character showed that certain parameters had a discriminatory value for certain species. A hair count showed that there is no difference between sexes; but the difference between species of the groups *palpalis* and *morsitans* is significant.

Trapping efficiency can be considerably improved by diffusing certain simple molecules (acetone, certain

■ TRAINING

Training in Livestock Production and Veterinary Medicine

IEMVT also conducts degree courses. These include a DESS[1] in livestock production in the tropics and subtropics (in collaboration with INA-PG, ENVA, and the Muséum national d'histoire naturelle), a diploma in tropical animal health, and the international training programme on sheep and goat production and pathology. In 1991, 38 students—including 18 foreign students—successfully completed one of these programmes of study.

The Université Paris VI and Université Paris XI have jointly started a DEA[2] in tropical ecology with three modules. One of them on tropical systems influenced by man is run by IEMVT; several specialists teach the courses. The programme focuses on the relationship between population dynamics and the environment.

Several practical training programmes of an average 3-month duration were organized in France and Africa by IEMVT for 74 foreign participants from 21 countries. One-month training in diagnosis of blood parasite diseases was provided in Burkina Faso for 10 students from African countries.

phenols) related to the animal odours that attract the fly. Several molecules that proved effective on the eastern and southern African tsetse flies were tested at CRTA. Work on the identification of other molecules is under way. The odours used are from reptiles as they are important hosts of the riverine tsetse fly species in western Africa.

Tropical Diseases

Respiratory diseases are a major threat to small ruminants in the Sudanian zone of Africa. One study conducted with ISRA showed that incidence of respiratory diseases varies greatly with the species. Variability may be linked to differences in nutrition and housing. Prevalence of symptoms in herds is linked to management practices rather than sanitary prophylaxis.

Studies on respiratory disease risk showed the importance of management techniques and provided guidelines for selecting measures to be tested. The observed links between risk factors and appearance of the disease indicate the conditions in which the animals run the highest risk although, as yet, no cause and effect relation has been established.

Newcastle disease is the main constraint to poultry production in Africa. Laboratory tests for developing a thermostable oral vaccine were completed. Studies in Burkina Faso showed that the best support for the vaccine is white sorghum. Field tests will be conducted in 1992 in collaboration with IRZ in Cameroon.

Ticks and Tick-Borne Diseases

Since 1967 the African tick, *Amblyomma variegatum*, has spread rapidly throughout the French West Indies.

The tick, which is associated with cowdriosis and dermatophilosis, is harmful to animals. A study of its life cycle showed that the cattle need to be treated every 2 weeks. Different synthetic pyrethroids were recommended depending on their efficacy and ease of application. Flumethrine was recommended as a pour-on application. A 2-year eradication campaign is cost-effective and technically feasible, although it raises practical, social, and human problems.

In 1991, the international cowdriosis-dermatophilosis network made rapid progress in epidemiology, pathogenicity, and particularly disease diagnosis. ELISA can be now done in the field. The network is coordinated by CIRAD and funded by the Commission

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

2. *Diplôme d'études approfondies.* A preparatory degree for doctoral studies.

of the European Communities (CEC), the French Ministry of Research and Technology, and the Commission de coordination de la recherche dans les départements et territoires d'outre-mer (CORDET). It links the IEMVT laboratories at Maisons-Alfort and Guadeloupe with Faculteit voor Diergeneeskunde, Utrecht; the veterinary laboratories in Dakar and N'Djamena; and Royal Veterinary College, London.

▼ *Theses Completed in 1991*

Etude de la composition botanique des régimes alimentaires des ruminants domestiques (bovins, ovins et caprins) en région soudano-sahélienne par analyse histologique des fèces [Study of the botanical composition of intake by ruminants (cattle, sheep, goats) in the Sudano-Sahelian zone using histological faeces analyses] by Mamadou Cellou Bogome Diallo (Guinea); Université Montpellier II; IEMVT trainee.

Utilisation conjointe de la télédétection et de l'enquête de terrain lors des inventaires d'occupation du sol. Recherche méthodologique appliquée au Sahel sud-mauritanien [Combined use of remote sensing and ground surveys for land use inventories. Methodological research applied to the Sahelian zone in southern Mauritania] by Vincent Godard (France); Ecole des hautes études en sciences sociales, Paris; IEMVT trainee.

■ PRODUCTS FOR DEVELOPMENT

An Atlas of Infectious Diseases of Ruminants

The Atlas des maladies infectieuses des ruminants *was published by IEMVT in collaboration with the Technical Centre for Agricultural and Rural Co-operation (CTA), The Netherlands, and Agence de coopération culturelle et technique (ACCT), France. The maps show worldwide distribution of 67 infectious diseases of domestic ruminants.*
A short description of the symptoms, epidemiology, treatment, prevention measures, and economic importance of the diseases is presented with the maps.

The scope of technology research at CIRAD was extended from postharvest processing and produce stabilization to all aspects of food technology; it now covers the stages through which a product pass until it reaches the consumer. CIRAD's work on new uses of agricultural produce, new products, and transfer of technology is based on a careful assessment of their potential for local and export markets. Technology adoption, a crucial component of this research, is supported by socioeconomic analyses.

TECHNOLOGY

Food Technology

Work on product quality and its improvement, development of primary and secondary processing techniques, and design of new products aims to encourage establishment of processing and production enterprises run by farmers' associations or artisans. Consumer acceptance in terms of nutritive value and taste are important aspects that are considered for product development.

Food Value of Cottonseed

The condition of young children suffering from malnutrition improved considerably when they were given porridge prepared from glandless cottonseed flour. Protein content of the flour exceeds 50%. But it also contains low quantities (5%) of phytates. Although they are nontoxic, phytates bind various minerals (calcium, magnesium, zinc, iron) into an insoluble complex in the duodenum that prevents assimilation. Moreover, the complex reduces the solubility and nutritive value of the proteins.

In a joint research programme, IRCT and the Ecole nationale supérieure agronomique de Montpellier (ENSAM) seek to eliminate phytates from cottonseed flour. A strain of edible yeast, *Schwanniomyces occidentalis*, was selected because of its high phytasic activity that destroys phytates. A method was developed for determining the level of phytic acid and hydrolysis derivatives (inositol phosphates) by high performance liquid phase chromatography. It was used to monitor breakdown of phytates, which were found to decrease by 70-80%.

Cooking Quality and Morphology of Rice

Until now it was believed that cooking quality of rice depended on the amylose content. But an IRAT study, conducted in collaboration with the Centre français du riz (CFR), showed that morphological characteristics were more important. This finding is the result of a principal component analysis of firmness and stickiness

■ PRODUCTS FOR DEVELOPMENT

Small-Scale Fruit Processing Units

In collaboration with the United Nations Industrial Development Organization (UNIDO); the Centre for the Development of Industry of the Commission of the European Communities (CEC); and a French manufacturer, Simaco, IRFA is involved in the establishment of small-scale tropical fruit juice production units. It conducts feasibility studies, provides technical support for the establishment of the units, determines the product formula, trains staff, and advises on management of production and general operation of the unit. Three operations were successfully launched in 1991. Royal Fruits in Douala, Cameroon, produces guava, pineapple, and passion fruit juice and has a daily output of 5000 bottles. The Khelam unit in Lomé, Togo, produces 500 bottles per day of ginger, guava, mango, passion fruit, and papaya juice. In Burundi, new packaging of passion fruit and pineapple juices will enable the Fruito company to increase current production.

Deacidification of Commercial Cocoa

Chocolate manufacturers are often faced with the problem of acidity particularly in Southeast Asian cocoa. IRCC developed a simple and rapid vapour treatment for deacidification of cocoa that can be introduced between the shelling and roasting operations. The influence of treatment conditions (vapour temperature and flow, duration of treatment, drying temperature) were studied in the laboratory on a small pilot unit. Depending on the intended use of cocoa beans, free acids can be reduced by 10-25% and volatile acids by 20-60% in less than 30 minutes. The treatment is designed for large-scale application and can be easily integrated in the production process. It does not alter aroma and in certain conditions even enhances overall organoleptic qualities.

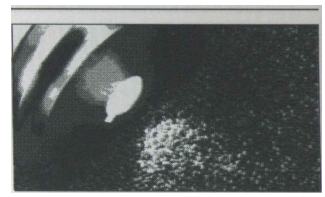
measurements for white cooked grains of 20 tropical and Mediterranean cultivars. Grain morphology, mainly length and thickness, showed stronger correlation with firmness and stickiness than starch content. This information will be valuable for breeding programmes and milling operations.

Novel Structured Food Products

Certain fruit, such as passion fruit, cannot be dried or cut into pieces because of their texture. Stable shape and heat resistance are the main requirements for using such fruit in various preparations (milk products, baked products). CEEMAT developed a process for producing novel structured fruit and vegetable products by mixing the pulp with alginate, a thermo-irreversible jellifying agent. The pulp can thus be shaped as required, pasteurized in a syrup, or dried. Suitable processing conditions—quantity of alginate, calcium (for gradual jellification), added sugar; temperature, pH, gradual acidification in the presence of glucono-∂-lactone—were determined for passion fruit, mango, grapefruit, and orange. After successful laboratory tests, the process has reached pilot stage, which will be undertaken with the company Gauthier, France.

Clarification of Lemon and Orange Juice

Macromolecules in fruit juice give them a cloudy appearance. Microfiltration in tangential flow through a mineral membrane was carried out to remove macromolecules and to stabilize the juice. The process was first tested with apple and grape juices. The filtered juice retains the main water soluble nutriments. IRFA and the Université Montpellier II tested the process on kiwi. COCI, a group of citrus producers in Côte d'Ivoire, requested IRFA to develop an application for clarifying lemon juice. The group plans to market this product in response to a new demand on the European market. The product obtained through the process conforms to market specifications and industrial-scale development can be started. Another project, which is still at research stage, aims to identify possible applications of tangential flux microfiltration for orange processing. The clear juices and pulp concentrates can then be used for preparing different types of fruit juices.



Essential Oils from Orange Peel

Essential oils extracted from orange peel are used in drinks (juices and alcohols) and cosmetics. Producers need stable-quality raw material that meets market specifications. But its characteristics differ according to the cultivar, climatic and cropping conditions, and extraction and preservation processes. IRFA therefore studied the characteristics of essential oils from different orange cultivars selected by it in Corsica and Martinique and compared them with raw material from Brazil, Côte d'Ivoire, Spain, and Italy. It concluded that climatic and soil conditions in Corsica and Martinique were conducive to high output of quality essential oils.

Extraction of Palm Oil and Coconut Oil

Traditional oil extraction methods leave large quantities of oil in fibres and centrifugation sludge. IRHO, in collaboration with the Institut technique d'études et de recherches sur les corps gras (ITERG), France, developed an enzyme treatment that will increase the extraction rate. In laboratory experiments, mixing of palm fruit with enzymes that destroy cellulose and pectins increased the extracted oil yield by 5%. The enzymes also improve static and dynamic decantation after pressing. The process could also be applied for recovering oil from oil mill effluents. The process will be tested, using industrial enzyme solutions, in an oil mill.

Coconut oil is used in certain tropical regions for cooking and everyday cosmetic use. Western consumers are also acquiring a taste for coconut. IRHO and the Université Aix-Marseille developed a process for extracting oil after maceration. The idea is based on the observation that the quantity of extracted oil can be increased substantially by macerating crushed coconut meat overnight instead of pressing it directly. This is probably due to enzyme digestion during maceration. The oil contained in the coconut meat cells is released as a result of the decomposition of the cellulose and hemicellulose, which are the structural components of the cells. The initial hypothesis was that enzyme digestion is induced by microbes present in the environment. But reproduction of the maceration process in the laboratory showed that, on the contrary, it was the result of endogenic enzyme activity (cellulases and hemicellulases). The experimental design focuses on maceration time, temperature, agitation, aeration, initial pH, and relative proportion of crushed meat and water.

Deacidification of Hyperacid Oils

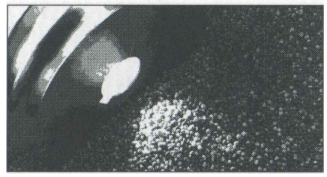
Hyperacid oils are very difficult to refine and require a costly process based on the use of solvents. Losses are also high. Two tropical oils are typically hyperacid: rice bran oil (10-15% free fatty acids) and palm oil (5-10%, mainly owing to kernel storage methods). IRHO developed a process that reduces acidity to almost 2%; it is based on know-how about industrial lipases and interesterification. Oil refining by traditional methods after such deacidification is less wasteful because of the reconversion of fatty acids into oil.

Biochemical Composition of Coffee

Information on the biochemical composition of coffee is useful for breeding programmes and for determining the impact on the quality of the end product. IRCC, in collaboration with the Institut français de recherche scientifique pour le développement en coopération (ORSTOM), analyzed 77 wild Malagasy coffee "varieties", mainly wild material, believed to contain no caffeine, low quantities of chlorogenic acid, and many bitter terpenic compounds. The analyses did not, however, support this assumption. Certain varieties revealed the presence of caffeine, other compounds of the same family, and a high chlorogenic acid content, and absence of terpenic compounds. Moreover, phenolic compounds that were never found in cultivated varieties were also identified. Further studies are required to study the impact of these phenolic compounds on quality. These findings may lead to a modification of the current classification of wild coffees.

Potato Flavour in Coffee

Arabica coffee from eastern Africa sometimes exhibits a potato flavour which reduces its value considerably. The flavour is caused by a substance produced by insect-transmitted bacteria that develop in the berries. In Burundi, where this is a serious problem, IRCC and the Institut des sciences agronomiques du Burundi (ISABU)



discovered a completely unknown bacterium in damaged berries. It was sent to the Institut Pasteur for identification. Meanwhile, the IRCC laboratory in Montpellier showed that the bacterium produced isopropylmethoxypyrazine, which is responsible for the potato taste. Other studies focused on the ecological conditions favourable to its development, insect vectors and transmission conditions, a rapid test for detecting the bacterium, and a preliminary control strategy.

Handling of Banana

The banana producers' associations in the French West Indies and the Office de développement de l'économie agricole des départements (ODEADOM), which is the funding agency for agricultural operations in the French overseas departments, seek to improve the quality and competitiveness of local produce for European markets. This requires improvements at various stages of the commodity chain from production to consumption. IRFA studied respiration of the fruit, gas exchange and aroma loss, water cooling and cold storage methods, and influence of packs and overwraps on refrigeration efficiency. The results revealed that thickness, shape, size, and perforation of cardboard packs, and type of plastic cover are the main factors to be considered for quality maintenance, storage, and ripening of fruit. Based on these findings, appropriate packages were recommended to growers.

Product Innovation

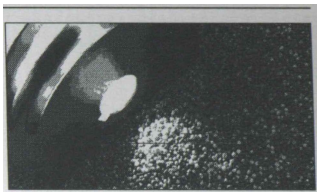
CIRAD's work on tropical plant material for nonfood uses (biodegradable packages, biofuels) responds to the need to use locally available raw material and to protect the environment. This research is conducted through international projects in collaboration with manufacturers.

Packages from Puffed Starch Foods

Puffed starch products have the same properties as polystyrene; CEEMAT tested their suitability for producing baskets to hold fruit and vegetables and disposable plates for street-side food vendors. The advantage of these products is that they use locally available raw material: whole or broken rice grains, cassava granules or flour, and coarse maize semolina. These offer a practical substitute for imported polystyrene. Such products also promote the development of small-scale industries. Such packages are not only biodegradable, they can also be fed to animals after use. CEEMAT obtained promising results with its pilot unit, particularly with rice and cassava. The mechanical properties and appearance of the baskets are satisfactory. The next step is to improve water resistance and malleability.

Synthesis in Lipochemistry

Long-chain ketones serve as excellent precursors for developing new types of surfactants with three-armed lipophilic molecules.
These compounds can be used for surface treatments (paints, anticorrosives) and cosmetics. In 1991, IRHO demonstrated that tropical oils with a high saturated fatty acid content such as copra oil, palm oil, and palm kernel oil gave the best results in terms of ketone yield.
Polyunsaturated oils (e.g., cottonseed, groundnut, tung seed) had lower output and the proportion of undesirable by-products was very high. CIRAD has now applied for a European patent based on this research. An Elf-Aquitaine subsidiary has signed a contract with IRHO for this know-how and is testing four ketone samples synthesized by IRHO.



Tropical Biofuels

Dependence on fossil fuels in many countries leads to balance-of-payments deficits because of oil imports. These countries could usefully recycle their abundant biomass for energy needs without affecting food self-sufficiency.

IRHO, with its long-standing experience in biofuel development, participated in the CEC-funded programme on rapeseed methyl esters. Another project assigned to the French company Technisucre, IRHO, and CEEMAT focused on the development of fuel from cane trash at the sugar refinery in Banfora, Burkina Faso. Ethanol from cane trash is combined with a plant oil (cottonseed oil) to develop two-component (ethanol-ester) or three-component (ethanol-ester-diesel oil) biofuels.

CEEMAT studied the characteristics of raw plant oils for use in diesel engines and their impact on output. Among the tested oils, coconut and palm oils gave the best results followed by cottonseed, groundnut, and sunflower seed oils; soybean and rapeseed oils were not satisfactory. Oils with a high content of saturated fatty acids are best suited for fuel production. Vapourization of plant oil droplets in the engine was observed to be similar to that of diesel oil. Plant oils are more sensitive to temperature. At temperatures exceeding 500°C all plant oils have the same output and their vapourization curve resembles that of diesel oil. In indirect injection engines or those with prechambers (cars, small industrial engines) in which temperature exceeds 500°C, all the oils can be used as they then have the same output and there is no carbon deposit. Direct injection engines (e.g., tractors, trucks) cannot be run on plant oils without certain mechanical modifications because of the low combustion temperature. CEEMAT and the Ecole supérieure d'énergie et de matériaux (ESEM), France, adapted the diesel engine of a widely sold tractor for John Deere France.

Biomass and Energy

Countries in Asia seek to convert excess biomass and harvest residue into energy (heat, electricity). At the same time, certain European countries are interested in exporting their know-how on conversion techniques. On the initiative of CTFT, the CEC financed a cooperative programme with the Association of South East Asian Nations (ASEAN). It was coordinated by the Asian Institute of Technology (AIT), Thailand, and also involved the ASEAN Sub-Committee on Non Conventional Energy Research (ASCNCER) and Centre de recherches agronomiques de l'Etat (CRA), Belgium. A preliminary mission by two specialists from CTFT and CRA explored the needs of the ASEAN countries. Production sites and the type and quantity of biomass were identified to evaluate production potential. In June

■ PRODUCTS FOR DEVELOPMENT

Promotion of Wood Enterprises

A project launched by UNIDO aims to promote the establishment of industrial units in Eastern European and Southern countries in collaboration with the French wood industry. The project is financed by the French Ministry of Agriculture and Forestry and involves several technical centres including CTFT. Two tools were established for the project. A computerized databank lists production and service companies in the wood industry that are interested in joint ventures. It indicates their activities and available technology. A handbook of wood processing operations for which French companies have exportable technology indicates the names of companies interested in technology transfer for each operation. It contains factsheets on operations such as sawing of deciduous and conifer woods, production of laminated wood and packing material, and wood torrefaction. These practical measures are expected to bring together industrial partners and encourage establishment of joint venture agreements.

TRAINING

Training Seminars for Coffee Professionals

In 1991, 44 coffee professionals (importers, dealers, manufacturers) and consumer protection officials participated in training seminars that IRCC has been organizing every 2 months for the past 10 years. The 1-week seminars deal with the theoretical and practical aspects related to recognition of coffee varieties, roasting, quality control of green coffee, and tasting.

Equipment for Sugarcane Cultivation and Harvest

Training workshops are organized by CEEMAT for field and equipment managers, and operators at the request of a group of 19 sugarcane plantations in Mauritius. They focus on the use of cultivation and harvest equipment in sugarcane plantations. A total of 144 persons has received training since the inception of the programme in 1988. It is a collaborative effort involving the Mauritius Sugar Industry Research Institute (MSIRI), Mauritius Sugar Producers' Association (MSPA), Regional Sugarcane Training Centre for Africa (RSTCA), and a team from CEEMAT. The topics include impact of farm equipment on soil and plant processes, equipment characteristics and methods of use, and organization of field operations. In 1991, two 6-week hands-on training sessions were organized on-site and were attended by supervisors and 24 operators. Through its "training the trainer" approach, CEEMAT aims to reduce gradually its involvement. The 1992 sessions will be conducted by staff who were previously trained through the programme; CEEMAT will provide technical support.

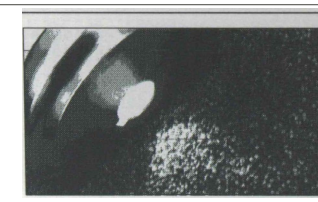
1991, a study tour was organized for a group of about 20 Asian manufacturers and researchers who visited industries in several European countries to learn about their know-how and equipment. A network was thus established linking potential clients and suppliers. A catalogue of European technologies and equipment for combustion, heat and power generation, pyrolysis, and fermentation was also compiled.

Quality of Plantation Wood

Eucalyptus is one of the main species used for reforestation. The wood is mainly processed into paper pulp because technical constraints limit its use as timber, although this would reduce the pressure on natural forests. CTFT studied this problem jointly with the Centre national de la recherche scientifique (CNRS) and the Laboratoire de rhéologie du bois de Bordeaux (LRBB), a joint CNRS-INRA-Université Bordeaux laboratory. Growth stresses are partly responsible for defects (splits, distortions) that appear at the felling and sawing stages. A detailed study was conducted in the eucalyptus clone plantations in Congo where uniformity of the material facilitated examination of the test parameters. Preliminary results revealed that growth stresses do not change markedly, at least up to the age of 10 years. Moreover, growth stresses in eucalyptus do not probably differ greatly from those in beech, wapa (wallaba), or maritime pine. The differences observed at wood processing stage are probably due to the structure and mechanical properties of eucalyptus rather than growth stresses. Additional studies on this aspect are under way.

Industrial and Farm Equipment

Development of equipment for agriculture and the food industry is CIRAD's traditional area of research. This work is combined with a training component.



Cereal Processing

The advantage of on-site processing of cereals is that it adds value and allows direct recycling of by-products. The prerequisites are a study of the different postharvest operations and close collaboration with farmers' organizations.

CEEMAT has designed a small rice milling system with independent precleaner, combined huller and polisher, and separator modules. (In Senegal where people are used to eating a mixture of whole and broken grain, the separator is not needed.) The unit has a capacity of processing 500-800 kg paddy/h or 1000-2000 t/year, which is approximately the total annual production at village level. In 1991, a complete pilot unit was installed in the lake Alaotra region in Madagascar to study its suitability for processing local rice and its integration in the commodity chain. An agreement was also signed with the company Gauthier, France, for manufacture and marketing of the system.

A small capacity (50-100 kg/h) millet and sorghum dehuller was produced by CEEMAT; it is designed for community use and small-scale units. Although several models of dehullers are available on the market, only one, a Canadian design that processes in batches, is available in western Africa. Dehulling is a laborious manual task often consigned to women. The CEEMAT machine is designed to process continuously and eliminates bran. In 1991, two pilot units were installed in Senegal in collaboration with the Institut sénégalais de recherches agricoles (ISRA): one in a village in the Bambey region and the other at a mill in Thiès. The planned capacity corresponds to local requirements. The machine was further simplified and plans for local manufacture are under consideration.

Equipment for Small-Scale Processing of Tropical Fruit

IRFA designs simple and low-cost devices and machines for small-scale processing of different tropical fruit. Three were developed and tested in 1991.

Cashew nuts are difficult to shell because of their shape. IRFA's manual sheller extracts the nut without damaging it, thus reducing losses. It is intended for use by village groups that produce export-quality cashew nuts. Marketing of the sheller was contracted to the company Lerous, France.

The manual pineapple cylinder trimmer can also be used for cutting the fruit in cylinders or adapted to cut quarters. Potential clients are small-scale canning companies in tropical countries or restaurant services in industrialized countries. Production and marketing were contracted to the company Auriol, France.

A commercial temperate fruit pulper was adapted for processing tropical fruit, particularly mango. It can also pulp other fruit (granadilla, soursop, guava) and is useful for small-scale processing units. It is also manufactured by Auriol.

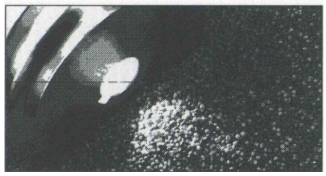
Cocoa Fermentor

Cocoa fermentation is a crucial operation for the development of aroma precursors. Well-fermented cocoa can command up to 20% more than the average international prices because of high demand. Despite its importance, the operation is often not carried out appropriately and therefore needs to be improved to obtain stable quality.

There are two phases: alcohol fermentation takes place in anaerobic conditions with only a slight rise in temperature; it is followed by acetic fermentation which takes place in aerobic conditions and temperature rises up to 50°C. IRCC's work demonstrated that turning the mass improves oxygenation, which has a favourable effect in the second phase and also reduces formation of lactic acids.

Cocoa quality was found to be correlated with the amount of energy released during the process.

Two fermentors were designed on the basis of these observations. Each of them is fitted with a temperature probe that is sunk into the fermenting mass. Information on temperature is transmitted to a programmable automatic device that turns the beans at the appropriate times and stops fermentation according to the required type of product. The first fermentor is a system of hoppers where the beans are turned as they are transferred from one hopper to another. The second is a vat in which the beans are rotated. The fermentors were



tested in Togo where the climatic conditions are normally not conducive to fermentation. Both systems produced cocoa beans of excellent and stable quality. The rotative system was found to be superior to the hopper system. The process and equipment were patented and licensed to Gauthier for production and marketing. Potential clients are large commercial plantations, associations of smallholders, intermediaries between planters and exporters, and certain chocolate manufacturers.

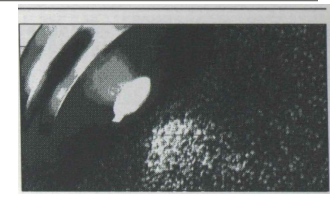
Elimination of Sticky Cottons

The problem of sticky cotton causes significant production and quality losses each year. It is caused by sticky sugary deposits (honeydew), usually deposited by insects, which can affect the entire manufacturing process. IRCT developed a thermodetector, a device for detecting sticky cotton, and a conditioner for samples. Their utility in eliminating sticky cotton was recognized at a meeting of spinning specialists organized in Montpellier in June 1991 by the French cotton industry syndicate.

Animal-Drawn Equipment

Crop yields in the Sudano-Sahelian zone depend on the cultivation profile and adjustment of cultivation operations to the crop cycle. However, traditional animal-drawn equipment is not suited to soil preparation before the rainy season. CEEMAT conceived a new technical itinerary for tilling dry soil and early sowing before the start of the rainy season. Two complementary implements were designed for this purpose. The first, a subsoil plough (*coutrier*) breaks compacted sandy-clayey soils up to a depth of 10-20 cm. This allows infiltration of water from the first rains which would otherwise be lost as runoff. The second, which resembles a disc harrow (*roliculteur*), is used for subsequent seedbed preparation on the wetted soil. The width of the implement makes it three times faster than the traditional plough and therefore accelerates crop establishment. These simple implements can be easily repaired on site and parts can be produced by local craftsmen. Field tests were conducted in five African countries, in collaboration with national research organizations.

CEEMAT studied different types of European and African harnesses in an effort to optimize animal power for cultivation operations, particularly soil preparation. The study led to the design of a yoke that meets basic requirements in the most cost-effective way. Comparative studies were conducted in Burkina Faso in collaboration with the Institut national d'études et de recherches agricoles (INERA), Burkina Faso, and Silsoe Research Institute, UK. They showed that "ergonomics" and better design can reduce pressure on the animal and thus improve its performance.



▼ *Theses Completed in 1991*

La texture de maïs africains : détermination de la vitrosité et de la dureté, relation avec les propriétés physico-chimiques et avec l'obtention des produits de transformation [Texture of African maize: determination of grain vitreousness and hardness and their relation with physicochemical properties and with processed products] by Antoine Louis-Alexandre (France); Institut national polytechnique de Toulouse; IRAT trainee.

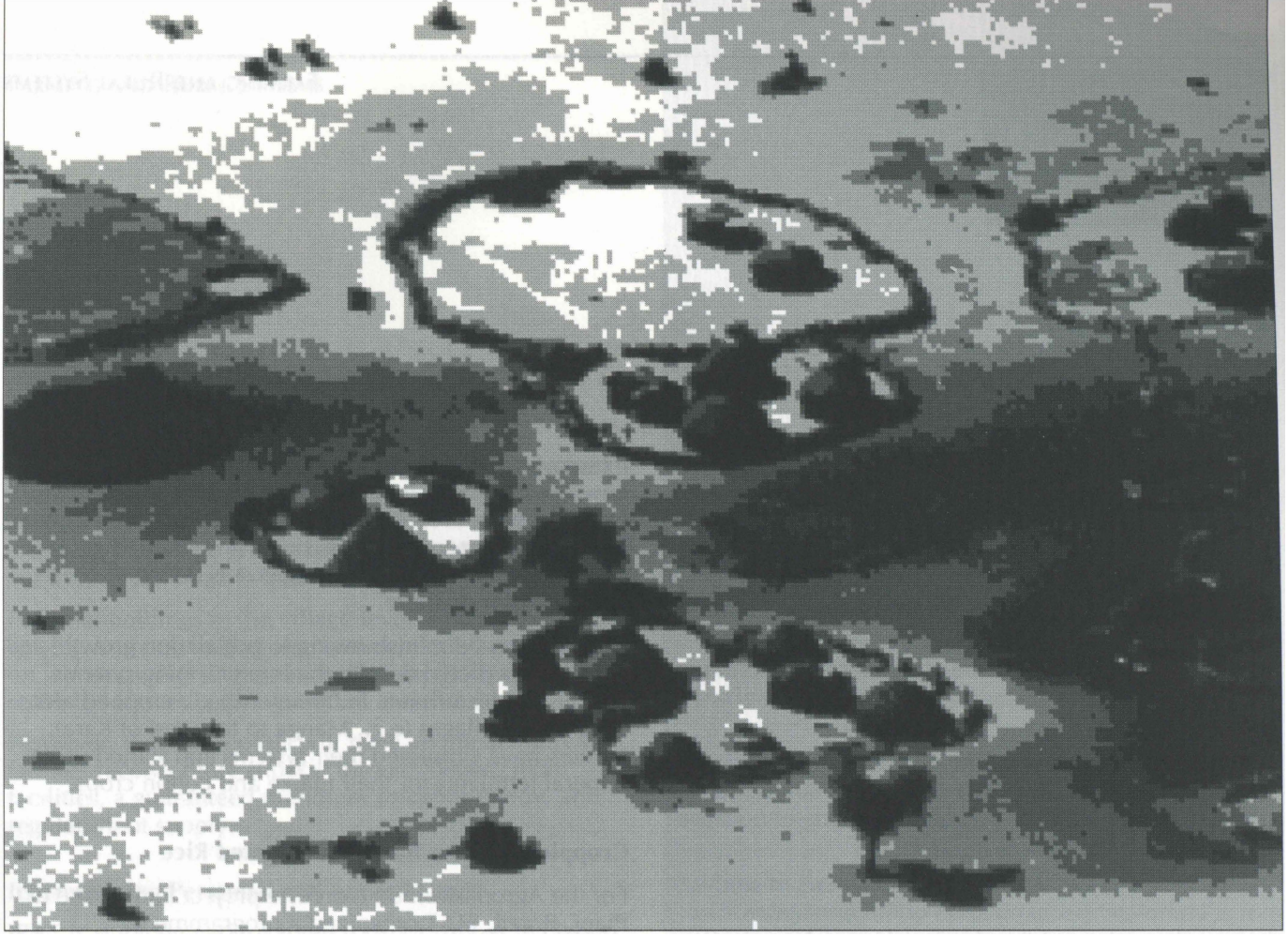
Les procédés de déshydratation-imprégnation par immersion dans des solutions concentrées (DII). Etude expérimentale et modélisation des transferts d'eau et de soluté sur gel modèle [Process of dehydration-impregnation through immersion in concentrated solutions. Experimental study and modelling of water and solute transfer in model gel] by Anne-Lucie Raoult-Wack (France), Université Montpellier II; CEEMAT staff member.

Microfiltration en flux tangentiel : applications et intérêts dans le procédé technologique de transformation de l'orange [Microfiltration in tangential flow: application to and advantage for orange processing] by Rana Bali (Syria); Faculté de pharmacie, Université Montpellier I; IRFA trainee.

Films et emballages comestibles : étude de l'amélioration des propriétés filmogènes du gluten [Edible films for packaging: improvement of the film-forming properties of gluten] by Nathalie Gontard (France); Université Montpellier II; CEEMAT trainee.

Farming and Rural Systems

Farming and rural systems research at CIRAD seeks to analyze and understand farmers' current production practices in an effort to adjust them to the need for increased food supply and sustainable development. Training of researchers and farm operators, and cooperation with farmers' organizations are complementary thrusts that aim to disseminate innovative technology by facilitating its adoption through social and institutional changes. Participation of farmers is a crucial factor. In many rural societies undergoing transition from subsistence to market-oriented agriculture, farmers are not always motivated by monetary gain. Systems analyses give due consideration to their aspirations in an effort to increase farmer participation.



Cropping Systems

The viability of a cropping system is based not only on its agronomic aspects (soil, climate, natural resource base) but also on its compatibility with farmers' aspirations and means. Action research, and innovation development and dissemination operations for the improvement and sustainable development of cropping systems should above all be conducted in close collaboration with farmers.

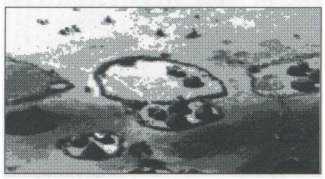
Rainfed Crops and Power Mechanization

Since 1989, IRAT has been conducting an action research project in the pre-Amazonian zone in Brazil. It is located in a hilly area in western Maranhão and concerns systems based on cereals (maize, sorghum, upland rice) and forage crops (*Brachiaria*, *Paspalum*). A rapid survey of the farming practices revealed certain weaknesses: erosion caused by cultivation on slopes exceeding 10%, the effects of which are aggravated by inadequate seedbed preparation; poor weed control (*Leptochloa*, *Echinochloa*, *Digitaria*, *Eleusine*, *Commelina*); and inadequate returns on equipment because of the monoculture system (maize).

After 3 years of research on erosion-control checks (broad-based terraces), tillage techniques, and rotation and cover crops, recommendations were made on the cultivation of maize, upland rice, sorghum, and soybean; weed control; and establishment of prairies of *Paspalum notatum* and *Chloris gayana*.

The recommendations aim at a more efficient organization of field operations. They can also be combined in different ways to adapt to changes in commodity prices and farmers' goals.

In the wet cerrados of Mato Grosso, Brazil, CIRAD has been collaborating with the Empresa Brasileira de Pesquisa Agropecuária (EMBRAPA) since 1984 for developing mechanized cropping systems. Recent trends in soybean and rice prices will prompt farmers to seek substitutes for soybean monoculture. Soybean–rice



rotation with a catch crop of sorghum after rice or soybean can pay off investments in tillage and harvest equipment. Dependence on the international soybean market can thus be reduced without affecting profitability of the enterprise.

In the Niari valley, Congo, IRAT cooperates with the Direction générale de la recherche scientifique et technique (DGRST) for the development and economic evaluation of maize- and soybean-based mechanized cropping systems.

Two crops can be grown annually in this medium-rainfall (1000 mm/year), equatorial zone. But the cropping schedule has to be carefully planned because of the fragile, clayey soils.

Technical itineraries developed after 4 years of study aim at complete mechanization of the operations. The draft implements (moldboard plough, disc harrow, seeder, fertilizer spreader, trailer) are mounted on a 70-HP tractor. With this equipment, 40 ha can be cultivated for the first crop (maize or soybean) and 30 ha for the second. Each plot is cropped only once a year to maintain satisfactory cropping conditions and to avoid depletion of soil fertility.

Prices of maize and soybean produced by this method can still compete with those of imported raw material for making animal feed.

Food Crops in Cotton-Growing Areas

In Togo, IRCT undertook zoning of the cotton-growing area according to land pressure and degree of market integration of the food crops. Surveys were conducted on farming practices and cropping systems in the five zones showing marked differences. The overall impression is that of high diversity of crops and crop combinations. In Poissongui village, northern Togo, 50% of the food crop area is sown to late pearl millet, sorghum, and cowpea intercrops; 30% to early millet, late millet, sorghum, and cowpea intercrops; and 20% to groundnut monoculture. In Waragni village, central Togo, 35% of the food crop area is devoted to sorghum monoculture; 30% to maize and sorghum intercrops with or without groundnut; 20% to yam and sorghum intercrops; and 15% to sorghum with groundnut or cowpea. The complexity of these systems shows the extent to which research on groundnut–cotton–sorghum and maize–cotton rotations is oversimplified, even if 90% of the food crop area in Kpové is devoted to sorghum monoculture.

But as fallows diminish owing to population growth, soil fertility is depleted despite the intercropping systems established by farmers. In the intensively cropped areas around the villages (e.g., Manga to the west of Kara), farmers have simplified their systems and started using mineral fertilizers for their maize and cotton crops.

Cropping Systems Based on Irrigated Rice

For the Agropastoril do Nordeste project in the state of Piaui, Brazil, IRAT organized a programme for development and dissemination of innovative technology. The project area is located on the banks of the Paranaiba river, which are covered with heterogeneous alluvial soils. The objective is to produce high-quality rice for cities in northern and northeastern Brazil. It is grown mainly as an irrigated crop during the dry season, and the operations are fully mechanized.

Constraints to increased yields are linked to the double crop system. Technical and organizational problems need to be overcome to achieve optimum use of equipment. Weed control and management of the variable soil fertility also need to be improved to obtain uniform maturity at harvest.

The irrigated, dry-season crop has a higher production potential than the rainy-season crop, which is affected by adverse climatic conditions. Rainy-season rice should be grown without bunds to facilitate organization of field operations and increase profitability. Rotation crops (maize, soybean) will be introduced to eradicate red rice.

At the request of the Mauritanian government, IRAT, DSA, and the Bureau pour le développement de la production agricole (BDPA), France, developed technical itineraries for intensive rice cultivation in Trarza (river Senegal delta).

For large mechanized farms, they recommended direct sowing of pregerminated rice after careful seedbed preparation. The transition from single- to double-cropping should be gradual as it needs rigorous weed control, which implies import of suitable herbicides.

For smallholdings in the village-level irrigation systems, sowing or transplanting was recommended depending on labour availability. Mechanized methods should be restricted to seedbed preparation and threshing.

However, these proposals will have an impact only if farmers receive more support through better credit facilities, a guaranteed minimum price for paddy, and regular input supply.

Intercropping Perennial and Annual Crops

IRAT is studying various intercrops for rubber in Gabon and Viet Nam. Food crops grown in young plantations provide income to smallholders until the trees reach production stage.

In Bitam, Gabon, the equatorial climate is favourable to double-cropping. Cassava and plantain, the local staples, can be easily grown on cleared land. Although upland rice is not grown in this area, conditions are suited to the crop. At present, cassava is forbidden as an intercrop in village plantations because of the risk of transmission of root diseases from cassava to rubber. But farmers are interested in growing cassava and are attentively following research progress. Various intercrops were proposed to planters on the basis of experimental results: upland rice (March-June), groundnut (September-December), and plantain (covering two cropping seasons). The rotation could also start with an upland rice crop for September-December.

In the Dong Naï province in Viet Nam, the Dan Giay and Long Thanh plantations were established at the beginning of the century. They now belong to the public sector and need to be replanted for the second time since their establishment.

Research for this project was started in 1991 with a survey of current farming practices of the plantation workers who were given recently replanted land for

■ PRODUCTS FOR DEVELOPMENT

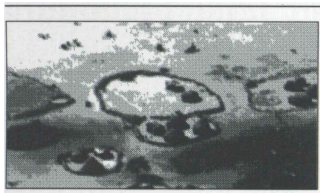
New Basis for a Traditional Cropping System

In Senegal, interest in confectionery groundnut has been revived for the groundnut-pearl millet system. In 1991, more than 28 000 ha were sown to cv GH 119-20. Despite unfavourable climatic conditions, the highly motivated farmers—with support in the form of seed and inputs—obtained high yields (1.3 t/ha unshelled groundnut). Groundnut is once again the principal intercrop component. Loans for inputs given by the company Novasem are an effective incentive to farmers, who repay them promptly. IRHO collaborated with Novasem to provide technical support. The target for 1992 is to extend the confectionery groundnut area to 40 000 ha, which will increase income for both farmers and the company.

■ PUBLICATION

Sorghum in Farming Systems

Le Sorgho, *authored by IRAT scientists, was copublished in 1991 by the Agence de coopération culturelle et technique (ACCT), Technical Centre for Agricultural and Rural Co-operation (CTA), and Editions Maisonneuve et Larose. It is part of the Technicien d'Agriculture Tropicale series. The publication reviews current knowledge on the crop, its role in farming systems and local diets in Africa, and technology available for intensive cultivation to ensure stable production.*



growing food crops. Some experiments involved maize, groundnut, and upland rice. But fertility levels in the almost century-old plantations are low, which leaves little room for innovation.

Animal Traction

There is renewed interest in animal traction and use of manure in Africa and Madagascar. But, although draught cultivation has progressed, animal management still needs to be improved.

In Cameroon, a survey was undertaken by the Institut de recherches zootechniques (IRZ) and IEMVT among 190 farm owners (*chefs d'exploitation*) in the cotton-growing area to analyze the role of animal traction in farming systems. Three main modes of integrating animal traction can be distinguished. Donkeys are generally used by young farmers with smallholdings or older farmers in straitened circumstances. New users of bovine traction and farmers with stagnating production have one pair of oxen for about 4 ha. Farmers who have the means to accumulate capital have two pairs of oxen for 8 ha and the necessary equipment.

The survey showed that draught animals are generally used for work outside the farm. Animal health and management, draught-cultivation systems, and equipment still need to be improved considerably.

In the lake Alaotra region of Madagascar, a team of scientists from the Centre national de la recherche appliquée au développement (FOFIFA) and CIRAD is studying draught management for an action research programme. The objective is to determine whether current management practices are compatible with the increased pressure (time, effort) on animals because of intensive farming. Thirty-two farmers in two villages (Fiadanana and Mangalaza), with whom the team has been working for several years, were surveyed for a detailed analysis. Feeding practices varied considerably. In Mangalaza, farmers practise a type of seasonal transhumance; they take the animals either to the hills near the village or further away to the western bank of the lake. In Fiadanana, the animals are stabled throughout the year near the farm houses. Feed supplements (e.g., green grass, cassava) also vary.

Different recommendations were proposed depending on the situation; some are being tested by the farmers.

Farming Systems

Cassava-Based Farming Systems

At the request of the Association française des volontaires du progrès (AFVP) and the French Ministry of Cooperation and Development, IRAT, DSA, and DGRST conducted a survey in the Pool region, Congo, for a socioeconomic analysis of cassava production and marketing. Cassava is a staple food in the country and the basic component of local farming systems.

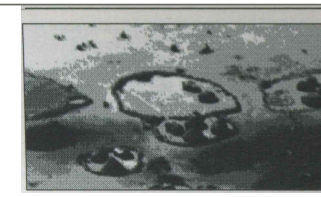
The survey covered 346 production units made up of 1852 fields in 7 villages of the Mindouli district. The main study parameters were land tenure status and crop management practices.

According to the population analysis, rural migration did not appear to affect production capacity in the villages. In fact, families in the village now had links with the city. Feedback through these links made them aware of the importance of innovative techniques for a more efficient integration of their produce in the market system through on-farm processing.

Investigation of field types and farming practices showed that know-how varied according to physical conditions. The fallow period was still more than 5 years in the sample fields.

Land tenure is still determined through the ancestral custom of matrilinear succession. However, 18% of the fields were rented out at rates fixed according to the farming potential of the land.

The marketing analysis confirmed the dominance of cassava over tomato, chili, and groundnut. Cassava is sold throughout the year. It is processed by women, who play an important role in the market economy.



Food Crop-Based Farming Systems

In Burundi, the Nyanzalac plain spreads over 30 000 ha, of which 6000 ha are undeveloped lowlands. An action research unit was created in 1987 to evaluate prospects for developing agriculture in this region.

A preliminary survey by IRAT of the physical conditions (morphopedological mapping) and farming (100 farms surveyed) in the region served to identify the different problems that need to be overcome for crop intensification. These findings were used to determine the most suitable techniques. Highlights of research to date concern: erosion control; development of lowlands; and distribution of maize cultivars with resistance to virus diseases, scale-resistant cassava, and rosette-resistant groundnut. Local and regional market potential of food crops was also studied in detail.

Irrigated Rice-Based Farming Systems

In several countries, rehabilitation of irrigation systems is accompanied by a transfer of responsibility for irrigation services from the state to farmers' organizations. CIRAD is participating in research projects for adjusting traditional crop management to the new context.

In Mali, for the Office du Niger, DSA is involved in a rehabilitation project covering 750 farms belonging to 10 villages. A preliminary analysis identified a wide range of farm enterprises: rice, vegetables, and various rainfed crops; livestock production, and nonagricultural activities. Agricultural advisers can base their recommendations according to the types of farms identified by the survey.

DSA is part of a common action research unit for the rice development and small-scale irrigation system rehabilitation projects in the Antsirabe highlands of Madagascar. The unit used results of previous farm surveys to establish a network of 50 reference farms distributed over 10 hamlets. These serve as a sample for studies on income and expenditure of farm households and the proportion of the budget spent on maintenance of the irrigation network. The complex rural systems reflect the wide range of enterprises: vegetables and other off-season crops in rice fields, rainfed crops on higher land, small-scale pig and poultry production, milk cattle production, brick production, etc. The main constraints are absence of credit facilities, land tenure problems, irregular input supply, and lack of veterinary services.

■ Rural Systems

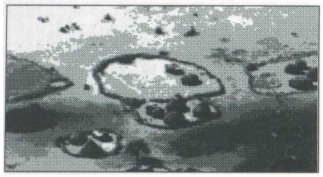
Constraints Faced by Land Use Management Projects

DSA participates in the working group on management of community lands (*terroirs*) of the Recherche-développement network along with the Institut de recherches et d'applications des méthodes de développement (IRAM), Centre international pour l'éducation permanente et l'aménagement concerté (CIEPAC), Caisse centrale de coopération économique (CCCE), and AFVP.

In 1991, the group analyzed 13 development and action research projects concerned with land use and resource management in rural areas. It studied how extension agents respond to new working methods that involve greater participation in an uncertain context marked by disengagement of government services, decline of regional development agencies, and strained relations between certain projects and national technical services.

Community land management projects have to bear the consequences of the contradiction between the declared objective of promoting concerted action with local communities and rules set by donors for execution, funding, and evaluation of the projects. This situation requires rethinking on project planning, evaluation, and impact. Irregular funding is hardly conducive to the long-term work of motivating and transferring the necessary know-how and means to farmers' organizations.

The projects analyzed by the group were established on the basis of rapid rural surveys that emphasized technical aspects. But as long as the social problems are not addressed, it is difficult to establish a dialogue with



rural communities for medium- and long-term management of natural resources.

Moreover, the rural surveys concentrated on local situations without relating them to the wider economic and institutional context. They do not provide adequate information on the possible impact of the projects on rural credit, creation of users' associations, and delimitation of individual and collective lands.

The quantitative and planned targets imposed by donors are often incompatible with the need to negotiate with farmers to obtain their participation. The methods adopted by development projects and agents are often conditioned by the obligation to produce results, as seen from the emphasis on erosion control, incentives (donations in kind, salaries) for reforestation, etc.

The group is currently seeking new operational methods for these projects so that social changes are given due consideration.

Mathematical Models of Rural Systems

The disparity between population growth and current agricultural output is a predominant concern of structural adjustment policies. Agricultural research organizations are under pressure to find viable solutions. But data needed to provide the answers are often fragmentary and inconsistent.

Mathematical models, however simple, can be useful for organizing these data more coherently. Data on physical conditions, and actual or potential techniques for crop and livestock production can be validated when they are combined at local system level through linear programming.

The Institut d'économie rurale (IER), DSA, and IRCT jointly undertook an analysis of the advantages and drawbacks of various technical recommendations for increasing food supply in the cotton-growing area of Mali. Crop intensification and introduction of forage crops (*Stylosanthes*) in the rotation were among the recommendations studied by the group.

Linear programming was used to vary the objective function (prices of factors of production and products) and constraint level coefficients. The sensitivity of the model was demonstrated by the accuracy of the simulated effect of changes in cotton and maize prices on crop intensification. The stability of the basic solution corresponding to the current agricultural situation was also confirmed. The model's description of the economic behaviour of farmers still needs to be improved by including constraints linked to risk and household cash flow.

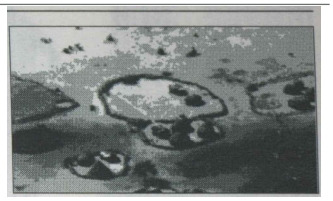
Shifting Cultivation in Forest Areas

The Zaire-Nile crest in Rwanda rises to an altitude of 3000 m; it is 160 km long and its width varies from 20 km to 60 km. This is a largely undeveloped region with marked relief and acid humic soils. The high-altitude equatorial climate is characterized by wide variations in temperature and rainfall according to the altitude. The high-altitude areas are sparsely populated.

The region was partly covered by forests, which were occasionally cleared by farmers from lower altitudes (below 2000 m) for cultivation. The forestry and agriculture project of the Zaire-Nile crest checked this process and established tea, forage crop, and reforestation areas. This led to an intensification of farming systems in the medium-altitude zone and the emergence of new and suitable systems at high altitudes. Since 1983, IRAT—and later DSA—has collaborated with the Institut des sciences agronomiques du Rwanda (ISAR) in analyses of the physical environment and farmers' practices, development of innovations (cultivars, fertilization, livestock production techniques), and monitoring of their impact. A review of this work in 1991 focused on the possibilities of transforming the farm structure in a context dominated by authoritative extension services.

In Côte d'Ivoire, DSA is working with the Deutsche Gesellschaft für Technische Zusammenarbeit (GTZ), Germany, for a study aimed at the protection of forests that were spared during the cocoa plantation boom.

With the current crisis in the coffee and cocoa sectors, young planters are tempted to abandon aging plantations and establish new ones by clearing the last



few forests. However, surveys show that several initiatives are being taken to find other options. These include conversion of old coffee plantations and diversification into livestock production. But these initiatives will not be successful as long as planters are still attracted by the idea of clearing remaining forests. Incentives in the form of credit and input supply are also needed to deter the planters and thus protect the forests.

TRAINING

Perennial Crops: Training Indonesian Managers

Eleven Indonesian managers involved in the development of perennial crops received training in 1991. The 2-year theoretical and practical training programme was jointly organized by the Centre national d'études agronomiques des régions chaudes (CNEARC) and CIRAD. In these 2-year programmes, participants spend the 1st year in an African country (Côte d'Ivoire, Togo, or Cameroon) and the second in their own country.

The objective is to familiarize managers with the practices and strategies of planters and thus widen their sectoral and assertive approach to rural development. The informative reports submitted by the participants on coffee, cocoa, and rubber planters in Indonesia prove the efficacy of this new method. CIRAD will maintain contact with the participants to ensure a durable impact of this training.

The policies of economic stabilization, structural readjustment, and liberalization that an increasing number of countries have been adopting over the past decade are gradually modifying agriculture and rural societies. CIRAD is analyzing their impact on markets, farmers' organizations, agricultural budgets, and access to credit in different regions. Land issues are re-emerging as the focal point in studies on the competitiveness of producer countries and analyses of natural resource use.

Economics and Sociology

Economics of Commodity Chains and Products

Outlook for Rice in Africa

Production costs of irrigated rice in Africa are higher than those of Asian rice, which is rapidly penetrating African markets. Since 1989, IRAT has been studying various aspects of the rice commodity chain (*filière*) to determine future prospects for irrigated rice.

The OSIRIZ database is the result of collaboration between the French Caisse centrale de coopération économique (CCCE), Office national interprofessionnel des céréales (ONIC), and CIRAD. It is made up of three complementary components. Detailed data on world rice trade (quantity, quality, price, origin, destination) are collected for the first component. The second is a collection of macroeconomic data on producer countries; it was established in collaboration with the International Rice Research Institute (IRRI). The third

concerns marketing of local and imported rice in different countries. The database thus provides information on the current rice status in different countries and on competition on the international market.

INTERNATIONAL MEETING

Workshop on Rural Credit

Microeconomic financial aspects are recognized as vital factors for promoting rural development in western Africa. In October 1991, the Burkinabe Caisse nationale du crédit agricole and Institut national d'études et de recherches agricoles (INERA), University of Burkina Faso, Ohio State University, and CIRAD organized a workshop on rural credit in Ouagadougou.

Although agricultural and household budgets are severely handicapped by shortage of funds, farmers lack access to financial services, which are affected by the structural adjustment measures. Meanwhile, the traditional informal sector fulfills the function of providing credit. Tontines, family groups, money keepers, money lenders, and shopkeepers, all form a network of solidarity, trust, and control that replaces the collateral required by institutional financial services. Despite their scattered structure and the small number and volume of transactions, informal networks could be developed further by linking them to the formal sector. The idea of combining the two systems led to the creation of a new type of mutual credit society. It minimizes transaction and mediation costs and offers various financial services (savings, loans). Approval and recovery of loans are scrupulously controlled. Systematic development of these rural financial markets could contribute substantially to the establishment of national market economies.

In Africa, locally produced rice cannot compete with imported rice because it is not supported by an adequate infrastructure. Until 1989, most of the rice was imported from Thailand and the USA. Thailand has only recently started granting farm subsidies to farmers, who face growing competition from Viet Nam. Rice produced in the USA is heavily subsidized and is often supplied in the form of food aid. Imports and food aid programmes have an adverse effect on local production. Private importers also face difficulties, but recently they have received support from governments interested in replacing the public distribution systems.

CIRAD's research focuses on the activities of African traders. They play a decisive role in price determination through their imports, re-exports to neighbouring countries, and in the distribution of local produce. The studies also cover local production dynamics, particularly in the western African lowlands.

Outlook for Maize in Africa

Maize is a traditional food in the coastal areas of the Gulf of Guinea. For a long time governments in the region have sought to extend production and consumption beyond these areas.

A detailed analysis of production, distribution, and consumption was undertaken in Côte d'Ivoire in collaboration with the Centre ivoirien de recherche économique et sociale (CIRES) and the French Institut national de la recherche agronomique (INRA). The government's efforts to promote maize production were aimed at increasing supply to the animal and poultry feed market, which is driven by the meat market. The traditional sector responded rapidly to this new demand. However, production developed in the cocoa- and coffee-growing areas in the western part of the country rather than the maize-growing area in the north. This is because immigrant farmers from the savanna to the western region are accustomed to growing maize. Land and labour are thus shared between maize, coffee, and cocoa.

But interaction between maize farmers and animal feed producers is not as effective as expected. Producers expect farmers to supply raw material at prices that

compete with those of imported cereals. These prices are too low to encourage farmers to grow maize. The government is thus faced with the dilemma of either supporting maize farmers or feed producers. The issue of protection level is therefore a constant preoccupation for the government.

Emergence of a Farmers' Movement

Farmers' Organizations

National agricultural policies influence the capacity of farmers' organizations to interact with government services and the growing number of private services that have emerged as a result of state disengagement. The policies determine the context in which the organizations develop, their ability to identify binding forces (cultural, social, economic), as well as their internal structure and external relations.

DSA collaborated with the French Institut de recherches et d'applications des méthodes de développement (IRAM) to study farmers' organizations in Burkina Faso, Cameroon, Madagascar, Mali, and Senegal. The results reveal wide disparities between national and regional institutions as well as competition and proliferation as a result of economic and social forces. However, the organizations are not yet able to form an influential political lobby that safeguards the interests of the rural sector. The exception is Senegal, where federations of farmers' organizations are gradually acquiring the intellectual and financial independence needed to retain their autonomy.

A more detailed study was conducted in the river Senegal basin by DSA in collaboration with the French Centre international pour l'éducation permanente et l'aménagement concerté (CIEPAC), Institut sénégalais de recherches agricoles (ISRA), and Société d'aménagement et d'étude du delta et des vallées du fleuve Sénégal et de la Falémé (SAED).

In the delta area, farmers are rapidly forming base organizations and federations of these organizations. A similar trend was observed in the valley, but more data are needed to confirm it.

Most farmers' organizations were registered as associations (*groupements d'intérêt économique*) for the purpose of obtaining access to land and credit. But the response of the rural land authorities (*communautés rurales*) and the credit agency, Caisse de crédit agricole de Saint-Louis, has not always been satisfactory.

The size ranges from 10 to 100 members. The mode of organization depends on the objectives (access to land, credit, and services). Economic performance and duration were also found to vary considerably.

There are two types of federations or unions of organizations. The first type corresponds to associations of irrigation users who were assigned the management of the irrigation system by SAED. They manage water distribution and cropping schedules, and follow up on requests for credit and services. The second type is represented by the regional federations. They fulfill wider functions such as obtaining access to land, irrigation systems, and equipment. The oldest federation is the Association sportive et socioculturelle des agriculteurs du Wallo (ASESCAW); it focuses on planning, technical training, and training of managers of subsidiary farmers' organizations. Crop diversification and input supply are important concerns. The federations are interested in developing relations with

external organizations and a group of leaders visited the Centre français du riz (CFR) in 1991.

A New Village Economy

Partial decentralization of government services appears to be inevitable in countries that have adopted structural readjustment. Responsibility for services that are of interest to the community will be transferred to local organizations. For example, community land, cropped areas, pastures, water, and services for education and water supply will be managed at local level. Economic and sociological research is now being concentrated on village organizations to study their ability to assume their new role. Local rules for management of common property and customary law are also examined for their suitability for sustainable development.

IEMVT's analysis of communal pasture management in the Sahel cautioned that access to forage resources was hampered by noncooperative relations between users because of obsolete social conventions that defied change. In other regions, equitable conventions and rules ensure renewal of these resources. The introduction of new technology often causes such problems among users as they renegotiate the distribution of new benefits. Negotiations for new, balanced cooperation within local organizations are therefore an important factor to be considered for any technological innovation in a community.

Agricultural Household Budgets

Credit Requirements

Credit and financial service requirements can be effectively assessed through analysis of farming systems and agricultural budgets. DSA and IRCT studied these aspects in different environments: coffee smallholdings in Mexico; mechanized farms in the delta region of Senegal; cotton plantations in western Africa, particularly Togo and Burkina Faso; and farms using animal traction or power mechanization. Shortage of funds is a chronic problem during the "hungry season". It is also a handicap for farmers who wish to apply for bank loans to buy equipment; they are obliged to make complicated deals with third persons to obtain the sums needed for their personal contribution.

Agricultural Household Models

Most agricultural household models used in economic analyses of smallholdings are based on the same hypotheses. The Long-term Forecasting and Agricultural Policies Unit of GERDAT compared the model of Singh, Squire, and Strauss with different "stylized facts" that describe the behaviour of households in the Nicoya region, Costa Rica. It concluded that this basic model needs to be modified so that it can be used for the local situation. The modifications include: introduction of a constraints framework for labour schedules and funding parameters; specification of labour and food crop market failures; and introduction of problems linked to production factor mobility. Response of farm households to unstable production conditions should also be considered.

Agricultural Policies

Response of Farmers to Fall in Prices

Coffee and cocoa producers in Cameroon, as in other countries of Africa, Latin America, and Asia, have suffered a setback because of the fall in prices on the international market. DSA's studies in Cameroon revealed three types of response to maintain adequate income to meet day-to-day expenses. In the first case, producers intensify production and specialize on these two crops (strategy of commercial plantation development or land accumulation). In the second case, they shift to other enterprises such as food crop production or off-farm activities (strategy of economic survival). In the third case, producers seek to diversify their income base in the expectation of an upswing in international prices (risk reduction and watch-and-wait strategy).

In all cases spending—particularly on inputs—is reduced. Cropping operations are confined to the most productive plantations. Diversification into food crops will level off as local markets reach saturation point.

Economic Policies and the Agricultural Sector

General economic policies appear to play a more important role than specific agricultural policy measures.

Case studies by CIRAD from Latin America (Colombia, Ecuador, Costa Rica, Mexico, Venezuela) show that the demand reduction measures for stabilizing the economy affected agriculture more than other sectors. Farm subsidies were cut, credit was reoriented, and investments and operating funds were reduced. On the other hand, the structural readjustment measures, including the modification of relative prices did not lead to expected growth in the agricultural sector. The measures in fact weakened family smallholdings. Reduction of public investments in agriculture affected the crops produced on these smallholdings. Moreover, they benefited only marginally from incentives offered for developing export crops. As they lacked the financial resources and direct access to the international market, they were obliged to accept the conditions imposed by the small number of enterprises that had profited from price rises due to currency devaluation and tax incentives offered by the government.

The Latin American countries have no other alternative but to support integration of smallholdings in the national and regional production systems because their produce is mainly intended to satisfy national or regional demand. It is for this reason that regional policies for integrating and supporting agricultural markets are probably more effective than national policies.

Agricultural Policies and Productivity

The French Centre d'études et de recherches sur le développement international (CERDI), in collaboration with the International Food Policy Research Institute (IFPRI) and CIRAD, organized a workshop on the policies and economic performance of low-income countries in Asia and Africa.

■ **PUBLICATION**

Agricultural and Food Policies in Africa

In 1991, the French Ministry of Cooperation and Development, in collaboration with CIRAD, published Les Politiques agricoles et alimentaires en Afrique, méthodes et outils d'analyse et d'aide à la décision. *The book is part of the Méthodologies series.*

The book proposes tools and methods for defining agricultural policies corresponding to the general macroeconomic policies. The first step is an analysis of the agricultural sector, including agroindustries, food industries, and the rural economy. It is followed by a long-term forecasting analysis to determine priority areas. Each step covers six areas: ecology and agricultural resource base; population and social aspects; farming systems; commodity chains, prices, and markets; institutions involved in the sector; interaction between the general economy and agricultural economy.

As macroeconomic policies often have a greater impact on agriculture than policies specifically defined for the sector, they should also consider its specific constraints. Sectoral leaders should therefore be involved in the definition of general policies. The book also proposes that economic policies should be aligned with long-term development perspectives to ensure that the proposed economic growth model is truly sustainable.

Just as in Asia 40 years ago, Africa needs to increase agricultural production to meet the food requirements of its growing population. This depends on a large number of variables; some of these are directly linked to farmers

and others to the economic environment. Agricultural policies play a decisive role. In the long run, rural population density, land tenure institutions, and efficiency of economic exchange and markets are also significant factors. Coherent and far-sighted policies are a requisite for agricultural growth. A comparison of Asia and Africa highlights the importance of infrastructure for stabilizing supply lines between cities and surrounding rural areas and for generally promoting a market economy.

■ INTERNATIONAL MEETING

Agricultural Growth in Africa and Asia: Population, Urbanization, Poverty

On the initiative of CERDI and CIRAD, John Mellor, Director of IFPRI until 1990, gave a seminar in Montpellier on comparative agricultural growth in Africa and Asia. Natural conditions, population, population density as a cost factor for service and infrastructure costs, and economic policies and institutions in the two continents were compared. The failure in Africa to arrive at a consensus in the tasks of institutions is a handicap to the efficient operation of public services. Africa has not been as innovative in its agricultural sector as the Asian countries in the early stages of the green revolution.

John Mellor stressed that biological innovations are a key feature. Increased productivity due to these innovations raises national income. It stimulates demand for higher-value food products such as meat and horticultural products. Agricultural growth is a driving force for rural food processing and input supply industries. Agriculture drives economic growth based on domestic consumption, which in turn reduces poverty. Agricultural research and education in rural areas (up to secondary school level) are the two main priorities for encouraging innovation and growth.

■ Management of Renewable Natural Resources

CIRAD has conducted several studies for technical management of renewable natural resources. Further research is needed for an economic analysis of the sustainable use of these resources and of solutions to economic and social conflicts linked to environmental degradation.

Strategy for Research on Externalities

Various studies were undertaken to determine research themes related to the management of renewable natural resources. They focus mainly on local issues: management of communal rangeland, community land, irrigation water, and fishing and hunting; access to firewood; and use of forests.

Following a workshop organized in Montpellier in September 1991, the Scientific Committee of the Mission économie et sociologie of CIRAD examined the possibility of conducting research based on an analysis of externalities that are observed at different scales in the rural sector. These include overall changes and local changes (watershed, village, production unit). The strategy draws on the work done in France on the management of externalities in the agricultural sector.

Land Tenure and Trees in Africa

Trees are territory markers, a source of energy, an obstacle for cultivating land, a refuge for spirits; their significance varies widely. They are central to many social and land tenure problems and their management depends on traditional social rules and customs.

The situation—preagricultural (natural forest), transitional (land clearing), or agricultural—determines the status of the tree. The range of situations is very wide because of the diverse nature of rural societies. However, CTFT demonstrated that this diversity held a common feature—the disparity between free access to land and private

ownership of trees. Trees are the private property of those who planted them, whereas land is common property. Consequently, the land on which a plantation is located belongs to the community but trees cannot be integrated in the local farming systems. Technical agricultural production models should address this constraint. But only an amendment of the law will ensure the integration of trees in farming systems.

▼ *Thesis Completed in 1991*

La filière maïs en Côte-d'Ivoire. Un exemple d'adaptation spontanée des appareils de production et de commercialisation à l'extension du marché intérieur [The maize commodity chain in Côte d'Ivoire. An example of spontaneous adaptation of production and marketing systems for extending the domestic market] by Jean-Louis Fusillier (France); Université Montpellier I; IRAT staff member.

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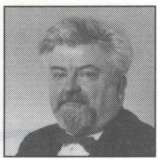

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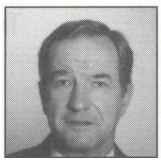

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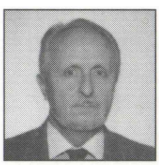
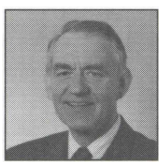
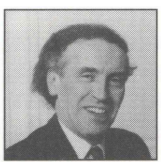
IRHO
Christian Brunin



IRFA
Jean-Marie Charpentier



CIRAD-SAR
Jacques Lefort



GERDAT
Jean-Marie Sifferlen

Chart of CIRAD (as of 1 Jan 1992)

General Secretariat, Common Services

Special Adviser
Raoul Tuffery

Personnel
Danielle Bonneau

Finance
Marc Gélis

Legal Affairs
Hervé de Font-Réaulx

Liaison,
French Overseas Territories
Gérard Montagut

Centre Directors,
French Overseas Territories
(see page 93)

Training
Jacques Dubernard

Scientific and Technical Information
Jean-François Giovannetti

Computer Services
Joël Sor

Laboratory Analyses
Paul Fallavier

External Relations

Deputy Director
Michel de Nucé de Lamothe

Africa
Roland Guis

Latin America
Jean Laboucheix

Asia, South Pacific
Patrick Safran

International Organizations
Marie de Lattre

Industrial Liaison
François Challot

Communication
Anne Hébert

Press Officer
Benoît Catrisse

Overseas Representatives
(see page 93)

Audit and Accounts

Internal Auditor
Antoine Bourgeois

Research Coordination *(Missions)*

Crop and Environment Management
(AGER)
Christian Pieri

Plant Improvement
(MICAP)
Jacques Meunier

Plant Protection
(MIDEC)
Jean-Loup Notteghem

Animal Production
(MIPA)
Gérard Matheron

Technology
(MITECH)
François Challot

Economics and Sociology
(MES)
Michel Griffon

Remote Sensing
Jacques Imbernon

Biometrics
Jean-Claude Bergonzini

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Jacques Poly

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Rémy Pochat, representing the Minister for Research and Technology
Jean Nemo, representing the Minister for Cooperation and Development
François Mongin, representing the Minister for Economic Affairs, Finance and Budget
Pierre Marsal, representing the Minister for Agriculture and Forestry
Gérard Plouchart, representing the Minister for Overseas Departments and Territories

President, Institut national de la recherche agronomique
Guy Paillotin

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Jacques Alliot, Deputy Director, CCCE
Alain Godard, Director General, Rhône-Poulenc Agrochimie
Michel Levallois, Chairman, ORSTOM
Marcel Mazoyer, Professor, INA-PG
Michel Teyssedou, Chairman, FDSEA du Cantal

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Jean-Louis Rastoin, ENSA Montpellier
Giuseppe Valentini, CEC (DG XII)

CIRAD members
René Billaz, Etienne Laville, Michel Benoît-Cattin, Vincent Dollé, Jacky Ganry, Philippe de Reffye, Marcel Tissot

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French Overseas Departments and Territories

French Guiana	**Jean-François Julia,** *Centre Director*
Guadeloupe	**Jean-Jacques Baraer,** *Centre Director*
Martinique	**Patrick Daly,** *Centre Director*
New Caledonia	**Pierre Bourdin,** *Centre Director*
Réunion	**Jean Servant,** *Centre Director*

Other Countries

Benin	**Christian Gaborel,** *Correspondent*
Brazil	**Jean-Marie Kalms,** *Representative*
Burkina Faso	**Robert Nicou,** *Representative*
Burundi	**Gérard Fourny,** *Correspondent*
Cameroon	**Jean-Louis Messager,** *Representative*
Chad	**Yves Maurice,** *Correspondent*
Congo	**Olivier Hamel,** *Correspondent*
Costa Rica	**Jean Laboucheix,** *Representative for Latin America and the Caribbean*
Côte d'Ivoire	**François Pointereau,** *Representative*
Gabon	**Patrice de Vernou,** *Correspondent*
Guinea	**Jacques Teissier,** *Correspondent*
Indonesia	**Pierre Rondot,** *Representative*
Madagascar	**Jean-Louis Reboul,** *Representative*
Mali	**Jean Charoy,** *Representative*
Morocco	**François Bertin,** *Correspondent*
Philippines	**Guy Bénard,** *Correspondent*
Senegal	**Edmond Viricelle,** *Representative*
Thailand	**Guy Machet,** *Correspondent*
USA	**Jill Barr,** *Correspondent*
Vanuatu	**Claude Calvez,** *Representative*

Research Departments (as of 1 Jan 1992)

CTFT

Centre technique forestier tropical

Jean-Marc Dubois	*Director*
Jean-Claude Bergonzini	*Research Director*
Claude Thévin	*Director, Administration and Accounts*
Régis Peltier	Agroforestry, soil and water conservation
Henri-Félix Maitre	Forest management
Oudara Souvannavong	Tree improvement
Bernard Parant	Wood technology

IEMVT

Institut d'élevage et de médecine vétérinaire des pays tropicaux

Georges Tacher	*Director*
Gérard Matheron	*Research Director, Livestock Production*
Gerrit Uilenberg	*Research Director, Animal Health*
Jean-Vital Declocquement	*Director, Administration and Accounts*
Vacant	Feed resources
Dominique Planchenault	Animal resources
Philippe Lhoste	Livestock production systems
Jérôme Lazard	Aquaculture and fisheries
Pierre-Charles Lefèvre	Infectious diseases
Gerrit Uilenberg	Animal pests
Pierre-Charles Lefèvre	Ecopathology

IRAT

Institut de recherches agronomiques tropicales et des cultures vivrières[1]

Didier Picard	*Director*
Jean-Claude Follin	*Research Director*
Alain Derevier	*Programmes Director*
Jean-Louis Caminade	*Director, Administration and Accounts*
Michel Jacquot	Rice
Guy Rouanet	Maize
Michel Hoarau	Sugarcane
Patrick Salez	Sorghum
André Bockelee-Morvan	Annual oil crops
Patrick Daly	Vegetable crops
Jacques Marquette	Other crops
Francis Forest	Climate–plant relations
Roger Bertrand	Soil–plant relations

1. IRAT and IRCT will be merged on 1 July 1992 to form CIRAD-CA, the annual crops department.

IRCT

Institut de recherches du coton et des textiles exotiques[1]

Michel Braud	*Director*
Jean-Claude Follin	*Research Director*
Jean-Louis Caminade	*Director, Administration and Accounts*
Michel Braud	Cotton

IRCA

Institut de recherches sur le caoutchouc[2]

Alain Weil	*Director*
Jacques Meunier	*Research Director*
Robert Jouanique	*Director, Administration and Accounts*
Alain Weil	Natural rubber

IRCC

Institut de recherches du café, du cacao et autres plantes stimulantes[2]

Paul Gener	*Director*
Jacques Meunier	*Research Director*
Robert Jouanique	*Director, Administration and Accounts*
Daniel Duris	Coffee
Guy Mossu	Cocoa

IRHO

Institut de recherches pour les huiles et oléagineux[2]

Christian Brunin	*Director*
Jacques Meunier	*Research Director*
Robert Jouanique	*Director, Administration and Accounts*
Pierre Quencez	Oil palm
François Rognon	Coconut

1. IRAT and IRCT will be merged on 1 July 1992 to form CIRAD-CA, the annual crops department.
2. IRCA, IRCC, and IRHO will be merged on 1 January 1993 to form CIRAD-CP, the perennial crops department.

IRFA

Institut de recherches sur les fruits et agrumes

Jean-Marie Charpentier	*Director*
Etienne Laville	*Research Director*
Jacques Billod	*Director, Administration and Accounts*
Bernard Aubert	Citrus
Pierre Martin-Prevel	Pineapple
Jacky Ganry	Banana and plantain
Jean-Pierre Gaillard	Fruits for diversification

CIRAD-SAR

Département des systèmes agroalimentaires et ruraux[1]

Jacques Lefort	*Director*
Jean Pichot	*Research Director*
Marc Le Moigne	*Programmes Director*
Léandre Mas	*Director, Administration and Accounts*
Jean-Philippe Tonneau	Economic development and constraints
Bernard Leduc	Sustainable development, income diversification, and marketing
Nicolas Bricas	Promotion of rural output and urban food supply
Vacant	Local development and institutional approach

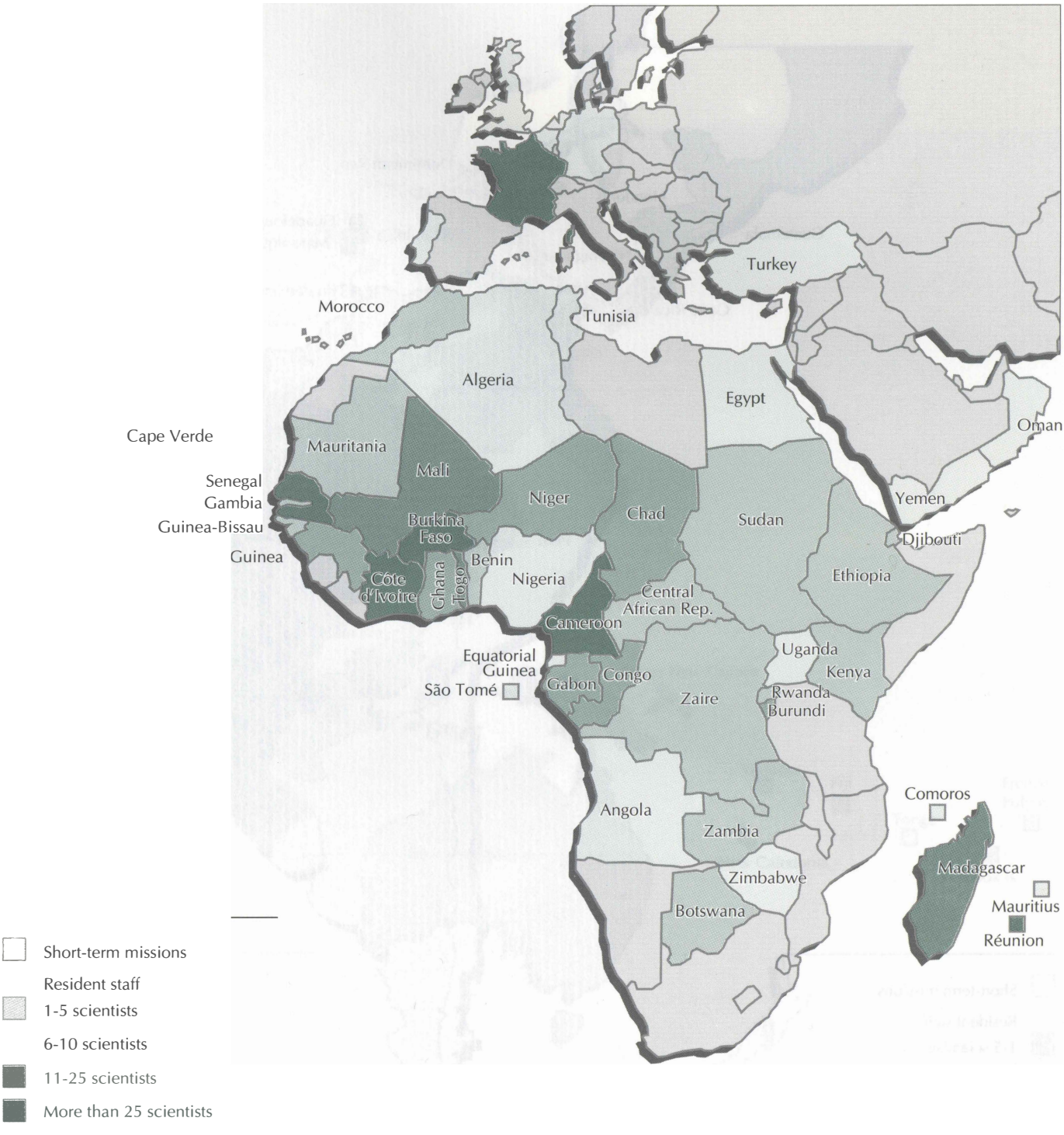
GERDAT

Département de gestion, recherche, documentation et appui technique

Jean-Marie Sifferlen	*Director*
Vincent Fabre-Rousseau	*Administrative Officer*
Michel Launois	Operational ecology, locust and grasshopper studies (Prifas)
Jacques Schwendiman	Molecular and cell biology (Biotrop)
Philippe de Reffye	Plant architecture modelling (Amap)
Michel Griffon	Agricultural prospects and policies

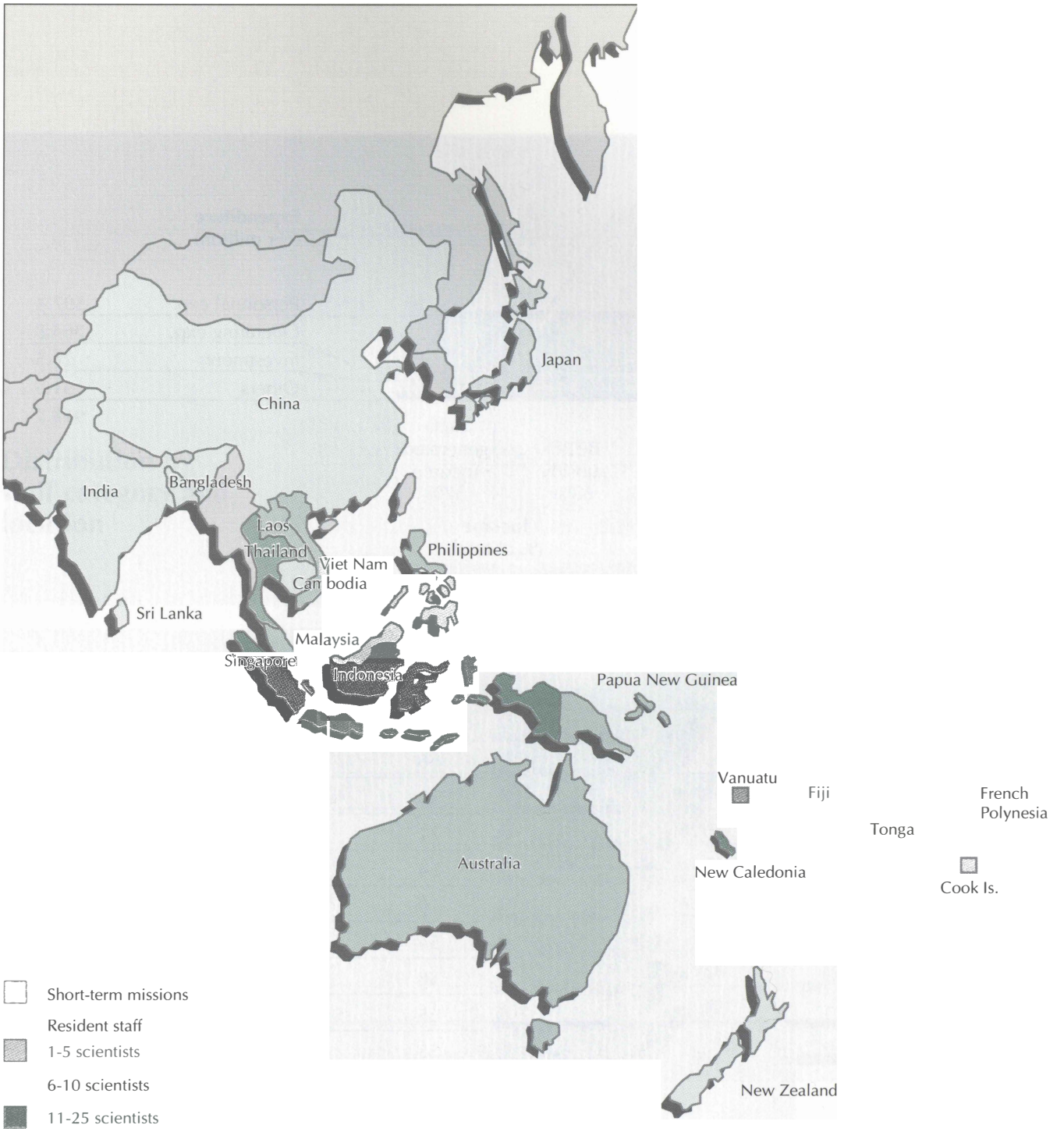
1. The agricultural engineering, energy, and food technology department (CEEMAT) and the agrarian and farming systems department (DSA) were merged on 1 January 1992 to form SAR.

CIRAD in Africa and the Indian Ocean Region



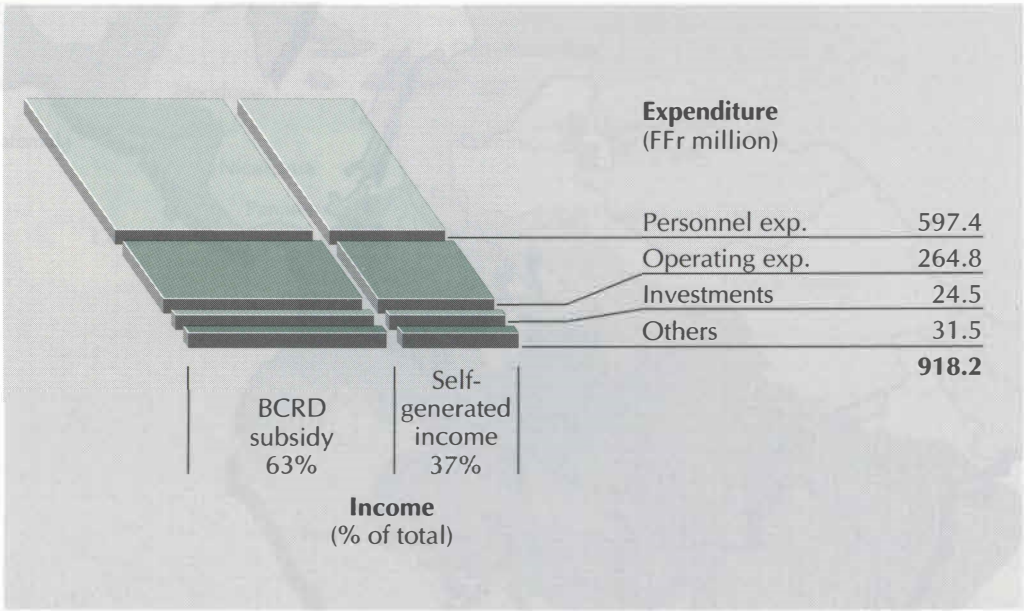
CIRAD in Latin America and the Caribbean

CIRAD in Asia and the South Pacific

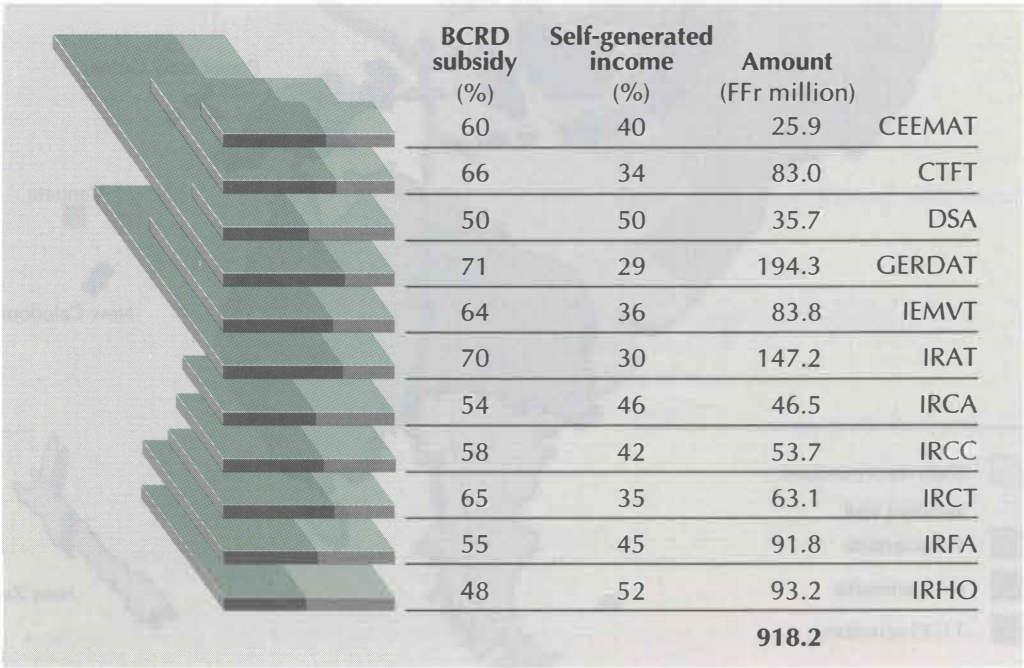


1991 Budget: FFr 918.2 million

Income and expenditure



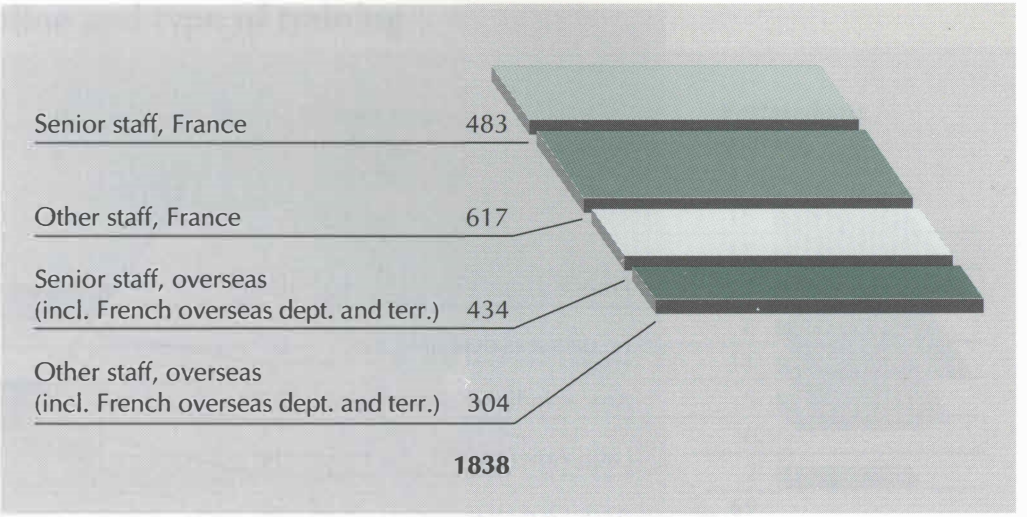
Distribution and origin of funds by department



BCRD subsidy (%)	Self-generated income (%)	Amount (FFr million)	
60	40	25.9	CEEMAT
66	34	83.0	CTFT
50	50	35.7	DSA
71	29	194.3	GERDAT
64	36	83.8	IEMVT
70	30	147.2	IRAT
54	46	46.5	IRCA
58	42	53.7	IRCC
65	35	63.1	IRCT
55	45	91.8	IRFA
48	52	93.2	IRHO
		918.2	

CIRAD Personnel: 1838 Staff Members[1]

Distribution by staff category and location



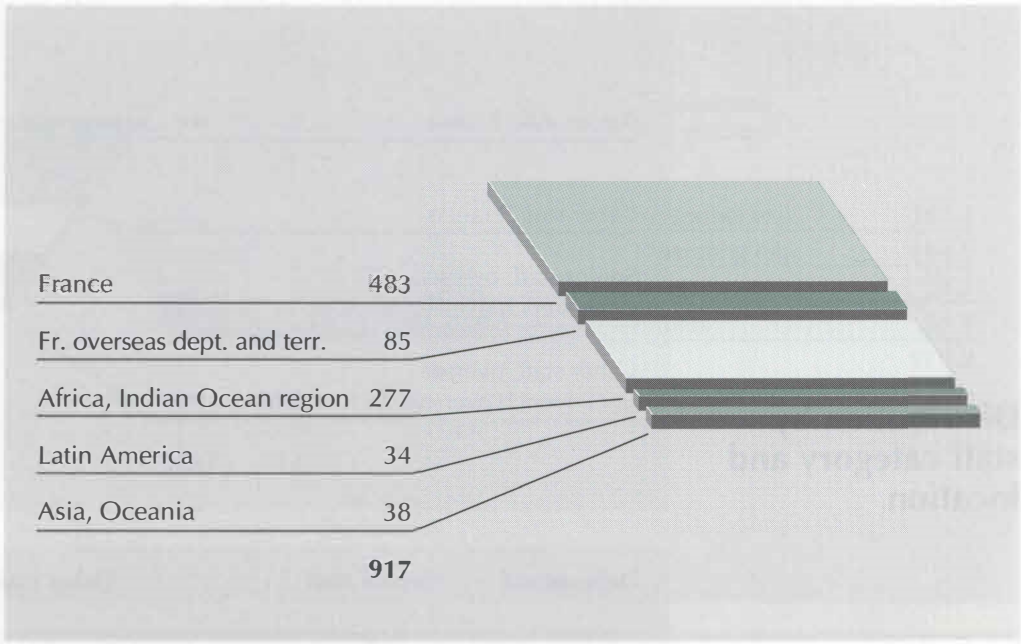
Distribution by department

Department	Senior staff	Other staff	Total
CEEMAT	33	28	61
CTFT	93	119	212
DSA	46	17	63
GERDAT	116	162	278
IEMVT	93	89	182
IRAT	145	206	351
IRCA	49	27	76
IRCC	70	24	94
IRCT	71	36	107
IRFA	96	156	252
IRHO	105	57	162
	917	**921**	**1838**

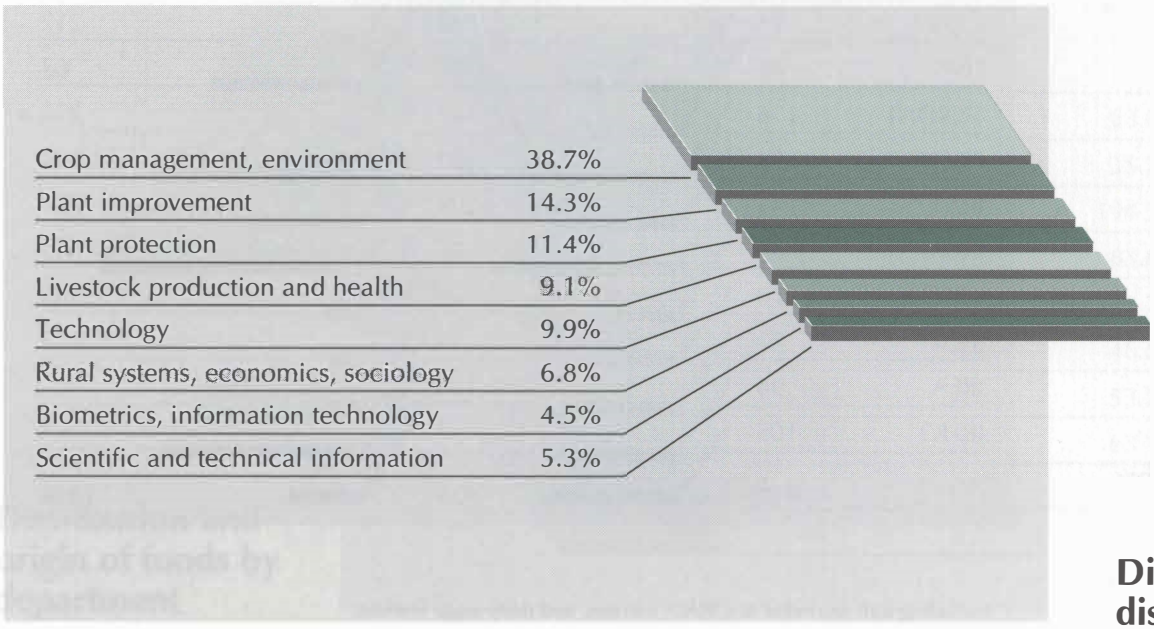
1. Excluding staff seconded to CIRAD, trainees, and daily wage workers.

Senior Staff: 917 Members

Geographic distribution

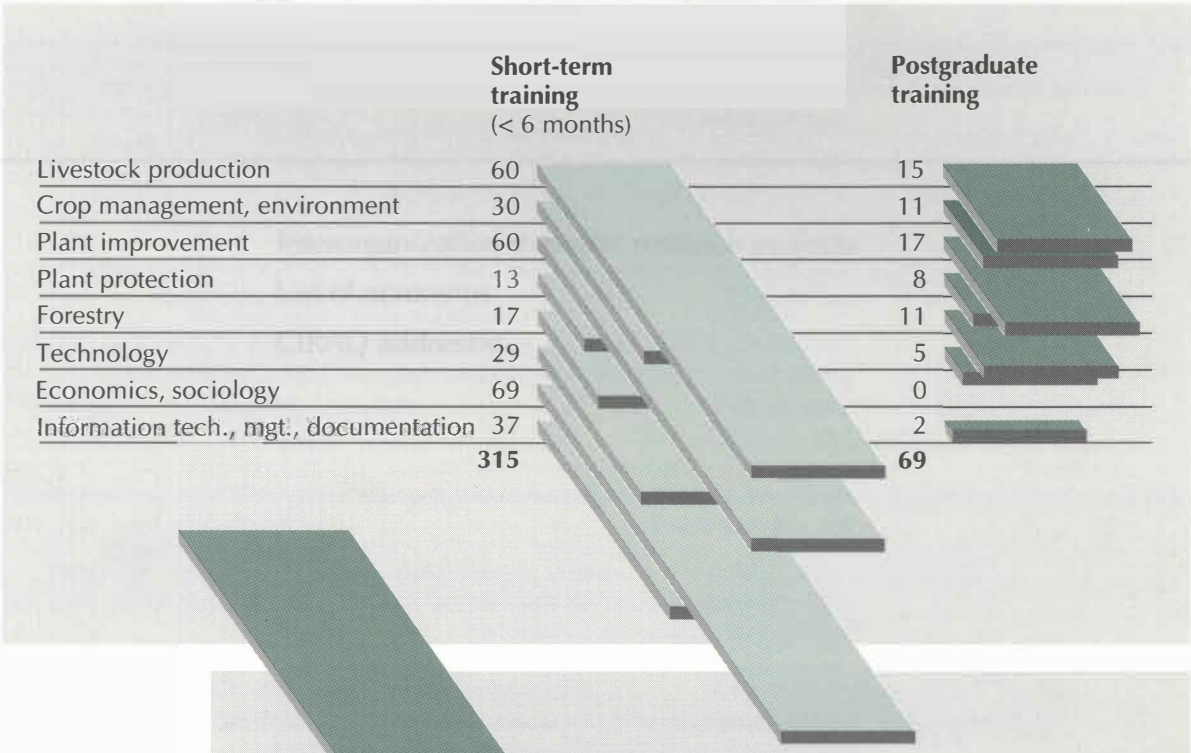


Distribution by discipline



Training: 384 Foreign Participants

Distribution by discipline and type of training



	Short-term training (< 6 months)	Postgraduate training
Livestock production	60	15
Crop management, environment	30	11
Plant improvement	60	17
Plant protection	13	8
Forestry	17	11
Technology	29	5
Economics, sociology	69	0
Information tech., mgt., documentation	37	2
	315	**69**

Distribution by geographic origin

Northern Africa	20
Western Africa	156
Central Africa	46
Eastern Africa	34
Southern Africa, Indian Ocean reg.	46
Latin America, Caribbean	35
Middle East, Asia	32
Europe	15
	384

ANNEXES

Interorganization thematic research projects

List of acronyms

CIRAD addresses

Interorganization Thematic Research Projects Financed in 1991

Work area	Theme	Partners
CROP MANAGEMENT, ENVIRONMENT		
Water–soil–plant relations	*Growth of and water uptake by roots in degraded soils*	Universität Hohenheim (Germany), INRA (France) GERDAT, IRAT, IRHO
Environment studies and remote sensing	*Survey of plant covers and analysis of surface states*	SOCFINDO (Indonesia) CTFT, IRCA, IRHO
	Recognition of crops in community lands of Burkina Faso	INERA (Burkina Faso) DSA, IRAT, IRCT
	Integration of data from maps and a numeric ground truth model with SPOT satellite data (Madagascar)	FOFIFA (Madagascar), ORSTOM (France) DSA, GERDAT, IRAT
Soil fertility	*Study and modelling of potassium supply at the soil–root interface*	DRA, IFDC-Africa (Togo); IDESSA (Côte d'Ivoire); INERA (Burkina Faso); IMG, INRA (France) GERDAT, IRAT, IRCT
	Effect of integrated land development on water and mineral balances in a watershed	CEMAGREF, ENSAM, IMG, ORSTOM (France) IRAT
Intercropping	*Improving fertility of depleted soils through the introduction of* Acacia mangium *in food crop rotation systems*	ORSTOM, CNRS (France) CTFT
	Coffee/pulse intercropping systems	ISABU (Burundi) IRAT, IRCC
PLANT IMPROVEMENT		
Plant breeding	*Improvement of forest species*	ENGREF (France) CTFT
	Breeding strategies for perennial crops	INRA (France) CTFT, IRCA, IRCC, IRHO
Biotechnology	*Study of the genetic diversity of tropical plants and their parasites by RFLP*	INRA, CNRS, Limagrain (France) GERDAT, IRCA, IRCC, IRFA

Work area	Theme	Partners
Biotechnology (continued)	*Use of RFLP for analyzing plant fungi and trypanosomes*	Institut G. Roussy, Université Paris XI (France) IRAT, IRCC, IRFA, IRHO
	Somatic embryogenesis (oil palm, Hevea*) and growth regulators*	CNRS, ORSTOM, Université Paris VI (France) GERDAT, IRCA, IRHO
	*Somatic embryogenesis and cell culture in liquid medium (*Hevea*, oil palm, rice)*	ORSTOM (France) GERDAT, IRAT, IRCA, IRFA, IRHO
	Genetic transformation of cotton and coffee for developing pest-resistant plants	PGS (Belgium), INRA (France) GERDAT
Databanks	*Germplasm databanks*	INRA, INA-PG, ISIM, ORSTOM (France) GERDAT, IRAT, IRHO
PLANT PROTECTION		
Pathology	*Study of groundnut clump virus in western Africa*	CNRS, ORSTOM (France) IRAT, IRHO
Entomology	*Study of vectors that transmit tropical crop diseases*	INRA, ORSTOM (France) GERDAT, IRAT, IRCC, IRFA, IRHO
	Early warning system using pheromone traps	INRA (France) IRCC, IRHO
	Development of tests for early detection of nematode-resistant plants	INRA, ENSA Rennes, ORSTOM (France) IRCC, IRFA
Expert systems	*Expert systems for disease diagnosis and decision-making*	INRA (France) GERDAT, IRCT
LIVESTOCK PRODUCTION AND ANIMAL HEALTH		
Aquaculture	*Feed value of agricultural by-products for tropical fish farming*	INRA, ORSTOM, IFREMER (France) CTFT, IEMVT
Livestock production	*Increasing forage production on community land*	IDESSA (Côte d'Ivoire), ORSTOM (France) DSA, IEMVT, IRAT

Work area	Theme	Partners
Animal health	*Genetic study of cowdriosis resistance in Creole goats in Guadeloupe*	Universität Bern (Switzerland), INRA (France) IEMVT
TECHNOLOGY		
Commodity chains	*Innovative technology for food production (short-cycle chains)*	ENSIAAC (Cameroon); ENEA, ISRA, CIEPAC (Senegal); ENSIA, ORSTOM (France) CEEMAT, DSA, IRAT
Processes	*Adding value to food products of animal origin through stabilization*	ENSAIA, GRET, IFREMER, INRA, Université de Clermont-Ferrand, Université Montpellier II (France) CEEMAT, CTFT, DSA, IEMVT
RURAL SYSTEMS, ECONOMICS, SOCIOLOGY		
	Methodology analysis for modelling increase in productivity	ISRA (Senegal); INERA (Burkina Faso); CNRS, INRA (France) DSA, IRAT, IRCT
	Socioeconomic aspects of the regeneration of plantations in Africa	MARDI (Malaysia); CIRES, SATMACI (Côte d'Ivoire); SRCC (Togo) DSA, IRCC
	Economics of agricultural production in the highlands of Madagascar	FOFIFA, Ecole normale (Madagascar); INRA, Université Paris I (France) CTFT
	Community land management	INERA (Burkina Faso); ISRA (Senegal); IRA (Cameroon); CIEPAC, CNRS, ORSTOM (France) CTFT, DSA, IEMVT, IRAT
	Response of farmers' organizations to state disengagement	ISRA, SAED, IRAM, CIEPAC (Senegal) CEEMAT, DSA, IEMVT, IRCT

List of Acronyms

ACCT, Agence de coopération culturelle et technique, France

AEC, Asiatique européenne de commerce, France

AFP, Association française de pastoralisme, France

AFVP, Association française des volontaires du progrès, France

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

AIT, Asian Institute of Technology, Thailand

ANACAFE, Asociación Nacional del Café, Guatemala

ANVAR, Agence nationale de valorisation de la recherche, France

ARC, Agricultural Research Council, Republic of South Africa

ASCNCER, Asean Sub-Committee on Non Conventional Energy Research, Thailand

ASEAN, Association of South East Asian Nations, Singapore

ASESCAW, Association sportive et socioculturelle des agriculteurs du Wallo, Senegal

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

BRGM, Bureau de recherches géologiques et minières, France

BSN, Boussois-Souchon-Neuvesel, France

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

CCCE, Caisse centrale de coopération économique, France

CEBV, Communauté économique du bétail et de la viande, Burkina Faso

CEC, Commission of the European Communities, Belgium

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

CEN, Centre d'études nucléaires, France

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

CERF, Centre d'essai, de recherche et de formation, France

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

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

CFR, Centre français du riz, France

CGIAR, Consultative Group on International Agricultural Research, USA

CIDA, Canadian International Development Agency, Canada

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

CIES, Centro de Investigaciones Ecológicas del Sureste, Mexico

CILSS, Comité permanent inter-Etats de lutte contre la sécheresse dans le Sahel, Burkina Faso

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

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

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

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

CNES, Centre national d'études spatiales, France

CNPAF, Centro Nacional de Pesquisa de Arroz e Feijão, Brazil

CNRADA, Centre national de recherche agronomique et de développement agricole, Mauritania

CNRS, Centre national de la recherche scientifique, France

COCI, Consortium des agrumes et plantes à parfum de Côte d'Ivoire, Côte d'Ivoire

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

CRA, Centre de recherches agronomiques de l'Etat, Belgium

CRTA, Centre de recherches sur les trypanosomoses animales, Burkina Faso

CTA, Technical Centre for Agricultural and Rural Co-operation, The Netherlands

DGRST, Direction générale de la recherche scientifique et technique, Congo

DRA, Direction de la recherche agronomique, Togo

ECART, European Consortium for Agricultural Research in the Tropics

ECMWF, European Centre for Mid-term Weather Forecasts, UK

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, Italy

FDSEA, Fédération départementale des syndicats d'exploitants agricoles, France

FHIA, Fundación Hondureña de Investigación Agricola, Honduras

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

IAM, Institut agronomique méditerranéen, France

IBPGR, International Board for Plant Genetic Resources, Italy

ICAFE, Instituto del Café de Costa Rica, Costa Rica

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

IDEFOR, Institut des forêts, Côte d'Ivoire

IDESSA, Institut des savanes, Côte d'Ivoire

IER, Institut d'économie rurale, Mali

IFAD, International Fund for Agricultural Development (FAO), Italy

IFDC, International Fertilizer Development Centre, USA

IFPRI, International Food Policy Research Institute, USA

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

IGN, Institut géographique national, France

IIBC, International Institute for Biological Control, UK

IICT, Instituto de Investigação Científica Tropical, Portugal

IITA, International Institute of Tropical Agriculture, Nigeria

ILRAD, International Laboratory for Research on Animal Diseases, Kenya

IMG, Institut de mécanique de Grenoble, France

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

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

INRA, Institut national de la recherche agronomique, France

INRAN, Institut national de recherches agronomiques du Niger, Niger

INRAT, Institut national de la recherche agronomique de Tunisie, Tunisia

IRA, Institut de la recherche agronomique, Cameroon

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

IRFED, International Research and Training Institute for Education and Development, France

IRRI, International Rice Research Institute, Philippines

IRZ, Institut de recherches zootechniques, Cameroon

ISABU, Institut des sciences agronomiques du Burundi, Burundi

ISAR, Institut des sciences agronomiques du Rwanda, Rwanda

ISIM, Institut des sciences de l'ingénieur de Montpellier, France

ISRA, Institut sénégalais de recherches agricoles, Senegal

ITERG, Institut technique d'études et de recherches sur les corps gras, France

KIT, Koninklijk Instituut voor de Tropen, The Netherlands

LRBB, Laboratoire de rhéologie du bois de Bordeaux, France

MARDI, Malaysian Agricultural Research and Development Institute, Malaysia

MRSTD, Ministère de la recherche scientifique et technologique pour le développement, Madagascar

MSIRI, Mauritius Sugar Industry Research Institute, Mauritius

MSPA, Mauritius Sugar Producers' Association, Mauritius

NMA, Núcleo de Monitoramento Ambiental e Recursos Naturais por Satélite (EMBRAPA), Brazil

NRI, Natural Resources Institute, UK

OAU, Organization of African Unity, Ethiopia

ODEADOM, Office de développement de l'économie agricole des départements d'outre-mer, France

ONIC, Office national interprofessionnel des céréales, France

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

PGS, Plant Genetic Systems, Belgiqium

PNG, Papua New Guinea Coffee Research Institute, Papua New Guinea

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

RAVI, Réseau africain de phytovirologie, Congo

RSTCA, Regional Sugarcane Training Center for Africa, Mauritius

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

SAFGRAD, Semi-Arid Food Grain Research and Development, Burkina Faso

SATMACI, Société d'assistance technique pour la modernisation agricole de la Côte-d'Ivoire, Côte d'Ivoire

SEAMEO, Southeast Asian Ministers of Education Organization, Thailand

SIAL, Salon international de l'alimentation, France

SMH, Société de microbouturage de l'hévéa, France

SOCFINDO, Société financière indonésienne, Indonesia

SPAAR, Special Program for African Agricultural Research, USA

SRCC, Société nationale pour la rénovation de la cacaoyère et de la caféière togolaises, Togo

STD, Science and Technology for Development (CEC), Belgium

UAIC, Unité d'afforestation industrielle du Congo, Congo

UNIDO, United Nations Industrial Development Organization, Austria

USDA, United States Department of Agriculture, USA

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