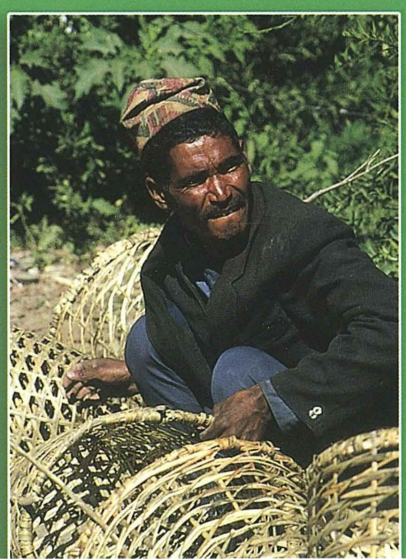
CIRAD 2002



CIRAD 2002

CIRAD, the "Centre de coopération internationale en recherche agronomique pour le développement", is the French Agricultural Research Centre for International Development. Its mission is to contribute to the economic development of the tropical and subtropical regions through research on agriculture, training, and dissemination of its results.

It employs 1 850 people, including 950 senior staff, working in the French overseas departments and some fifty other countries. Its budget amounts to approximately 180 million euros.

CIRAD has seven research departments: annual crops; perennial crops; fruit and horticultural crops; animal production and veterinary medicine; forestry; land, environment and people; and advanced methods for innovation in science. CIRAD operates through its own research centres, collaborating national agricultural research systems, or development projects.

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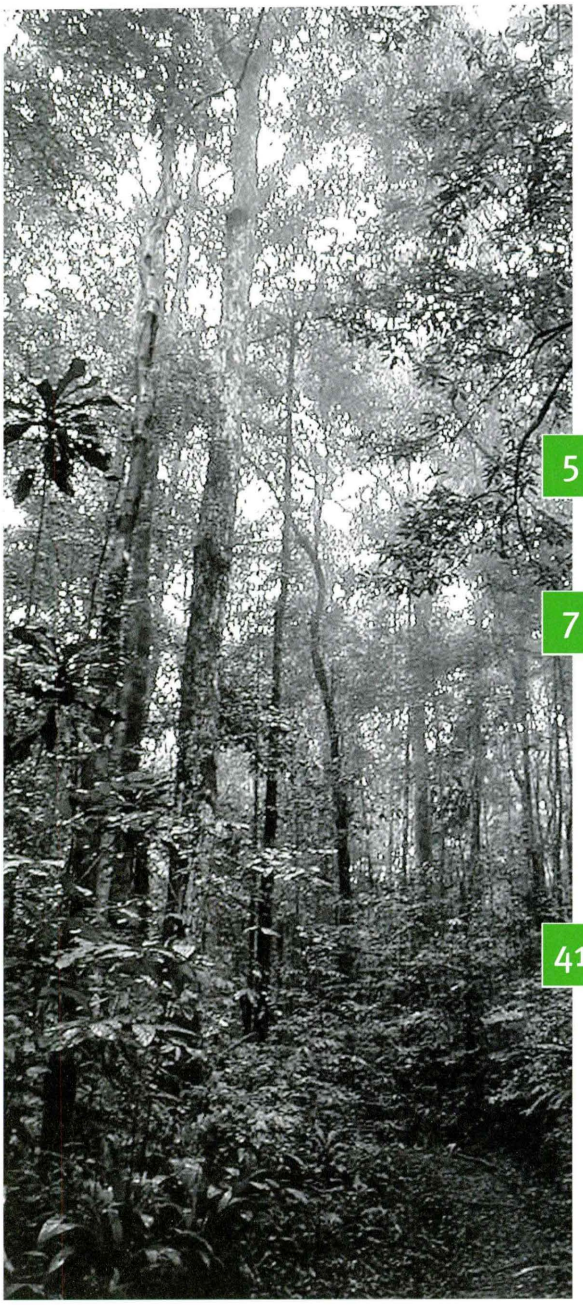


Message from the President

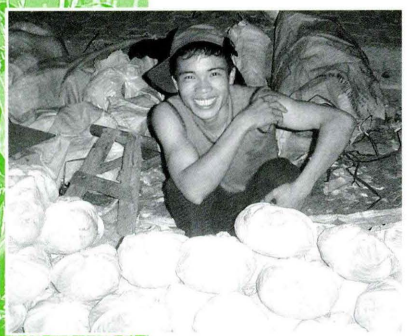
Sustainable development is a cornerstone of CIRAD's strategic project, which was adopted by the Board of Trustees on 20 March 2002 following constructive in-depth discussions. This priority also naturally supports the Agreement on Objectives endorsed by the French government and CIRAD on 26 April 2002. The World Summit on Sustainable Development held in Johannesburg in 2002, along with the national sustainable development strategy promoted by the French government, shed fresh light on and stressed the importance of this orientation. This has fuelled CIRAD's ambition to fulfil its development-oriented research role in France and abroad in partnership with other research institutions, community-based organizations and private enterprises. Over the last decade, the view that research on agricultural activities and rural environments should be designed from a sustainable development perspective gradually gained ground within the national and international scientific communities. CIRAD adopted this strategy from the outset, thus considerably boosting its assets, which include a well-established foothold and collaborations with stakeholders in developing countries, closer but still to be consolidated ties with universities, and a multidisciplinary approach to development issues. The results presented in this CIRAD 2002 report clearly confirm the relevance and quality of the research. These research results are pooled under four priority themes: Ensuring food security and safety; Preparing crop varieties for the future; Promoting stakeholder involvement in research; and Saving the planet. The present report also includes indicators for monitoring the agreement on objectives in 2002. This agreement obviously infers that the entire centre must strive to collaborate closely with its scientific, professional and financial partners. Positive impacts should soon be visible if the evaluation policies voted by the Board of Trustees are promptly implemented. Hence, the identification of a first set of research units to be assessed before the end of 2003 is an important initiative that will lay the foundation for an enhanced future.

Jeanne-Marie Parly
President, CIRAD Board of Trustees

Research results

Ensuring food security and safety

Agrifood product safety is now a major priority. Consumers are concerned by the issue, producers are keen to satisfy demand and the authorities are drawing up regulations and introducing controls. This poses obvious questions in terms of detecting sources of contamination and organizing commodity chains. What emerging diseases might be a threat to animal production? What pathogens are spread by frozen foods? Where do the mycotoxins found in some goods come from? How can antibiotics be detected? How can we prevent toxic residues in periurban agricultural products?



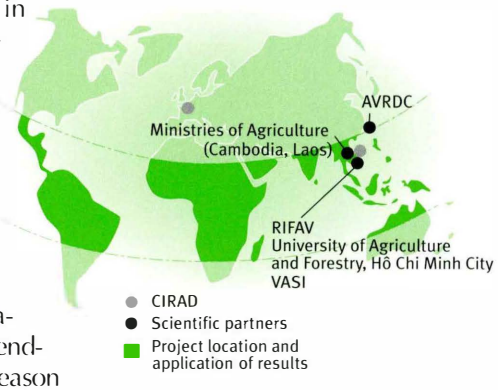
Full text on CD-ROM

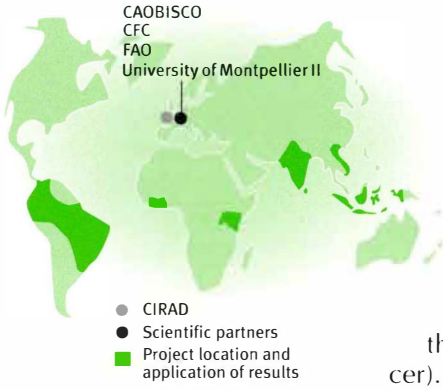
The changing periurban farming sector in Asia

Farming in Vietnam, Laos and Cambodia has changed substantially over the past 10 years or so. However, local agricultural production has run up against a lack of confidence among consumers in terms of food safety and very considerable price fluctuations.

Researchers from CIRAD and Vietnamese organizations are working together in a research platform on a regional periurban agricultural development project headed by the Asian Vegetable Research and Development Center (AVRDC) and CIRAD. The aim is to strengthen the positive role of periurban agriculture and minimize its adverse effects. Vegetable marketing in the region was studied in 2002, in conjunction with local organizations (RIFAV, VASI, Ministries of Agriculture).

Periurban agriculture is crucial in supplying towns with leafy vegetables, whose safety as food has to be closely controlled. In terms of other vegetables, periurban production supplements that of rural areas, where production depends on the agroclimatic conditions. It should be possible to increase the market share of periurban products in relation to imports, for instance by extending the market garden cropping season in rural and periurban areas. Another possibility is to promote local food safety, notably by introducing credible and tested methods of controlling chemical residues. Also, setting up selling associations of local producers should improve the competitiveness of these production chains, which are currently suffering from a lack of economies of scale and of information exchanges between customers and vendors. The second year of the project is being given over to implementing these recommendations and informing producers about market trends.





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Moustier P., Vagneron I., Bui Thi Thai, 2003. Some insights on the organisation of vegetable markets supplying Hanoi. Working series paper, MOISA Joint Research Unit, INRA, Montpellier, France, 15 p.

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Ochratoxin A: coffee and cocoa are under scrutiny

The recent crises in the agrifoods sector have made consumers very demanding about what they eat, and political decision-makers very concerned about preventing food contamination. Foodstuffs are now under close scrutiny, and the authorities have introduced strict regulations governing levels of bacteria, pesticide residues, heavy metals and toxins.

Ochratoxin A is a mycotoxin produced by fungi of the genera *Penicillium* and *Aspergillus*, both of which are widespread, the former in temperate and the latter in hot areas. The toxin causes kidney disease in pigs, and is also suspected of being toxic to man (it is thought to cause kidney cancer). Cereals, dried fruits and pulses, beer, wine, spices, coffee and cocoa can all be contaminated by this mycotoxin. The European Union has already introduced standards for certain foods: the maximum authorized ochratoxin level is 4 microgrammes per kilo in cereals and 10 in dried fruits. The standard for roasted coffee and cocoa is due to be set in 2003, and could be around 3 microgrammes per kilo.

A benchmark method

Drawing up a standard and ensuring that it is respected requires means of measuring and controlling levels. To this end, the FAO, the Common Fund for Commodities and CAOBISCO, a European chocolate manufacturers' group, have contacted several laboratories, including CIRAD, with a view to developing a way of extract-

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Arabica coffee drying on table.

ing and quantifying ochratoxin in coffee and cocoa.

Ochratoxin is found not only on the surface of the beans, but also inside the cells. However, it is easy to extract as it is water-soluble. The beans are ground and placed in a solution of water and alcohol for 20 minutes to extract the toxin. The solution is then purified in an immunoaffinity column. An ochratoxin-specific antibody is bonded onto a polymer, and when placed in contact with the solution, it retains only the toxin. Rinsing in alcohol denatures the antibody and releases the pure ochratoxin, which is then quantified by spectrofluorometry.

This method is now in routine use. In 2002, it was used to analyse over 600 samples for research teams, roasters and buying divisions of supermarkets. It is much more sensitive but also more costly than the rapid methods used in the field by agrifoods firms, and is used as a benchmark in the event of disputes.

The conditions favouring contamination

This work was combined with field surveys to produce an initial picture of the degree of product contamination and to propose preventive measures. Low-quality coffees, which already have a range of bean defects, are also among the most highly contaminated types. They are mainly processed using the dry method, in which the coffee cherries are left to dry in the sun, often directly on the ground, and only lose moisture slowly due to their mucilage content, despite the fact that a moisture content of over 13 or 14% is known to favour mould development. The pressure placed on growers to sell coffee to traders when it is still wet—hence at a lower price—plays a significant role in contamination by preventing growers from completing the drying operation. Poor storage conditions exacerbate the problem still further. As far as cocoa is concerned, it is insufficient bean fermentation, rather than drying conditions, that could be at fault.

Changing practice

It is therefore crucial to improve cropping and postharvest techniques. Technical solutions are available. For instance, using racks, which speed up drying, reduces the risk of contamination. Rationalizing and simplifying coffee marketing chains has a similarly positive effect, although it is more complex. All the players in the commodity chain, from growers to exporters, now need to be made aware that quality depends on each and every one of them.

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Product origin and composition: measurement for certification

Full text on CD-ROM

The standard method used to determine or check the composition or origin of a product is conventional biochemical analysis. However, this is slow, costly, and leads to the destruction of the sample. CIRAD therefore decided to look into the possibilities of near-infrared spectrometry, which is faster and non-destructive. The method is based on the capacity of organic molecules to absorb light with a wavelength of between 800 and 2500 nanometres. A spectrum database is built up from a very large number of samples, defining the limits of each population by statistical analysis. Models are then developed by relating the spectra for each product with the reference quality and quantity data. Once validated, the model can be used to characterize and identify a product rapidly. In this way, it is possible to determine the composition of a cocoa sample, distinguish an Arabica coffee from a Robusta, or determine the proportion of each type of coffee in a sample ground coffee blend. The method should eventually be suitable for certifying the geographical origin of a given product.

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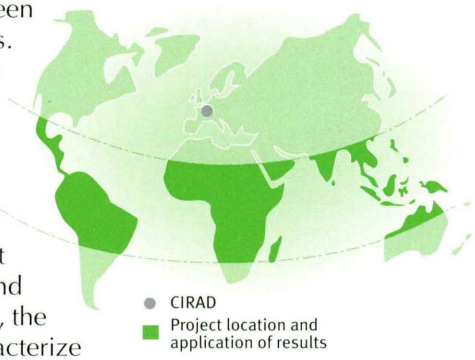
Near-infrared spectrometry of green coffees.



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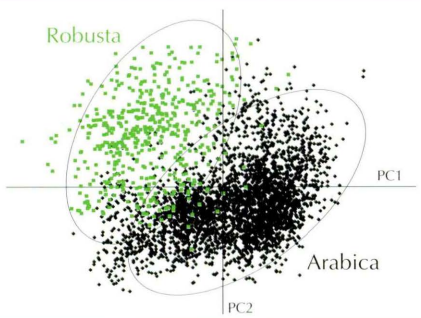
Separation of Arabica and Robusta coffees by spectrometry

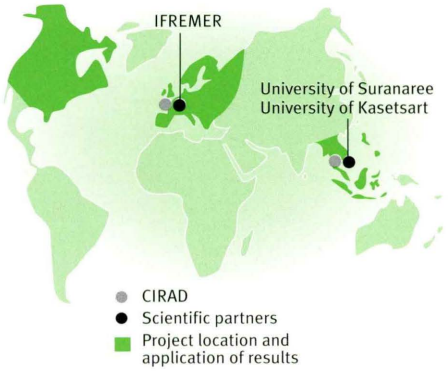


A biological "bar code" for fish from Asia

In Europe, all fish products must be labelled, albeit only with the sea or ocean in which they were fished or farmed. This makes it difficult to tell whether imported fish was farmed in Thailand or Vietnam. Such products must also have a health certificate. However, these documents do not provide any indication of where the products were packed, or who the exporter is. Nor is there generally any information on the production site or the origin of any other ingredients or additives.

As it is not always possible to introduce identification systems or to trace foodstuffs in developing countries, CIRAD and its partners have set out to detect specific markers that could be used to establish the origin of fish from Southeast Asia on the international market. These markers could be microbial species found naturally in the products concerned, myofibrillar proteins in the fish, or fish or bacterial gene fragments. They could be used to establish a biological "bar code" for foodstuffs.

Several teams are working on the project. CIRAD, the research coordinator, has three teams involved: one is analysing the bacteria found on



fish and studying the effect of processing on these markers, the second is working to optimize microorganism genome analysis protocols and the third is studying aquacultural commodity chains, collecting samples and helping to identify fish species using microsatellite markers. IFREMER, the French marine study centre, is working to determine fish species by analysing their sarcoplasmic proteins and nucleotide sequences. In Thailand, two teams from the universities of Suranaree, in Korat, and Kasetsart, in Bangkok, are supervising students sent by the French teams.

Feeding in floating cages.

© J. Lazard

Commodity chains in Vietnam and Thailand

Catfish farming has really taken off recently in the Mekong delta of Vietnam. Production has increased ninefold in 10 years, reaching 76 000 tonnes in 2000. Two species are farmed: *Pangasius hypophthalmus*—90% of the total output—and *P. bocourti*. Yields are high: up to 17 kilos per cubic metre per month in floating cages and up to 344 tonnes per hectare per year in traditional lakes. Most of the fish produced comes from floating cages—4 600 cages producing 55 000 tonnes per year—and 90% of the total is sent to processing plants to make frozen fish fillets that are subsequently exported under various brand names. Exports totalled 20 000 tonnes in 2000, mainly to Southeast Asia and the United States.

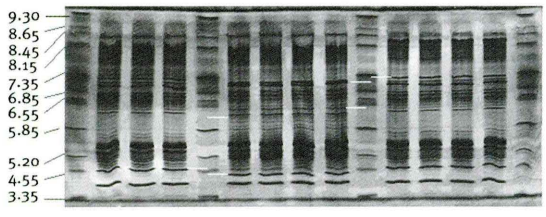
Tilapia production in Thailand reached 2 million tonnes in 2001, 1.3 million of which were farmed. Most of the output is sold on the domestic market, which is currently booming, while the export market is still limited and concerns only a small number of operators. However, tilapia fillets could replace white fish fillets (hake or cod), which are highly sought after in Europe; they have already found a niche on the US market, which imported 75 000 tonnes in 2001.

Identifying species and quality

There are two standard electrophoretic methods of identifying the species of processed products: isoelectrofocalization (urea-IEF) and SDS-PAGE. These techniques are based on the fact that the soluble sarcoplasmic proteins in raw fish reflect the genome, and are thus characteristic of the species. The isoelectrofocalization technique has now been used to distinguish unequivocally between the two catfish species: *P. bocourti* and *P. hypophthalmus*.

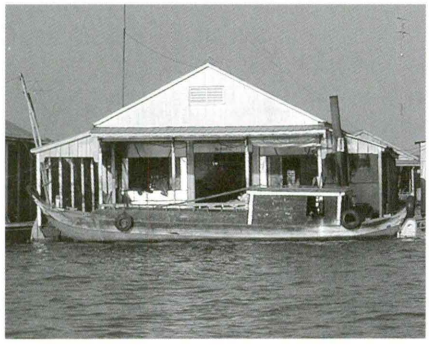
The analysis of commensal microbial floras began with the facultative aerobic and anaerobic floras, which are usually mesophilic and some of which are toxic to man and fish. The study was conducted on catfish produced and frozen in Vietnam and shipped to Montpellier, and on tilapia from Thailand. Several strains of the following bacterial species and genera were isolated and identified in each of the samples: *Enterobacter*

Identification of catfish species by sarcoplasmic protein electrophoresis



cloacae, Enterobacter sakizakii, Enterobacter aminogenus, Klebsiella pneumoniae, Proteus vulgaris, Proteus mirabilis, Providencia alcaligenes, Escherichia coli, Pseudomonas aeruginosas, Pseudomonas putida, Aeromonas hydrophylia, Aeromonas salmonicida, Aeromonas sobria, Vibrio cholerae (to be confirmed), *Vibrio parahaemolyticus, Bacillus* sp., *Staphylococcus* sp. and *Streptococcus* sp.

A sample of *P. hypophthalmus* reared in floating cages in Vietnam was tested for antibiotic-resistant germs. Of the 102 bacterial strains isolated, 64 had a degree of resistance to at least one of the 12 antibiotics commonly used on fish farms and 38 were susceptible to the 12 antibiotics tested.



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The trials conducted during the first phase of this project suggest that the microorganisms found in or on an animal, or even a plant, can be used as markers of its origin: the bacteria found on fish are one example. The next step is to characterize them. Biomolecular typing and the detection of antibiotic-resistant strains have already proved their efficacy.

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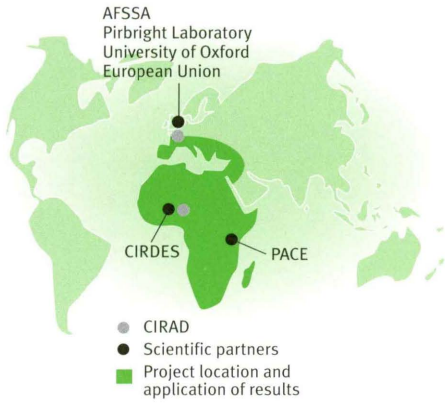
Controlling animal health risks

Increased global trade, climate and ecological change, and new animal production practices have created an environment that favours the spread and emergence of infectious and parasite-borne diseases. In the tropics, the phenomenon has been exacerbated by inadequate animal health systems and a lack of information on certain epidemiological cycles. Epitrop, a group of researchers from various teams at CIRAD's Animal Production and Veterinary Medicine Department, was set up in 1998 to provide a more satisfactory response to requests from international organizations in terms of disease prevention and control. The epidemiological research being conducted at CIRAD is oriented towards monitoring, analysing and modelling the major tropical infectious and parasite-borne diseases: trypanosomiasis, contagious bovine peripneumonia, rinderpest, peste des petits ruminants (goat plague), African swine fever, Rift Valley fever, bluetongue, etc. The network is working with numerous scientific and technical organizations in both industrialized and developing countries. Its operations in 2002 concentrated on three diseases.



Bluetongue

Bluetongue surveillance has been stepped up in Corsica and on the mainland. Predictive models are now being developed.

Surveillance is based on entomological, serological and virological monitoring. Bluetongue is a viral disease, spread by midges of the genus *Culicoides* (Diptera: Ceratopogonidae), and more precisely by *Culicoides*

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Sheep with bluetongue.

© G. Libeau

Oryx, a wild animal susceptible to *peste des petits ruminants*.

imicola in the Mediterranean region. It is a major disease that can have serious economic consequences. It has been considered as an emerging disease in the Mediterranean since 1998. After the epizootic in Corsica in 2000, the food products division of the French Ministry of Agriculture set up a surveillance system, with scientific and technical support from CIRAD, which is the French national reference laboratory for bluetongue and which as such works closely with AFSSA, the French food safety agency.

Predictive models have now been developed, in partnership with the Pirbright Laboratory and the University of Oxford in the United Kingdom, using satellite data (vegetation indexes, temperature, etc) and entomological data gathered from surveillance operations in Corsica and on the mainland. These models were validated using entomological data obtained by *Culicoides* spp. trapping operations in 2002. The correlation between predictions of the vector *C. imicola* and the bluetongue foci actually recorded in Corsica was proof of the accuracy of the model used.

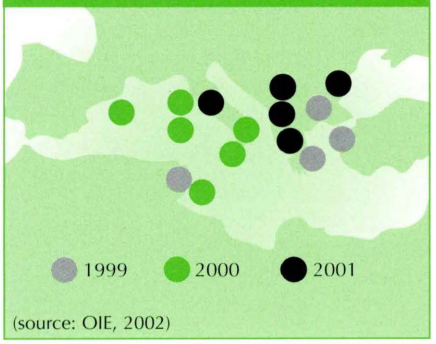
Statistical models have been used to draw up a map forecasting *C. imicola* abundance in the Mediterranean, and thus the risk of the disease. The map shows large numbers of insects in many zones recently affected by bluetongue. It suggests that certain regions around the Mediterranean and several zones in southeastern and southwestern France are at considerable risk in the near future. Global climate change has favoured the spread of zones propitious to the development of vector insects, which may be one of the reasons for the spread of the disease in the Mediterranean basin, and particularly in Corsica. These results show that it is vital to step up epidemiological surveillance operations in France and pinpoint the priority zones in the Mediterranean basin. This work has strengthened the relations between CIRAD and its European partners, but should also, in the medium term, lead to new links with Mediterranean countries, particularly in the Maghreb, in relation to epidemiological issues.

Peste des petits ruminants and trypanosomiases

While monitoring rinderpest in wildlife under the Pan-African Programme for the Control of Epizootics (PACE), CIRAD also tested for the presence of peste des petits ruminants (PPR). This programme is run by the Organization of African Unity and largely funded by the European Union. PPR is spreading rapidly in the tropics and, as analyses of samples have shown, the multiplicity of hosts receptive to the virus among the local wildlife could prove to be a major obstacle in controlling the disease. It is therefore essential to establish its epidemiology, notably through molecular epidemiology and modelling studies.

Several years' work in conjunction with the International Centre for Animal Husbandry Development and Research in Sub-humid Regions (CIRDES) has resulted in the development of targeted control methods against trypanosomiases that are accessible to animal farmers in developing countries. CIRAD is currently working with CIRDES on the epidemiology of trypanosomiases in West Africa, and particularly on their transmission: the mechanism involved and identification of zones in which the diseases are spreading.

Bluetongue focus development in the Mediterranean basin from 1999 to 2001



(source: OIE, 2002)

CIRAD is continuing to supplement its expertise in epidemiology. It is working to transfer tools and methods to partners in developing countries—evaluation of the efficacy of surveillance networks, risk analysis and management, emergency intervention capacity—and to develop new research topics—analytical and molecular epidemiology, spatial analysis and modelling. Since 2002, it has been looking at how to structure these operations so as to increase their efficiency and clarity.

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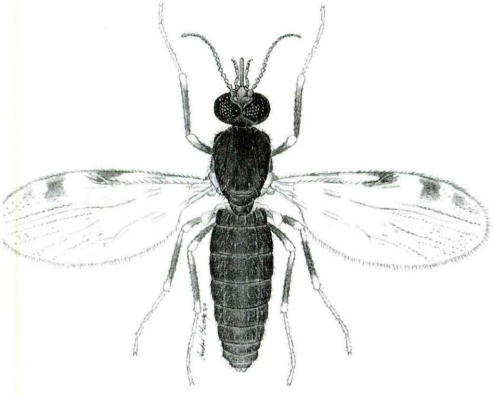

***Culicoides imicola*, the bluetongue vector, one of the smallest bloodsucking insects (1 to 3 mm).**

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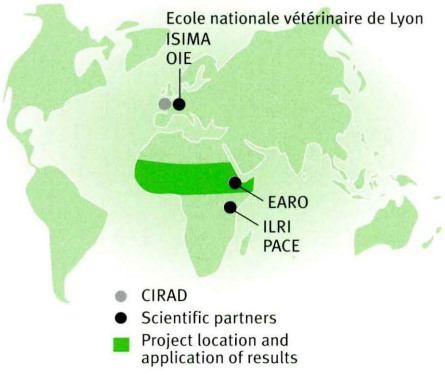
Full text on CD-ROM

The spread of contagious bovine pleuropneumonia

Contagious bovine pleuropneumonia (CBPP) is a respiratory disease that affects domestic cattle and is transmitted by contact between animals. It is a major constraint on cattle production and trading in sub-Saharan Africa. In view of the situation, CIRAD has launched a study aimed at establishing methods and developing tools to provide support when making decisions on how to control the disease and quantifying its development under animal production conditions. The study concerns the upland plateaus of Ethiopia, where contamination often results from exchanges of animals among farmers.

The first component of the project concerns disease spread within a herd. A model of disease spread has been developed, based on epidemiological parameters recorded in 80 herds, both healthy and infected. The model has been used to quantify the potential risk that chronic carriers represent and as a basis for an economic evaluation of several control strategies.

The second component concerns disease transmission among herds.



A survey of over six thousand farms in the region provided data on rearing practices and exchanges of animals. These data were input into a geographical information system and are now being used as the basis for a study of the extent to which the risk of transmission as a result of animal movements is regionalized. The aim is to develop mathematical or computer models to simulate disease spread between herds, which will be used for an economic evaluation of control strategies, from the point of view of both individual farmers and territorial farmers' groups.

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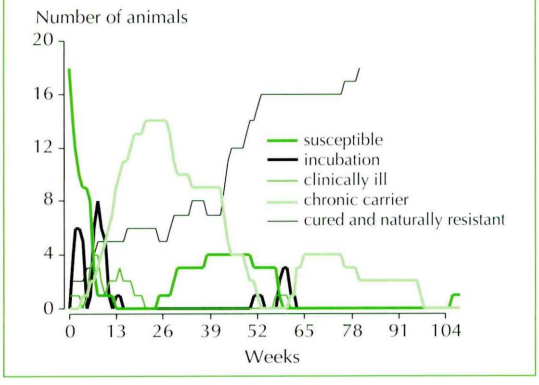
Modelling pleuropneumonia spread within a herd



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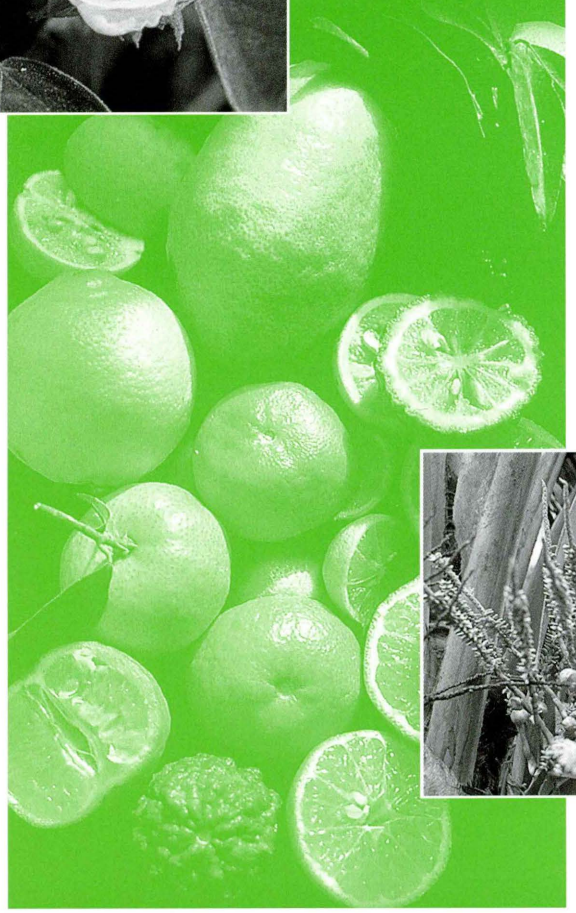
Preparing crop varieties for the future

Molecular markers have enhanced the efficacy of varietal improvement and creation to help meet the manifold objectives. The development of improved varieties by tapping the genetic diversity, which is especially rich in tropical species, is a better known strategy and also more effectively utilised. Crop improvement is now integrated in overall strategies, and new varieties thus provide growers with environment-friendly solutions tailored to constraints in different cropping systems. They also meet consumer demand for more varied and better quality products.

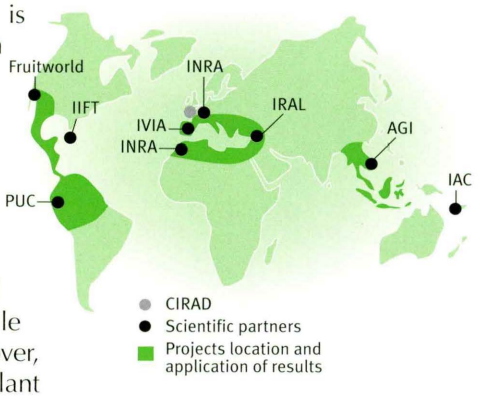


Citrus breeding: quality and disease resistance

Citrus is the top fruit crop in the world, with around 93 Mt produced during the 2001-2002 season. A major share of this volume is for domestic consumption. The fresh citrus fruit export market is booming and currently represents some 10% of the overall volume. The market trends are also evolving with respect to citrus fruit types, eg orange, grapefruit and lemon exports have levelled off, while small citrus fruit exports are rising. Countries in the Mediterranean Basin, especially Spain, dominate the fresh citrus fruit market. Juices and preserved fruit account for a third of the production, ie chiefly concentrated orange juice, but there is also a market demand for non-concentrated juices. Brazil, the top orange juice producing country, and USA control a major part of this market.

High environmental pressure

The vitality of the citrus industry is fuelled by intense varietal creation activity: increasing the range of varieties, ever longer production seasons, etc. Citrus growing must also take advantage of available biological diversity to enhance sustainable development by creating varieties adapted to the many biotic and abiotic constraints and to various cropping systems, while fulfilling consumer needs. Moreover, the widespread application of plant variety protection policies is an incentive for citrus-producing countries to develop their own cultivars.



In Brazil, it has become essential to breed new varieties to ensure integrated protection of citrus orchards in response to the emergence of diseases such as variegated chlorosis and the sudden dieback of orange trees grafted on lime cv Rangpur rootstock. This would also be crucial to overcome the problem of citrus cercosporiosis in Africa and citrus greening (*huanglongbing*) in Southeast Asia.

In the Mediterranean Basin, citrus growers have to produce top quality fruit to meet the needs of the demanding fresh fruit market. Orchards must also be renewed by planting new rootstock to offset the problem of the introduction of tristeza virus in this region, which is already hampered by major environmental constraints (salinity, chalky soil).

Seedless citrus fruit and adapted rootstock

To fulfil the requirements of the small citrus industry in the Mediterranean Basin, seedless, high-quality citrus fruits with an extended production period should be created, while breeding rootstock adapted to constraints that prevail in the region. To this end, research has been under way for about 10 years, jointly coordinated by CIRAD and INRA, the French agricultural research institution, using germplasm from the repository maintained at the San Giuliano research station in Corsica.

Studies are focused on creating triploid cultivars, which are known to be highly sterile, thus avoiding the problem of cross pollination with clementine, a potential source of seeds. The French teams have been using biotechnology strategies to enhance triploid breeding schemes: embryo rescue techniques, ploidy assessment by flow cytometry, creation of somatic allotetraploid hybrids to enlarge the pool of potential parents, and direct creation of 150 triploid hybrids through diploid and haploid protoplast fusion. The triploid hybrids are being tested in Corsica, French West Indies and in New Caledonia under the partnership with IAC. Their high sterility was confirmed at the first fruiting.

Other studies have been geared towards breeding rootstock adapted to the Mediterranean environment by inserting tolerance traits extracted from citrus germplasm. *Poncirus trifoliata*, which is tolerant of many different pests and diseases, thus complements certain *Citrus* sp. that are well adapted to salinity and chalky soils. The strategy involves pooling favourable genes in allotetraploid hybrids synthesised by protoplast fusion. The first hybrid obtained, ie Flhorag1 (*P. trifoliata* x *Citrus deliciosa*), turned out to be quite interesting: it is resistant to tristeza and much more tolerant of salinity and chalky soils than *P. trifoliata*, and also seems to be compatible for grafting with most citrus cultivars. Its seed propagation capacity was confirmed at the first fruiting.

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Varietal innovations in collaboration with many partners

CIRAD and INRA have forged many partnerships to strengthen upstream research and validate methods through large-scale applications in a range of different environments.

A project, conducted in collaboration with INRA of Morocco, to pinpoint the factors that affect spontaneous development of triploid hybrids, came to an end in 2002. Collaborations are under way with the Catholic University of Chile (PUC) and the Agronomical Genetic Institute (AGI) in Hanoi, Vietnam, to develop new methods for creating triploid cultivars. Small triploid citrus varieties are also being bred in collaboration with private companies based in California, and soon in Morocco and Chile.

Studies to assess allotetraploid Flhorag1 rootstock under abiotic constraints (salinity, chalky soils) have begun at IRAL, the Lebanese agricultural research institute, and at INRA of Morocco. This hybrid will be tested in other regions in the world where cropping constraints are similar to those affecting the Mediterranean Basin. Thus, in Cuba, a project to create varieties and breed rootstock adapted to conditions in the West Indies has been initiated in partnership with IIFT, the Cuban tropical fruit research institute.

In addition, CIRAD is investigating new methods for specifically modifying genotype structures, without involving genetic engineering, to utilise tolerance, quality and productivity traits already present in citrus germplasm. These methods will be suitable for improving varieties of orange (*C. sinensis*), or grapefruit (*C. paradisi*), and also for enhancing clementine diversification. IVIA, the Spanish citrus research institute, and several Brazilian research institutes, have expressed an interest in these approaches. Concomitantly, basic integrative biology studies, rapid phenotyping and molecular assisted selection of different characters (salinity tolerance, quality factors) will be developed to support the breeding initiatives.

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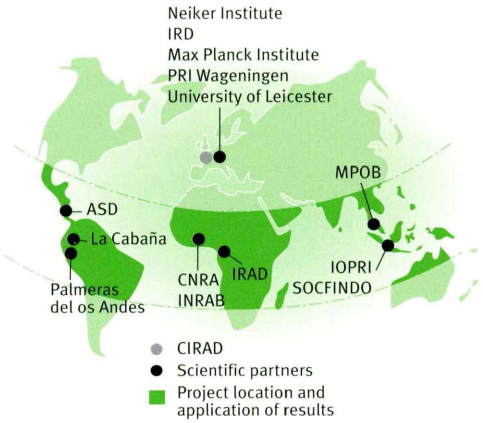
Full text on CD-ROM

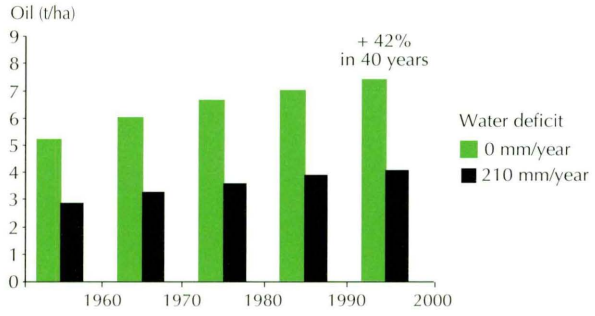
Oil palm: from gene to variety

Oil palm ranks second in the world, for vegetable oil production, just behind soybean. Producers, smallholders or estates, all require access to high-yielding planting material that is adapted to local constraints to enable sustainable intensification of this crop. In 2002, more than 50 000 ha were planted with oil palm planting material bearing the "CIRAD" label. Oil production volumes reached a record 7.5 t/ha in the best oil palm plantations of Indonesia.

CIRAD's breeding strategy aims to increase oil palm productivity while ensuring its long-term cost-effectiveness. This plan is being implemented within a research network developed through partnerships in the main oil palm growing regions of Africa, Southeast Asia and Latin America. This system makes effective use of germplasm obtained locally or through exchanges, and new hybrids are tested to prepare seed for the future. The considerable body of data collected in more than 300 field trials including 620 000 trees has been compiled since 1960 in an oil palm database.



Genetic progress from 1960 to present: increased oil production



In 2002, the main collaborative research projects were focused on identifying genetic sources of resistance to *Ganoderma* sp., which is threatening to destroy plantations in Southeast Asia, and on evaluating the efficiency of molecular markers for detecting unwanted "mantled" variants obtained through micropropagation.

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Joint research units: polymorphism of agronomic interest, developmental biology of tree crop species, biology and genetics of plant-parasite interactions for integrated crop management
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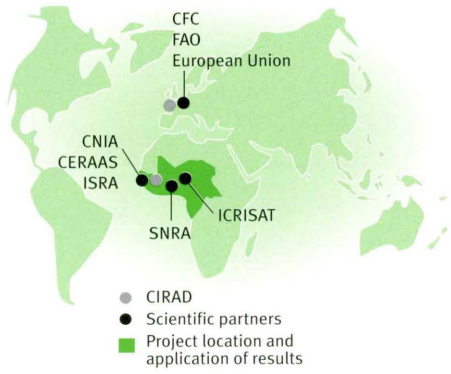
Groundnut: better climatically adapted varieties

Groundnut is a crop of high agricultural plasticity that is grown throughout Africa and cherished by consumers in its many culinary and commercial forms (oil, edible nuts, confectionery, pastes, seedcake, fodder). It is one of the very few crops that can be grown in areas with annual rainfall levels as low as 350-450 mm. However, genetic erosion of the species is very high, due to the fact that it is cropped almost exclusively in dry areas and to the poor maintenance of groundnut germplasm collections. It is thus considered essential to protect groundnut diversity by preserving plant material, while promoting breeding and the effective use of new cultivars. This also applies to other food crops such as sorghum in Mali and Burkina Faso, and taro and yam in the Pacific region.

Preserving groundnut diversity via germplasm collections

The Groundnut Germplasm Project (GGP), sponsored by FAO and funded by the Common Fund for Commodities (CFC), was carried out from 1996 to 2002 by the International Crops Research Institute for the Semi-Arid



Tropics (ICRISAT), CIRAD and ISRA, the Senegalese agricultural research institute, with the aim of restoring groundnut genetic diversity in western and central Africa. A regional collection of 6 000 accessions was assembled through an institutional and scientific partnership with the national agricultural research services of the main groundnut-producing countries of the region. It is currently being maintained according to international standards by ICRISAT in Niger. All national breeders and developers have ready access to this genebank to meet their varietal creation or improvement needs. A core collection, representative of the genetic diversity of the regional collection, is also available. It consists of the five main groundnut botanical varieties (*hypogaea* bunch, *hypogaea* runner, *vulgaris, fastigiata* and *peruvian*) and the four maturity groups (very early to late).

CIRAD and ISRA have also developed a modified atmosphere packaging process, i.e. seeds are stored in vacuum packs or inert gas packs, which means that they can be preserved for at least 2 years without loss of germination viability. This technique is more cost-effective and requires less facilities than cold storage.

A high yielding early groundnut variety.

© A. Mayeux

Creating drought-resistant varieties

Groundnut varieties created or improved using material from the germplasm collection should be adapted to the climatic conditions and cropping practices of the regions for which they are targeted, thus ensuring their cost-effective dissemination. In Senegal, CERAAS, the Senegalese research centre that focuses on crop responses to drought, which is affiliated with ISRA, is trying to develop varieties that could produce stable yields when grown under dry climatic conditions.

After characterising drought patterns in Senegal, two sets of very early maturing genotypes (80 days) were bred and found to be better adapted to the shorter rainy seasons that have prevailed in recent years. Varieties obtained by backcrossing and introgression of earliness traits yield well in different environments. A long-term recurrent selection programme is also under way. Populations with a broad genetic base have thus been obtained and should enhance physiological adaptation to drought. Three recombination cycles were conducted, involving intercrossing of lines selected on the basis of their adaptive traits (root growth, protoplasmic resistance and stomatic regulation). The resulting population could be further improved by focusing selection pressure on the most heritable traits, or its variability could otherwise be tapped for breeding varieties adapted to different specific conditions. Several lines have already been bred to fulfil requirements in Senegal, Burkina Faso and Botswana.

Stockpiled groundnuts.

© C. Weiss

Meeting the subsector's needs

Forty-six varieties, classified in a document published by GGP, are currently recommended for planting in western and central Africa. They are resistant to major cropping constraints (leaf and virus diseases, drought, aflatoxins) and meet edible groundnut market requirements. Some of these varieties have

already been released to national agricultural services and are being multiplied for subsequent seed production.

An edible groundnut programme, funded by the European Union, is also under way in Senegal, coordinated by CNIA, the Senegalese interprofessional groundnut committee. A range of 33 new varieties, which could potentially meet domestic and export market phytosanitary and technological quality standards, has been assessed in irrigated cropping conditions. Yields under irrigation are generally substantially higher than those obtained in rainfed conditions, i.e. 4 t/ha versus 1 t/ha, thus offsetting irrigation costs (around 610 /ha). Breeding initiatives to improve drought resistance have led to the development of short-season varieties that yield well in low rainfall areas. In irrigated conditions, these varieties also produce yields that are almost as high as those obtained with long-season varieties. This impressive performance under irrigation could lead to potentially considerable water savings for growers because of the 3-week reduction in the growth cycle. These early varieties are especially interesting for their capacity to adapt to different environments. At least seven short-season varieties and four long-season varieties have been shown to perform well in terms of crop yields and quality.

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An observatory for yams from Oceania

Full text on CD-ROM

Four Pacific Islands countries (Papua New Guinea, Fiji, Vanuatu, Solomon Islands) have joined hands in the South Pacific Yam Network (SPYN) with the aim of gaining further insight into the genetic diversity of *Dioscorea alata*, which is endemic to this region and the most commonly cropped yam species in the world. One key result of this project was the development of a regional database, currently managed by CIRAD and which pools information on the morphological, agricultural and tuber traits of 1 100 yam varieties. The project benefited from 4 years of European Union funding.

The 90 best performing cultivars, selected on the basis of their yields, taste quality and disease resistance, have been released to growers in each of the four countries to be cropped for domestic consumption and export to Australia and New Zealand.

A phytosanitary analysis, carried out in partnership with the Natural Resources Institute (NRI), UK, highlighted the presence of many virus diseases and very high genetic variability in the fungus that causes anthracnose. Tests to detect the seven identified viruses are now available through the network. SPYN, in collaboration with the Secretariat of the Pacific Community (SPC), launched a programme to promote disease elimination and germplasm conservation in yam through *in vitro* culture techniques.

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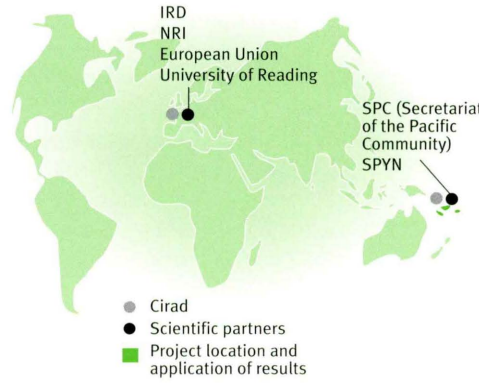

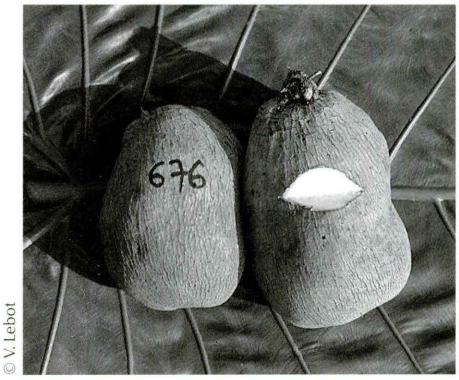

Compact white-pulped tubers of a recommended yam variety.

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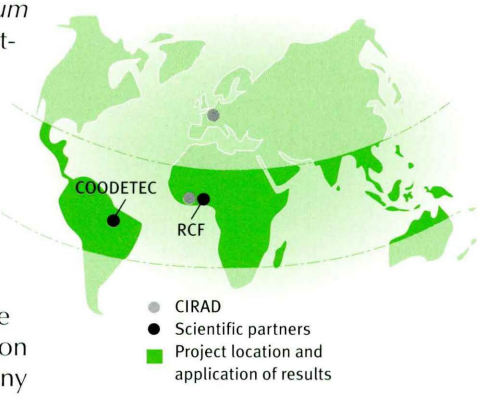
Genetic factors that determine cotton quality

Gossypium hirsutum and *Gossypium barbadense* are the two major cotton species grown around the world. *G. hirsutum* varieties, which are cropped on 90% of the overall area under cotton, are hardy and high yielding, but the fibre is only of medium quality. *G. barbadense* "long-staple" cotton varieties produce superior quality fibre. Since these two species are interfertile, cotton breeders have been trying for many years to combine the agronomic assets of *G. hirsutum* with the fibre qualities of *G. barbadense*.



Benefits of marker-assisted selection

Strategies involving conventional breeding of interspecific *G. hirsutum* x *G. barbadense* hybrids are tricky because of the high number of progeny that must be screened due to factors that hamper recombination between the genomes of these two species. This selection functions on the phenotype level.

Marker-assisted selection concerns the genotype. DNA molecular markers are used to pinpoint chromosome regions where quantitative trait loci (QTL) corresponding to the expression of specific agronomic traits are located. By this method, introgressed *G. barbadense* QTLs of potential interest for improving fibre quality can be monitored in the interspecific progeny.

A molecular marker study of *G. hirsutum* x *G. barbadense* interspecific recombination was launched in 1998. The first combined saturated map of the cotton genome was described in 2000 and highlights the chromosome locations of the different markers. The next phase of the project was to locate QTLs linked with the expression of cotton fibre quality.

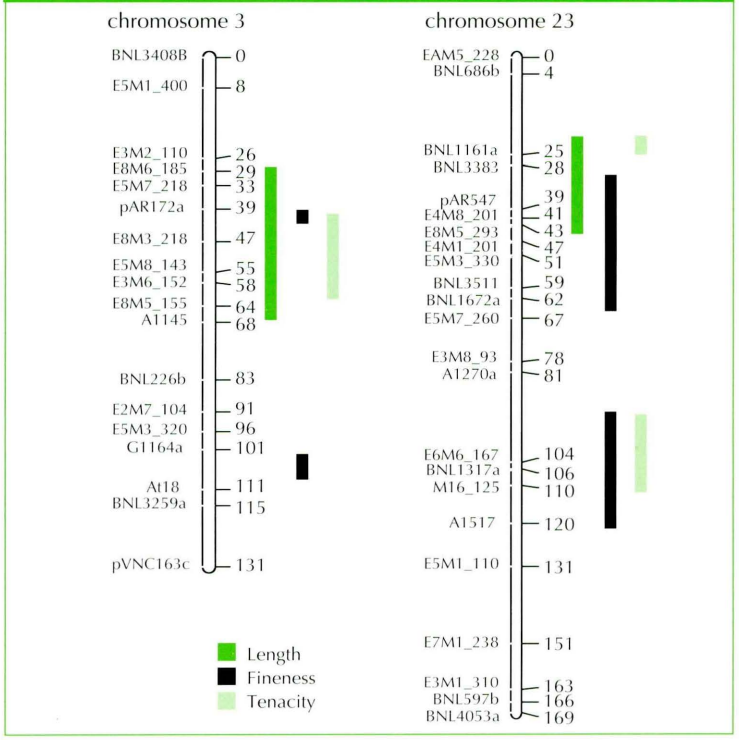
Pinpointing QTLs associated with fibre quality

Progeny derived from the first and second backcross of an interspecific *G. hirsutum* x *G. barbadense* hybrid with the *G. hirsutum* parent were genotypically and phenotypically characterised.

The genotype analysis involved determining the affiliation—with respect to *G. hirsutum* or *G. barbadense*—of marker alleles distributed uniformly over a set of 26 chromosomes, ie 890 in the first generation and 360 in the second. Phenotypic parameters were measured for several technological fibre traits, with the most important being fibre length, tenacity, fineness and colour.

All of these analyses were performed in the Biotrop and cotton technology laboratories at CIRAD. Three generations were assessed, the

Map showing fibre length, fineness and tenacity regions on chromosomes 3 and 23



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first consisting of 75 plants that were sown in a glasshouse in Montpellier in 1999, the second involving 200 plants field tested in Montpellier in 2000, and the third generation which was tested under tropical conditions in South America in 2001.

In each of the three phenotypic datasets, correlations between molecular markers and the technological value of cotton were studied by the interval mapping technique, and QTLs were thus located on the genetic map.

Quality, a combination of several QTLs

Technological cotton fibre parameters were determined through complexes of several QTLs. The expression of a single character is actually controlled by 8 QTLs for fibre tenacity and up to 12 for fibre length. These QTLs are sometimes located in different areas on the same chromosome and on different chromosomes. Each QTL generally has a very minor impact, accounting for only 8-20% of the expression of a trait. In many cases, QTLs associated with different traits are located in the same chromosome regions. Breeding will therefore be focused on creating lines that include these segments. QTL locations and effects were checked in the first and second generations. As expected, for each character, suitable alleles were chiefly derived from the *G. barbadense* donor parent, but also from the *G. hirsutum* recipient parent in about one quarter of the cases.

Building a genotype with optimal quality and yield traits

A dozen chromosome segments, covering about 10% of the length of the genetic map and bearing QTLs associated with fibre length, tenacity and fineness traits, were chosen.

In 2002 and 2003, efforts were focused on building an optimal genotype in the third and fourth generations. To overcome the difficulty of handling a high number of chromosome areas at once, different families of introgressed lines will be developed separately on a per QTL group basis, with subsequent crossing between these groups.

Breeding strategies are aimed at obtaining combinations with 10% segments of interest from the *G. barbadense* genotype and 90% from the recurrent *G. hirsutum* parent.

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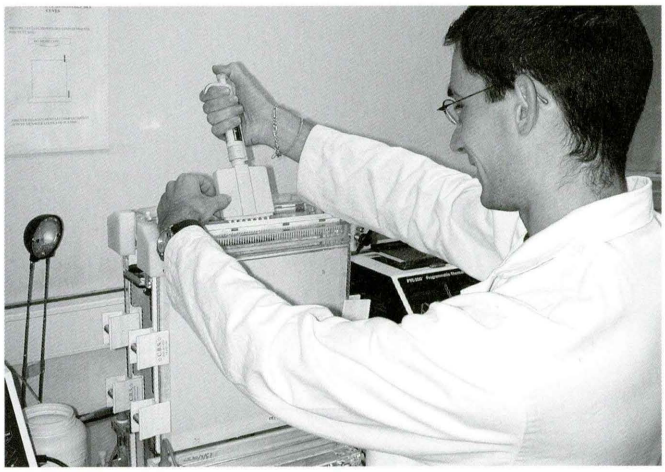

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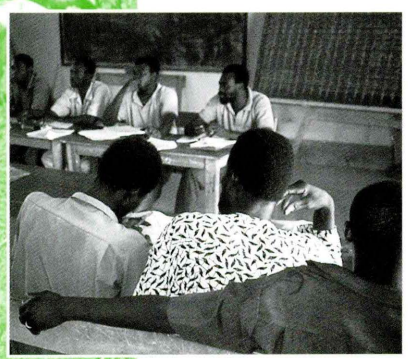
DNA sample deposition for electrophoresis.

Promoting stakeholder involvement in research

Opportunities to tap the full potential of the expertise of developing countries and to find outlets for their agricultural products must be constantly sought to facilitate adaptation to changing markets. In research partnerships, local dynamics are developed through environment-friendly strategies that are increasingly focused on agricultural and food product diversity and quality. CIRAD and partners collaborate through networks, while interacting closely with local farmers and development stakeholders to underpin the coordination and consistency of their initiatives.



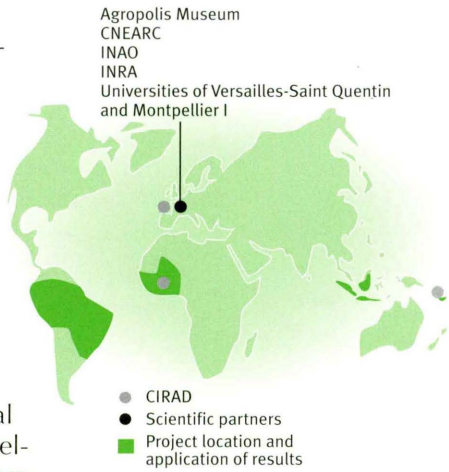
Agrifood systems: food quality and local dynamics

Current trends towards globalization and the opening of markets has kindled increasing interest in new agrifood models as an alternative to conventional models based on mass production and standardization. These innovative models are more environment friendly, promote local development dynamics and are geared to addressing fresh challenges facing the rural community. They foster local resources, ie products, knowledge, expertise, enterprises and institutions. Agricultural and food production enterprises must strive to enhance consumer awareness of the specific features of local food products.

This situation has given rise to a research issue at CIRAD: which food product qualification processes could be set up in developing countries?

How food product quality is developed

A workshop on geographical indications and appellations of origin was organized by CIRAD and INAO, the French institute for appellations of origin, and held in Montpellier (France). The aim was to assess the benefits, drawbacks and efficiency of various product qualification processes in different settings. The origins, historical and cultural aspects of these processes, their technical and legal complexity, and international intellectual property agreements, were also covered. This was done while discussing the advantages of a "geographical indication" approach, which seems more simple than appellations of origin with respect to specifications and regulations. Presentations on a few projects jointly implemented by CIRAD and partners illustrated the different settings.



In the Camajarca region of Peru, around 40 small-scale cheese makers have formed an association and collectively created an appellation of origin label for *Mantecoso,* a typical cheese of this region that is popular throughout Peru. This CIRAD-backed association is involved in training producers, improving cheese quality, product advertising, and scouting for new market outlets.

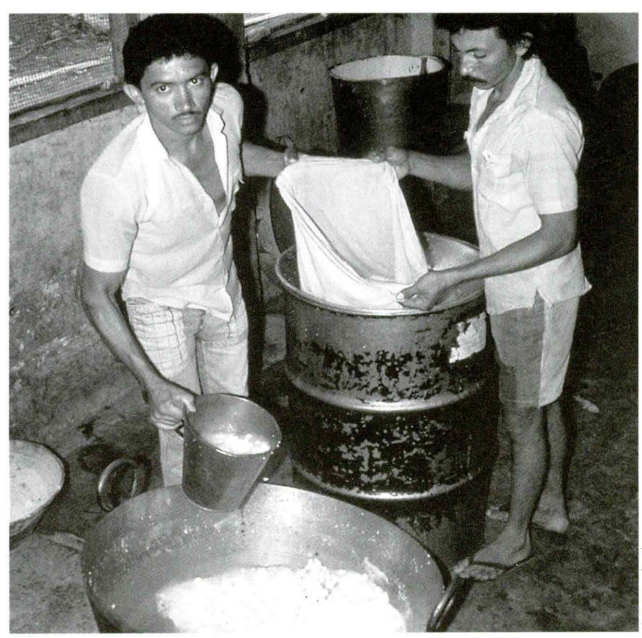
In Vanuatu and Ecuador, organic cacao commodity channels are being set up in a participatory manner in collaboration with CIRAD and a French chocolate manufacturer. These commodity channels will ultimately involve 500 cacao producers in each country. A negotiated price restraint policy guarantees a fair minimum price for producers. The elimination of market intermediaries enables consumers to purchase organic chocolate at the same price as standard chocolate. On the basis of the results of a research project conducted at the request of the Indonesian Ministry of Agriculture, Balinese coffee was selected to create the first Indonesian geographical indication.

Models promoting local resources

The promotion of local expertise was the focus of in-depth discussions during the international conference "Local agrifood systems: products, enterprises and local dynamics", held in Montpellier, and coordinated by SYAL, a scientific interest group created by CIRAD, INRA, the French agricultural research institute, the French universities of Versailles Saint-Quentin and Montpellier I, CNEARC, the French centre for agricultural research in hot regions, and the Agropolis Museum.

More than 200 participants exchanged experience on: the role of local stakeholder networks and the clustering of agrifood enterprises; local food product qualification processes; knowledge, skills and apprenticeship processes; identity ownership processes and their relationships with places, history, knowledge and territorial identities; and the drawing up of public policies.

Local agrifood systems can differ substantially in terms of their history, market links, activities, socioeconomic organization, urban or rural location, and territorial foothold. The "local"



Adding butter to make *arequeijao* in Latin America.

© J. Muchnik

aspect of the food product is also variable and can change with time: a product associated with the physical and climatic features of a production site can subsequently be linked with the image or reputation of this site.

Research is under way to develop methods for analysing agrifood systems: delineation of valid analysis units and their internal interactions; specification of local resources and ways to activate them; institutional dynamics; and forms of mutual action.

The conference proceedings and a document on territorial coordination of agrifood activities and another on rural cheese makers in Peru are the first of a series of publications on local agrifood systems and territory building.

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Processing palm oil on a small scale in Benin.

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Office du Niger, managing the rice granary of Mali

In Mali, irrigation schemes managed by the Office du Niger currently produce excess volumes of paddy rice. This rice contributes substantially to ensuring food security in this country and other parts of West Africa. After some 75 years of futile initiatives, this socioeconomic success can be explained by the strong market-oriented family agricultural system that prevails.

© E. Bacary Daou

Around half a million people inhabit the region, and the wealth generated by this system—solely through draught agriculture—is shared among some 20 000 farmers. This process and future prospects are presented in a document entitled *L' Office du Niger, grenier à riz du Mali,* published in French by CIRAD and Éditions Karthala. It combines an in-depth study with many scientific and technical contributions from specialists in different fields (scientists, extension agents, sponsors, representatives of socioprofessional organisations).

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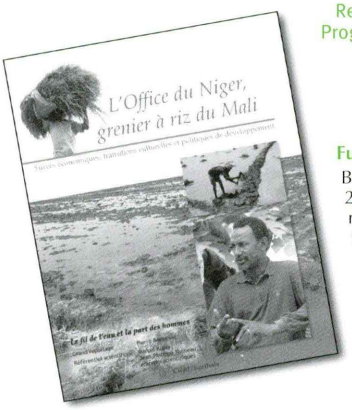

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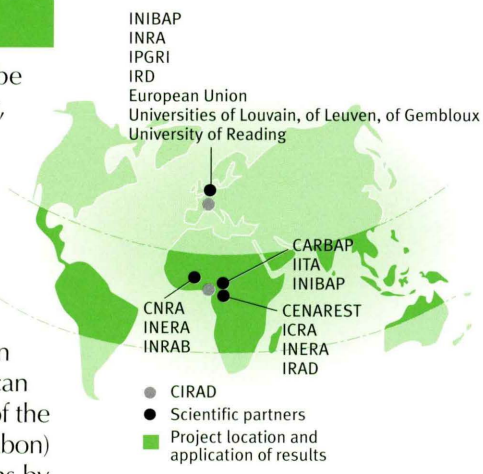
CARBAP, an integrated collaborative plantain research consortium

How can plantain production be increased from the very low, mean estimated yields of 4 t/ha on smallholdings whereas this crop has a production potential of more than 30 t? How can the consumer demand for top quality and less expensive plantain be fulfilled?

In 2001, five central African countries (Cameroon, Central African Republic, Democratic Republic of the Congo, Equatorial Guinea, and Gabon) decided to address these questions by founding CARBAP, the African banana and plantain research centre. In partnership with CIRAD, CARBAP is following up the activities of CRBP, the regional banana and plantain research centre, which was founded in 1989. CARBAP—founded on an intergovernmental basis and recognised by the international scientific community and the West and Central African Council for Agricultural Research and Development (WECARD)—sets the stage for regional cooperation on research, extension, and training for all stakeholders in the plantain subsector.



Enhancing the performance of the plantain subsector

Plantain is a vital staple food throughout West and Central Africa, where annual production is around 10 million t, which means that it is also an important cash crop. Plantain is the third ranking staple food of the region after rice and maize, but it is still too expensive for urban dwellers and relatively inaccessible to rural people. It is grown on scattered smallholdings under low-intensity cropping conditions, and smallholders find it hard to market their harvested plantain in urban centres because of the high transportation costs and poor road conditions. One prime goal of CARBAP is to boost plantain yields by proposing innovations that could help smallholders intensify plantain cropping.

CARBAP published and disseminates *Plantainfo,* a newsletter that promotes efforts to improve the performance of the plantain subsector. A participatory approach, supported by the European Union and Fondation Aventis, and with the help of a plantain growers' network, boosts farmer awareness on innovations designed to gradually intensify plantain cropping and increase yields, including the adoption of improved hybrids, horticultural multiplication of healthy plants, efficient crop management, integrated pest management, and soil fertility conservation. Technical training is also offered for plantain growers.

Breeding higher yielding varieties

CARBAP is located in central Africa, a region where the plantain subgroup has undergone secondary diversification. It has the largest plantain germplasm collection in the world, including 135 cultivars. It is also involved in the *Musa* Germplasm Information System (MGIS) of the International Network for the Improvement of Banana and Plantain (INIBAP).

The adopted conventional genetic improvement scheme is designed for breeding—especially from parental clones supplied by CIRAD—highly sterile triploid hybrids that are as close as possible to natural plantain varieties. The natural diversity, along with taste and marketing criteria (long bunch, bulky fingers) are taken into consideration for varietal selection, in addition to other traditional features sought

Banana and plantain growers' market in Cameroon.

© E. Desdoigts

Harvesting plantain on a plantation within the growers' network.

© K. Tomekpe

Hybrid CRBP39.

by farmers. The key agronomic characteristics are resistance to parasites and pests, high suckering and small size.

Dwarf plantain hybrids are currently being bred. A first generation tetraploid hybrid (CRBP39), which has shown suitable resistance to black leaf streak disease, yield and fruit taste qualities in the research station and in growers' plantations, is being disseminated throughout West and Central Africa.

Sustainable pest management for plantations

CARBAP is developing integrated techniques for controlling different plantain pathogens and pests. Solutions to control the harmful aspects of black leaf streak disease are being promoted: elimination of necrotic leaves, crop management, and breeding of resistant hybrids. CARBAP, CIRAD and INRA, the French agricultural research institution, are also investigating genetic diversity of the causal pathogenic fungus *Mycosphaerella fijiensis,* virulence variability within its populations, the epidemiology of the disease and modelling the disease patterns.

Growers have adopted a technique for horticultural multiplication of healthy plants to control banana root knot nematodes. Fallowing and crop rotations are recommended as a complement to this technique. Early endomycorrhization of plants—tested under controlled environmental conditions—could enhance the efficacy of these techniques.

Biological control procedures are being developed to control banana weevil borers: mass pheromone trapping, and introduction of the entomopathogenic fungus *Beauveria bassiana*.

Increasing and diversifying regional cooperation

CARBAP has established partnerships in West Africa (Benin, Côte d'Ivoire) and benefits from funding from the European Union, French and Belgian cooperation agencies and the Cameroonian government. These collaborations with French research institutions (CIRAD, INRA, and IRD) and international centres (International Institute of Tropical Agriculture, IITA, and the International Plant Genetic Resources Institute, IPGRI), and the privileged relationship with INIBAP—MGIS, International Musa Testing Programme, and Global Programme for Musa Improvement projects—enhance CARBAP's scientific and technical potential. Moreover, it has established links with local development agencies such as AGRISUD, and with national agricultural research systems of 15 African countries, within the framework of INIBAP's MUSACO network, with the aim of validating and disseminating innovations for the benefit of plantain growers and urban inhabitants of developing countries.

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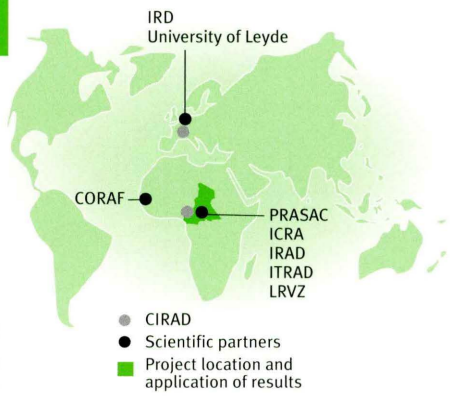
Savannas of central Africa: technical and institutional innovations

Since 1998, PRASAC, the regional development-oriented research consortium focusing on savannas of central Africa, has been bringing together national agricultural research institutions from Cameroon (IRAD), Central African Republic (ICRA) and Chad (ITRAD, LRVZ), in collaboration with European scientific partners, including CIRAD, IRD, the French development-oriented research institution, and the University of Leyden (Netherlands). It coordinates research initiatives of the three countries and pools their resources and data with the aim of disseminating the innovations throughout the rural areas. It is dependent on a network of regional laboratories, research stations and village lands. This collaborative research consortium of the West and Central African Council for Agricultural Research and Development (WECARD) is now a recognised specialized institution of the Central African Economic and Monetary Community (CEMAC).

Farmers' organizations

High population growth and rural migration are disrupting farming systems in African savanna regions. Arable land is increasingly scarce, land tenure is becoming a major issue, and there is rising pressure on renewable resources. Urban-rural economic exchanges are spurred by the market demand from medium-sized inland towns and large cities, and crop intensification is essential to meet this need. Cotton is still the driving force behind the agricultural economy, but the food crop market is now developing. The increase in livestock herds has, however, put further pressure on the dwindling resources.



A review of resource access regulations is needed, but it would be hard to apply any potential revisions because there have been serious delays in decentralization projects, which in any case often boost the power of important people when local conditions are unfavourable for democracy and when the government is no longer able to fulfil its law enforcement role. There is also concern that the privatization of cotton subsectors will lead to degradation of some agricultural services, which has prompted the creation of farmers' organizations to protect farmers' interests and provide services for members.

Products for development

A development observatory pools information derived from national databases and PRASAC. An assessment of this information highlighted dynamic local and transboundary trends concerning commodity marketing channels for agricultural products and livestock, land-use patterns, livestock transhumance, development policies and rural migration. A regional geographical information system (GIS) was set up and has led to the publication of an agricultural atlas for central Africa. Fifteen reference sites—representative of different savanna environments and their inherent problems and potentials—were the focus of field studies.

Technical innovations have been tested in collaboration with farmers: animal draught equipment, direct seeding, organic manure application, improved fallows, cotton pest control, preserving foodstuffs through drying techniques, and cassava processing. Ninety technical data sheets were published to enable farmers to benefit from the results of these tests. Agricultural consultancy methods were drawn up by development agencies. Methodological changes were noted in 70% of farms for contingency plan and crop management assess-

Weeding onions at Koza, Cameroon.

© L.-Y. Jamin

ments and in 40% of farms for a cash flow management evaluation.

This work has given rise to many publications, including technical data sheets, bibliographical monographs and photographic reports. *La Lettre des savanes*, a regional quarterly agricultural newsletter (500 copies per issue), has been published and disseminated since November 2000.

PRASAC has also established links with different universities. Around 20 scientists of the consortium, including about 10 PhD thesis students, have attended degree-qualifying training courses held in PRASAC facilities, as well as more than 100 students from various universities.

Landuse changes and new challenges

A conference involving heads of farmers' organizations, extension agents, scientists and donor agencies was held in Garoua, Cameroon, from 27 to 30 May on the topic "African savannas, landuse changes, and stakeholder responses to new challenges". After summarizing their work, participants stressed that to obtain pertinent information it is essential to adopt multidisciplinary approaches and evaluate issues at a range of levels (field, herd, farm, local area, country, and regional subunit). They outlined future needs: diversifying research partnerships, creating an observatory to monitor changes, working downstream from production, and continuing to integrate social sciences and geography in research strategies.

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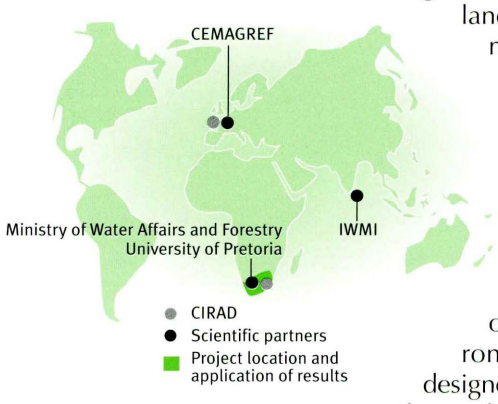

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Water management in South Africa

Full text on CD-ROM

After the abolition of apartheid, irrigation schemes in the former homelands of South Africa must now make it through a difficult and inevitable management transfer period to quickly become self-sustaining and efficient. This process is hampered by technical, economic and sociocultural impediments. The Sustainable Management of Irrigated Land and Environment (SMILE) project is designed to assess the potential of these schemes and to determine ways to promote their sustainability, especially financial. A simulation software package is being applied for prospective evaluations of these schemes in collaboration with local operators: it analyses the prevailing situation and tests scenarios under different technical, economic and institutional conditions. The results showed that these irrigation schemes could become viable as long as the government does not completely withdraw from its commitment—smallholder involvement alone would be inadequate.

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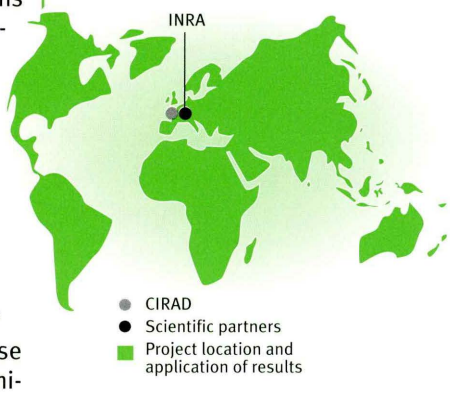
Herd management support tools

Livestock farmers in both developing and industrialized countries are reshaping their production methods in favour of a more environment-friendly approach. As the interactions are highly complex, it was considered essential to model and simulate the effects of changes in production practices on herd performance to be able to assist farmers in their decision making.

The same tools can be applied even when the livestock production objectives and conditions vary markedly. CIRAD and INRA, the French agricultural research institution, thus decided to collaborate with the aim of developing a common set of analytical tools and study methods. These studies have already given rise to three seminars and a special issue of the journal, *Animal Research*.



Herd performance modelling involves matching species-specific biological data, environmental conditions under various constraints, and different livestock farmers' decisions. For 10 years, technical and economic performance models have been used to investigate the impact of changes in management strategies on dairy and suckling farms. In tropical countries, studies are focused on developing performance indicators—numerical productivity, stocking rates on rangelands—to be used for diagnostic assessments of situations or to remedy shortcomings.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Models currently being developed are aimed at establishing livestock farmers' decision-making guidelines and identifying herd management subunits. These models take temporal changes into account (climatic and feed uncertainties, disease factors, herd replacement). They utilize spatial data at different scales and animal-specific data, ie the basic information unit.

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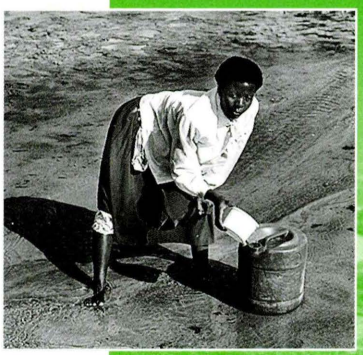
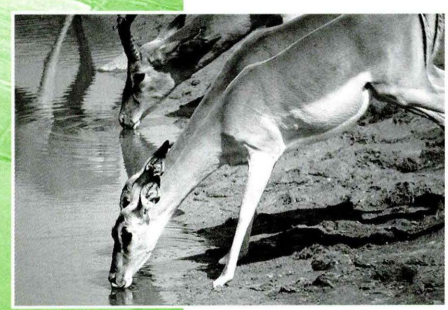
Saving the planet



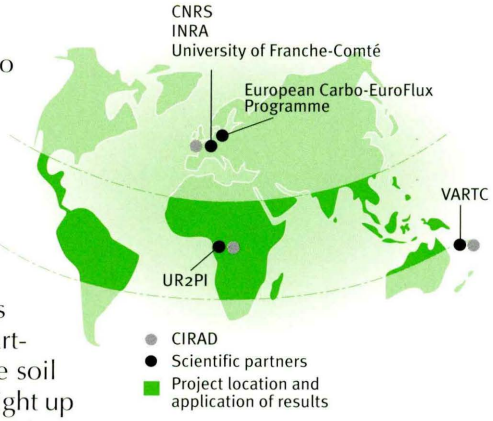
The Kyoto Protocol set a target of a 5% reduction in greenhouse gas emissions in relation to the 1990 figure, over the first commitment period (2008-2012). All the signatories are already preparing for this. This target, which is binding on the industrialized and intermediate countries that signed the protocol, necessitates a degree of solidarity with developing countries. CIRAD is involved in regional and international projects aimed at encouraging collaboration with developing countries, assessing the impact of reforestation and agricultural choices on carbon sequestration, controlling cultivated soil erosion in upland areas and also developing non-polluting wood preservation techniques, safeguarding carbon stocks and optimizing natural resource management.



Carbon flux: measuring and modelling

Under the Kyoto Protocol, the clean development mechanism (CDM) is the implement intended to encourage the North and South to work together on cutting greenhouse gas emissions. It is one of the so-called "flexibility" mechanisms that put a trade value on reductions in carbon emissions, thus creating a carbon market. This market is governed by strict eligibility criteria.

In the forestry sector, only afforestation and reforestation are eligible during the first commitment period (up to 2012). It is therefore urgent to find reliable ways of measuring carbon



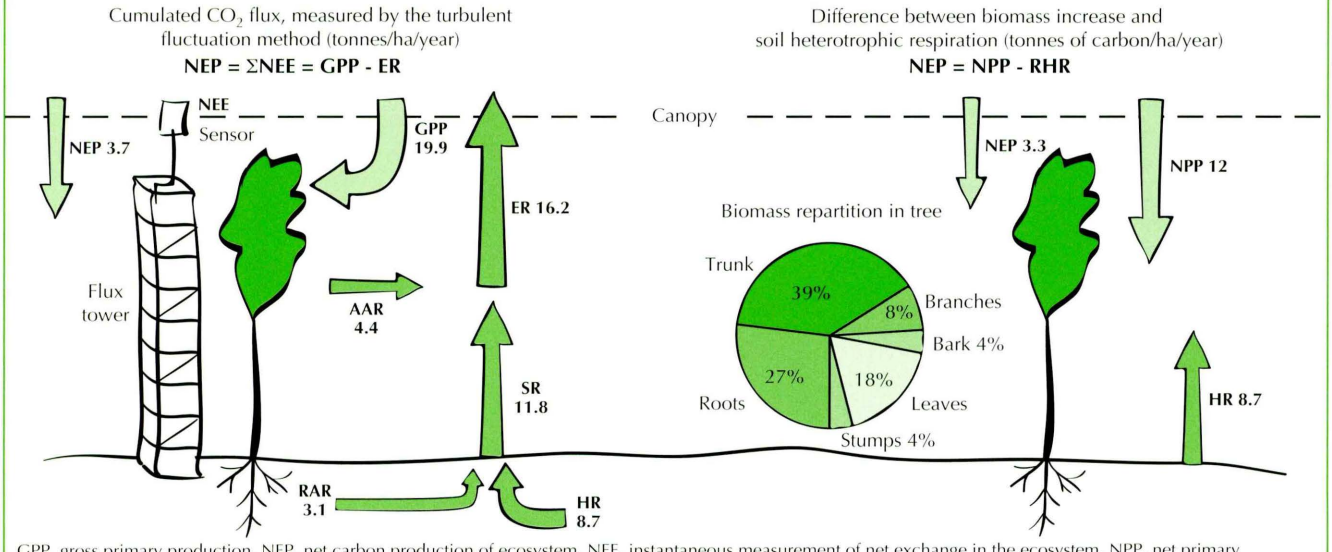
emissions and sequestration so as to be able to establish a certified balance for individual projects. Forest inventories can be used to assess the variations in the amount of carbon stored in trunk biomass. However, on a plantation scale, carbon balances have to cover all the compartments of the ecosystem, in the soil and elsewhere, from the plot right up to the plantation as a whole. It is essential to take account of soil heterogeneity, and also of intra- and inter-annual climatic variations and the effects of farming systems.

The leading tropical forest species, eucalyptus, covers 14 million hectares; coconut, the leading agroforestry crop, covers 13 million hectares. CIRAD, INRA, the Université de Franche-Comté and CEFE, the Centre d'écologie fonctionnelle et évolutive at CNRS, are working together to establish and model carbon balances in clonal and commercial plantations: eucalyptus in the Republic of the Congo and coconut in Vanuatu.

These sites are the first of their type in Africa and Oceania. They are associated with the European Carbo-EuroFlux programme, which is itself part of the global network monitoring carbon dioxide exchanges in terrestrial ecosystems, Fluxnet. The Congolese site, at Pointe-Noire, is part of the Observatoire de recherche en environnement sur le fonctionnement des écosystèmes forestiers, a thematic research network recognised by the French Ministry for Research. The first measurement site was set up in the Republic of the Congo by CIRAD in 2000, in conjunction with UR2PI, a research unit working on commercial plantation productivity. The same approach was adopted in Vanuatu as of 2001, in conjunction with VARTC, the Vanuatu Agricultural Research and Training Centre, where the same measurement methods are being used in plots of Vanuatu Red Dwarf x Vanuatu Tall coconut hybrids.

The approach comprises two methods, each of which validates the other. One is overall modelling of the ecophysiological functioning of the ecosystem on a plantation plot scale, while the other is based on a dendrometric model that evaluates the increase in biomass and on measurements of soil heterotrophic respiration. The carbon stocks in trees and the soil are measured at different ages using the conventional dendrometric method and near-infrared spectro-

Net carbon balance for a three-year-old eucalyptus plantation, obtained using two methods

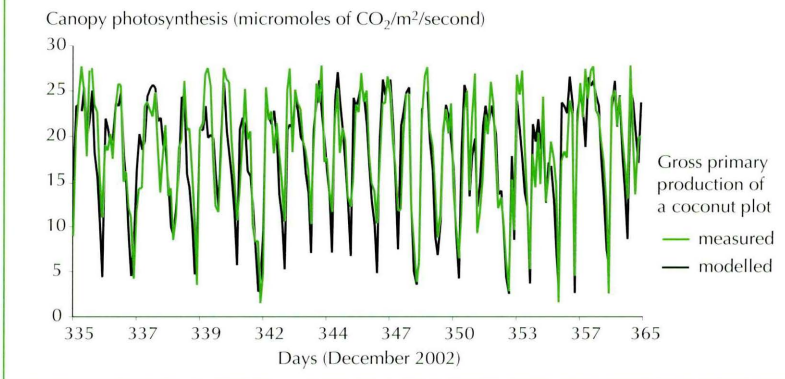


GPP, gross primary production. NEP, net carbon production of ecosystem. NEE, instantaneous measurement of net exchange in the ecosystem. NPP, net primary production. AAR, aerial autotrophic respiration. RAR, rhizospheric respiration. ER, ecosystem respiration. HR, heterotrophic respiration of soil. SR, soil respiration.

metric analysis, to establish a storage graph. Instantaneous CO_2 flux is evaluated using flux towers or turbulent fluctuations, on an ecosystem scale, making a distinction between the two components of that flux, photosynthesis and respiration. All the components of the water balance and energy balance are also recorded and measured. Lastly, the response of the different components of carbon flux within the ecosystem—soil autotrophic and heterotrophic respiration, plant aerial respiration, photosynthesis—to climate variations is modelled.

After two years of flux measurements in a three-year-old eucalyptus plantation, the evaluations of net carbon production by the planted plot are very similar. What little difference there is probably stems from an underestimate of the rhizospheric biomass and of nocturnal flux. Soil respiration measurements on stands of different ages have shown that roots contribute to carbon emission, and that their contribution increases with stand age, from 27% at three years to 57% at six years.

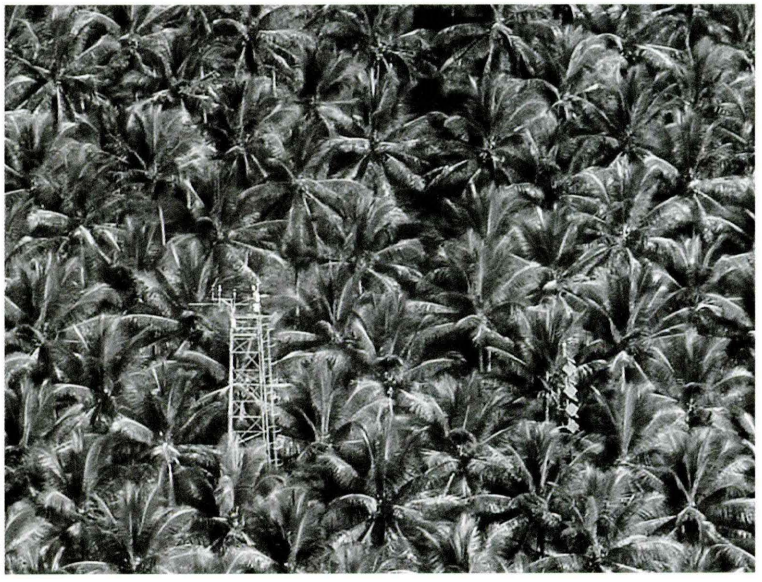
Photosynthesis and leaf respiration model



For coconut, the carbon exchange model includes the prediction, on a canopy scale, of photosynthesis and leaf respiration. These forecasts are then compared with the data recorded by turbulent fluctuations. The daily carbon balance for the coconut plantation is moderate, but continuous, as a result of the climatic conditions in Vanuatu, hence the very high annual carbon sequestration figure of seven tonnes per hectare in a 20-year-old planting.

Both coconut and eucalyptus have the dual advantage of being both carbon sinks and renewable energy sources. Coconut oil can be used as a substitute for diesel, in either natural or esterified form, while eucalyptus wood can be used to make charcoal.

The next step will be to adapt these methods to reference species such as rubber, cocoa, oil palm, teak, pine or okoume. This will enable the establishment of models and certified carbon balances for forest and agroforestry plantations.



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Flux tower in a coconut plot in Vanuatu.

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The clean development mechanism

The talks held under the agreement on climate change have resulted in the clean development mechanism (CDM), which enables bodies such as governments or firms in industrialized countries to obtain carbon credits (emission reduction credits). To this end, they have to conduct projects in developing countries aimed at reducing greenhouse gas (GHG) emissions or fixing carbon. Initially, until 2012, only new plantings and replantings, which are recognised as "carbon sinks", will be eligible as far as forestry operations are concerned, and there will be precise eligibility criteria.

There has to be some proof that the reduction is in addition to what was being done before, ie not simply a displacement of emissions. The rules for crediting forestry operations have not yet been established. "Temporary credits", not equivalent to those obtained through reductions in emissions, are planned. However, if carbon prices on the future emission permit market are too low, the resulting leverage intended to encourage truly new forestry operations may be limited. Conversely, decentralized rural electricity generation using wood and plant biomass, which is "neutral" in terms of the carbon balance, could have a ratchet effect on certain wood subsectors.

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For further information

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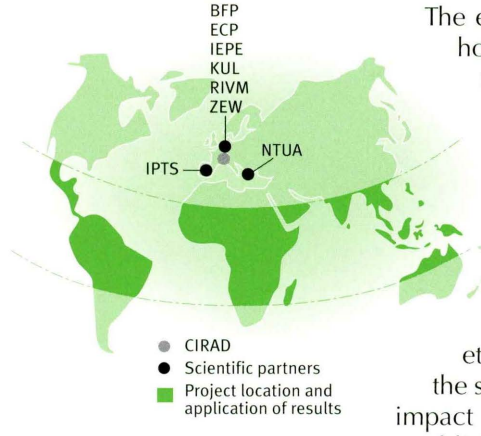
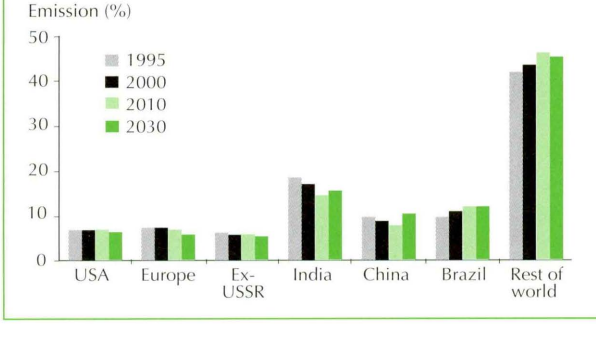
The price of carbon: a regionalized global model

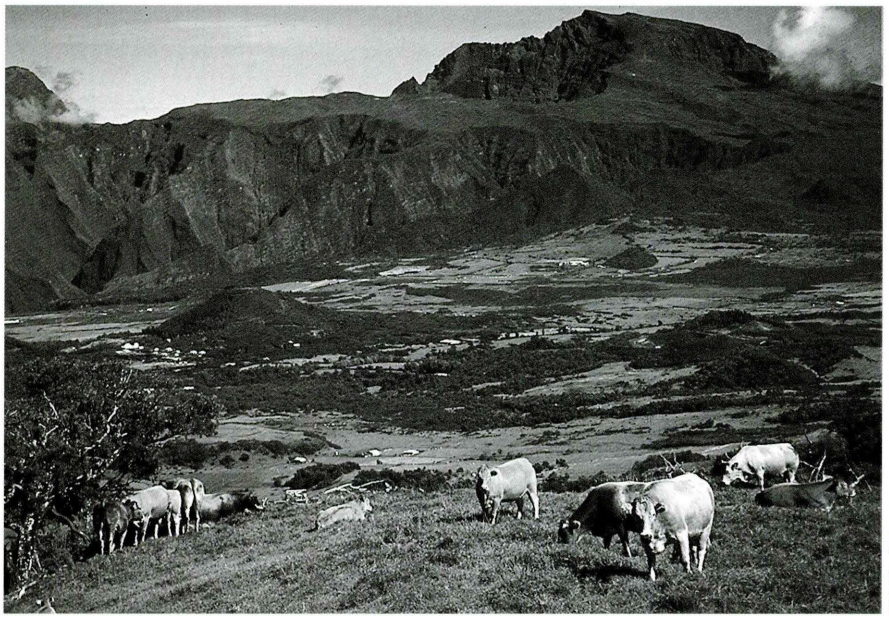


The exponential growth in greenhouse gas emissions is posing major climatic risks. Economic activities affect the atmosphere, which modifies the climate, which in turn transforms the biosphere and has a boomerang effect on the economy: agricultural yields, heating or air conditioning requirements, etc. It is now crucial to analyse the sources of emissions and their impact in order to find solutions and establish a climate policy. This is an international issue that concerns each and every sector of activity.

The studies used as a reference for negotiations combine techno-economic and macroeconomic approaches. They are based on medium-term comparisons of sectors of activity, world regions, greenhouse gases (primarily carbon dioxide, methane, nitrous oxides and various hydrofluorocarbons), and decision-making methods and schedules. Those used by the Global Climate Research Group generally centre on data from industrialized countries and energy sectors. Global evaluation models integrate the available, often global, data on agri-

Agricultural sector emissions





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cultural practices and land use in order to reflect reality. However, the data on agricultural activity need to be enhanced, since the factors that determine their evolution, such as technical progress, intensive or extensive farming, have an impact on greenhouse gas emissions.

It is essential to build up knowledge of regional farming practices in order to shed light on the issues. CIRAD is contributing to this operation through its experience of modelling and of agriculture in developing countries, which has hardly been taken into account so far, if at all. The Agripol model was developed under a European project on greenhouse gas emission control strategies (GECS). It evaluates the consequences of various types of land use and production techniques in 40 world regions in 1995, 2000, 2010 and 2030, and takes account of the agricultural sector's ability to adapt to policy changes.

The model sets a carbon price. The related cost of greenhouse gas emissions is therefore added to production costs. This makes it possible to estimate the savings made in terms of emissions by making changes to farming systems and land use. This information is used to draw up marginal abatement cost curves that can in turn be used in models concerning other economic sectors.

By linking Agripol and the Image global model developed by the National Institute of Public Health and the Environment (RIVM) in the Netherlands, which takes account of agricultural potential, it is possible to produce a more accurate picture of the medium-term effects of climate change and of economic and demographic growth. The results obtained with Agripol can thus be integrated into the underlying scenario of the changing global situation.

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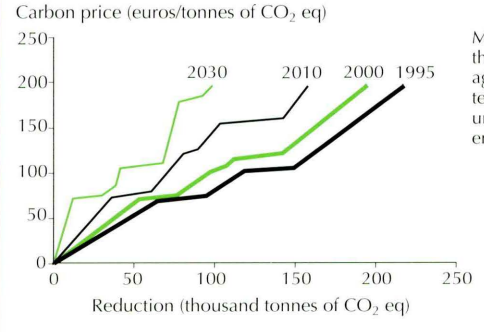
Marginal reduction cost charts



Margin of manœuvre that would be offered by agriculture, with the available technical alternatives, under a greenhouse gas emission reduction policy.

Full text on CD-ROM

Monitoring of protected areas in Africa

For over 10 years, the EU-funded ECOFAC regional programme for the conservation and rational use of forest ecosystems in central Africa has been operating in seven countries: Cameroon, Chad, Central African Republic, Congo, Equatorial Guinea, Gabon, and São Tomé and Príncipe. In 2002, CIRAD was entrusted with a study of the establishment of a global system to monitor and evaluate the different national components of the programme, which covers a total of 100 000 sq. km.

Establishing the situation in each of the protected areas concerned was only the first stage in setting up this regional system, based on the principles, criteria and indicators of sustainable development. The aim was also to ensure that national managers were trained in the method and above all were capable of adapting and applying it in line with local requirements. To this end, it has been proposed that RAPAC, the network of protected areas in central Africa, which includes the various management bodies in charge of these zones, will provide the necessary backup, supervise operations on a regional level and express a single, unanimous opinion. In the debate on conservation in central Africa, the Congo basin is already covered by a large number of international programmes adopted at the Johannesburg Earth Summit.

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For further information

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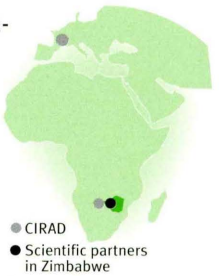
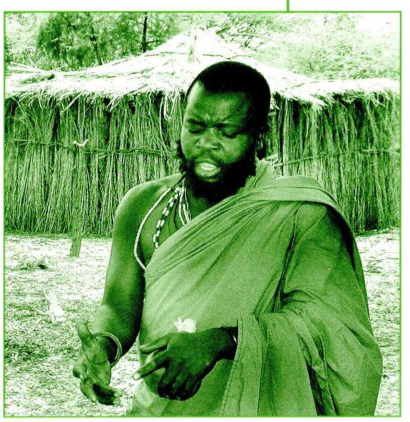
From Zimbabwe to the Earth Summit



Zimbabwe has adopted an innovative environmental policy that combines wildlife conservation, protected area management and local exploitation of resources. These resources are managed on a local level in conjunction with rural communities, using the Campfire (Communal Areas Management Programme for Indigenous Resources) approach. This approach is an institutional and legal reference and a model for the sustainable exploitation of natural resources in Africa.

For over 10 years now, CIRAD has been working in three regions of Zimbabwe, in partnership with national and local institutions, on implementing this approach in the field. The aim is to effectively decentralize decision-making powers and ensure that local communities really benefit from the economic advantages of the approach.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CIRAD reported on its experiences at the Global Summit on Sustainable Development in Johannesburg. The approach has created a synergy between the different players and enabled discussions to take place on the local wildlife and its habitat. It has made it possible to identify the conditions for local resource and biodiversity management and to determine the necessary steps to be taken. The approach has secured the land ownership rights of local communities and access to resources. It has also enabled the development of land-use planning and multi-functional land development systems, and the definition of the roles, responsibilities and authority of the various actors at different levels.

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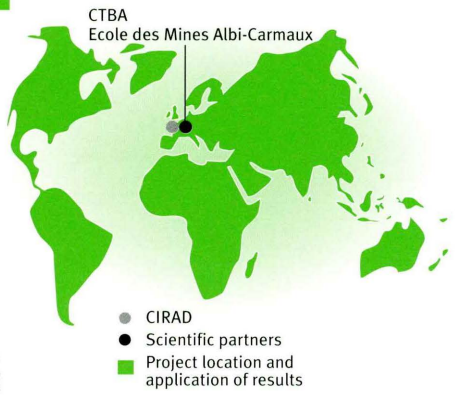
A wood preservation technique

If the wood used is not naturally durable, open-air structures, buildings and outdoor furniture have to be protected. The current treatments against weathering, insects and other types of damage involve impregnating the wood with pollutant or toxic products. They improve its durability but require complex, costly treatment equipment. CIRAD is working with CTBA, the French technical centre for wood and furniture, on a new wood preservation technique that is simple, relatively cheap and ecofriendly. CIRAD has been granted a French patent on the basic principle, and has applied for an international patent extension. The aim now is to broaden the range of applications and optimize the efficacy of the treatment.

A simple, ecofriendly treatment

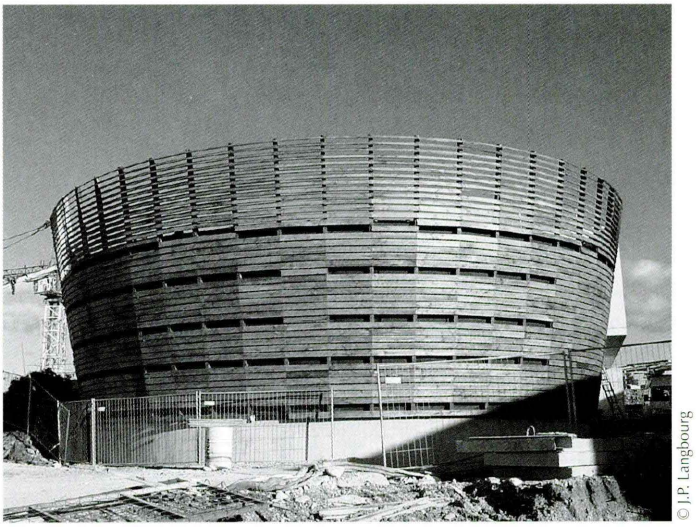
The technique consists in dipping the wood in two oil baths. The first, at a temperature of 110 to 210°C, raises the temperature of the wood and reduces its moisture content, and the second, at 10 to 90°C, impregnates and treats the wood. The wood is transferred rapidly from the first to the second bath, to ensure effective impregnation. Natural, preferably siccative, oils such as linseed or rapeseed can be utilized, either mixed or pure, and even used or recycled.

The heating system requires only two tanks, and a conveyor to transfer the wood from one to the other. The hot tank comprises a heating element and an oil circulation pump, with a basket to keep the wood submerged in the oil and to transfer it to the cold tank, which contains only the treatment oil.



The current research is intended to determine the operating conditions for the optimum penetration of components of different species and sizes: logs and planks of lengths between a few dozen centimetres and several metres. The efficacy and persistence of the protection are to be checked, along with the choice of heating oil, treatment solution formula, and investment and operating costs in industrialized and developing countries. The aim is to make use of the range of scientific and technical skills available at CIRAD and its partners: process engineering, equipment design, wood science, biochemistry, physical chemistry and economics.

The technique has been tested successfully on broadleaf and conifer wood samples including spruce, which usually resists impregnation. The results have proved its technical and economic feasibility. Combined oil and heat treatment of wood produces similar results to traditional procedures but is less polluting. Specific molecules can be added to the treatment oil to modify the colour of the wood and increase its resistance to fire, ultraviolet light and pathogens. Moreover, the technique reduces peripheral splitting and kills pathogens by sterilization. Lastly, the hydrophobic treatment compounds form a barrier on the surface of the wood, reducing wood shrinkage and swelling that cause deformation and splitting and consequently insect and fungal contamination. The combined effects of heat treatment and hydrophobic substances therefore improve wood performance.



Construction of an amphitheatre in oiled chestnut wood, at the Pic-Saint-Loup high school (Hérault, France).

From industrialized to developing countries

The technique works on species that are difficult to impregnate, such as spruce, eucalyptus and Douglas fir. With tannin-rich woods such as oak, treatment reduces the leaching of tannins, which act to preserve the wood.

This innovative technique could open up new markets for woods that are not naturally durable. It could also stimulate interest in using wood as food packaging: the process pasteurizes the wood, making it suitable for contact with food, and the wood is easy to dispose of after use.

The results obtained thus far have confirmed the technological, economic and ecological merits of this impregnation technique for both developing and industrialized countries. Also, as it fits in with current concerns and with legislative changes being made, industrialists have expressed a keen interest.

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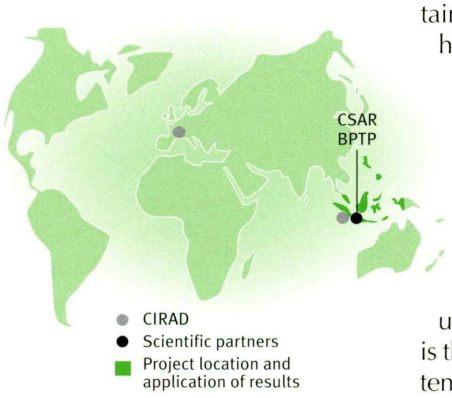


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Upland rice growing in Indonesia

Over the past 10 years, the mountainous regions of the island of Java have seen the establishment of new landless farmers practising extensive upland rice growing, which has resulted in erosion and soil deterioration on sloping land. Moreover, the El Niño phenomenon, the source of a prolonged drought, has led to a reduction in cultivated areas and yields, particularly in the Yogyakarta region, and is threatening different production systems in the area.

CIRAD, the Centre for Soil and Agroclimate Research (CSAR, Bogor) and the Sleman agricultural technology research workshops (BPTP) have combined a participative approach and water resource modelling. They have designed a network of bunds along the primary and secondary lines of water flow in the Bunder smallholder basin. These installations, built by the farmers, serve to irrigate crops on terraces by distributing surface water. The work will pay for itself within four years, through an increase in yields—from 1 to 2.5 tonnes per hectare—and the possibility of a second crop cycle. Decision support tools and a participative approach are being extended to other Indonesian provinces, and the efficacy of these hydraulic installations is being evaluated.

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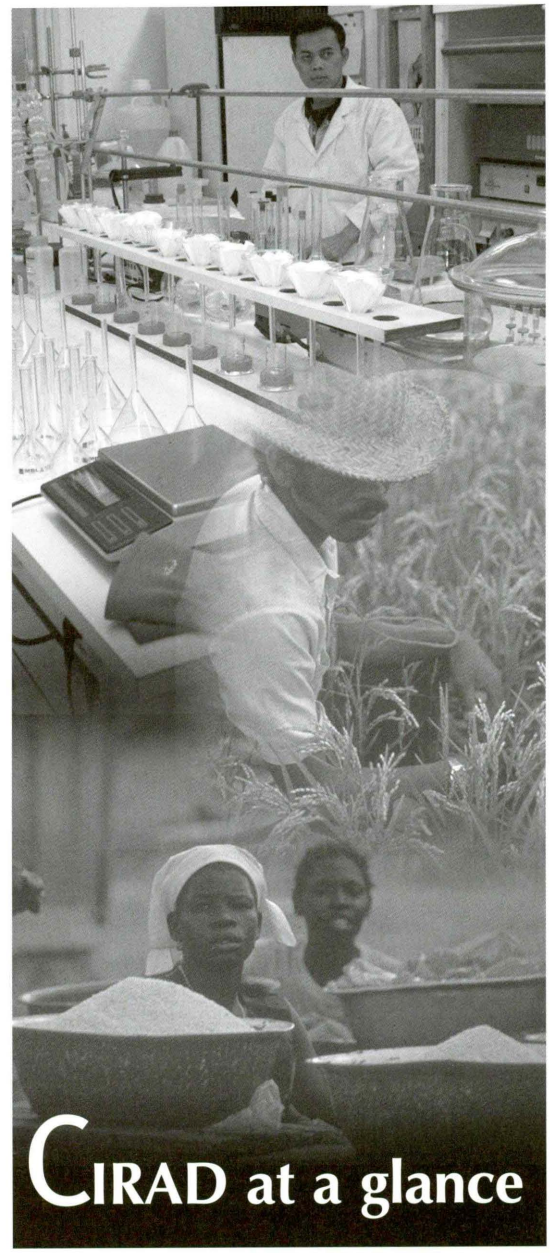


CIRAD at a glance

Indicators

The 2001-2010 strategic plan describes the changes in the international environment to which CIRAD needs to adapt and outlines the main strategy guidelines for the coming 10 years. In April 2002, CIRAD signed a contractual agreement with the Ministries for Research and for Foreign Affairs, covering the period 2002-2005. The agreement sets out the strategic priorities, the specificities to be built on, the adjustments required in terms of scientific policy, the priority geographical areas, the partnerships to be strengthened, and the method of governance CIRAD should adopt. The document also contains monitoring indicators. Those selected to reflect CIRAD's activities in 2002 concern scientific policy, the number of students received, human resources, financial resources, and transversal projects.

Scientific policy

Skills among researchers

CIRAD had 839 researchers in 2002, up 24 on the 2001 figure (table 1).

Priority topics. CIRAD's scientific operations are concentrated in three fields: sustainable agricultural production; sustainable management of natural resources, the environment and quality; and agricultural product safety.

To this end, for the duration of the contractual agreement, CIRAD scientific policy will favour the redeployment of skills through recruitment and internal training in several fields related to the agrifoods sector, applied mathematics and informatics, ecology and the environment, and applying genome studies to agronomy. The target by 2005 is to have an additional 40 staff members working in these fields.

The year 2002 saw an additional 10 researchers working in these priority fields, half of them on ecology and the environment: 15 new recruits and 2 promotions, minus 7 departures (table 2). There were no changes in the numbers involved in agrifoods research.

Theses and authorizations to supervise research. The change in the proportion of researchers holding a doctorate or the equivalent needs to be analysed over a longer period,

Table 1. Number of researchers (excluding associates and related project staff)

	Annual Crops	Tree Crops	FLHOR	EMVT	Forêt	TERA	AMIS	General Management	Total
As of 31 December 2001	154	128	82	95	84	87	140	45	815
As of 31 December 2002	158	127	87	98	87	92	145	45	839
Change 2001-2002	+ 4	- 1	+ 5	+ 3	+ 3	+ 5	+ 5	0	+ 24

Senior researchers are those who are primarily assessed based on scientific criteria, particularly their publications. Doctoral students are not taken into account.

Table 2. Change in the number of researchers working in priority research fields (31 December 2001-31 December 2002)

	Annual Crops	Tree Crops	FLHOR	EMVT	Forêt	TERA	AMIS	General Management	Total
Agrifoods	0	0	0	0	0	0	0	0	0
Applying genome studies to agronomy	0	+ 1	+ 1	+ 2	0	0	- 2	0	+ 2
Ecology and the environment	- 1	0	+ 1	- 2	+ 2	+ 1	+ 2	+ 2	+ 5
Applied mathematics and informatics	0	0	0	0	+ 1	0	+ 2	0	+ 3
All fields	- 1	+ 1	+ 2	0	+ 3	+ 1	+ 2	+ 2	+ 10

given that the researchers recruited now have to hold such a qualification (table 3). The proportion of CIRAD researchers authorized to supervise research was 8% in 2002.

Scientific partnerships

Joint skills centres. CIRAD undertook to renew its cooperative research structure in 2001 and 2002 by setting up joint skills centres. These centres foster joint research and training for partners, and involve research bodies, universities and local organizations. They bring scientists together in teams based at different, individual sites abroad, with a view to addressing development issues that call for clearly identified scientific skills.

Six joint skills centres (JSC) were officially founded on 31 December 2002 (table 4). Two agreements had been signed with Senegal in 2001, and a further four were signed in 2002, two in Vietnam and two in Madagascar.

CIRAD staff members account for about a quarter of the 100 researchers now working at these joint skills centres: 27 from CIRAD and 73 from partner organizations (table 5). The proportion of CIRAD researchers involved outside metropolitan France in the JSC centres, and in other centres in the French overseas departments and territories, increased from 8% in 2001 to 19% in 2002.

The partnerships established prior to 2002 are now being redefined and steered towards the establishment of joint skills centres, several of which are being set up in 2002-2003 (table 6).

Some of these joint skills centres will become international joint research units (IJRU) as of 2003.

Table 3. Number of researchers holding a doctorate and an authorization to supervise research (HDR)

	2001		2002		Variation
	Number	%	Number	%	
Researchers	815		839		+ 24
With doctorates	408	50.0	419	49.9	+ 11
HDR	59	7.2	67	8.0	+ 8

Table 4. Joint skills centre agreements signed in 2001 and 2002

	Purpose	CIRAD Department	Other partners
PPZS, Senegal	Pastoral resource management in dry zones	EMVT, Forêt, TERA	ISRA, Universities of Dakar and Saint-Louis (Senegal)
CERAAS, Senegal	Plant adaptation to drought	CA, AMIS	ISRA, University of Dakar, ENA Thiès (Senegal), Universities of Paris-Créteil (France), of Hohenheim (Germany) and Greenwich (UK)
MALICA, Vietnam	Urban consumption and supply economics	FLHOR, AMIS	VASI, RIFAV, ICARD, IOS, IAE, AIT (Vietnam)
PRISE, Vietnam	Intensification of animal production systems	EMVT	NIAA, University of Can-Tho (Vietnam)
SCRID, Madagascar	Sustainable rice-based cropping systems	CA, TERA	FOFIFA, University of Antananarivo (Madagascar)
F and B, Madagascar	Sustainable forest management and biodiversity protection	Forêt, TERA	FOFIFA, University of Antananarivo (Faculty of Law, ESSA), CNRE (Madagascar)

Table 5. Senior researchers working at joint skills centres

	CIRAD	Partners	Total
GIS PPZS, Senegal	5	9	14
CERAAS, Senegal	2	9	11
MALICA, Vietnam	4	6	10
PRISE, Vietnam	7	7	14
SCRID, Madagascar	5	17	22
F and B, Madagascar	4	25	29
Total	27	73	100

Table 6. Joint skills centres currently being redefined or established

	CIRAD department	Partner
Being redefined		
Sustainable management of fast-growing forest species in Congo	Forêt	UR2PI
Development of animal production in sub-humid zones of Burkina Faso	EMVT	CIRDES
Improvement of plantain and other banana production for local consumption in Cameroon	FLHOR	CARBAP
Being established		
Savanna ecosystems management in Mali	TERA	IER, Institut polytechnique de Katibougou
Integrated management of family farms in the humid agroforest ecosystems of Cameroon	-	-
Agrifoods technology and food safety in Brazil	-	-

Joint research units. Agreements were signed for 12 joint research units in 2001 and 2 in 2002, bringing the total number to 14 as of 31 December 2002 (table 7).

CIRAD's main partners in joint research units are Agro Montpellier and INRA. Over 27% of CIRAD's researchers belong to these units, four of which are headed by a CIRAD researcher or associate: PIA, AMAP, System and PVBMT (table 8).

There are three joint research units involving the University of Montpellier, and five are currently being validated (table 9).

Table 7. List of joint research units agreed with CIRAD in 2001 and 2002

	Purpose	Head	Partners
BEPC	Biology of cultivated tree crop development	F. Dosba	Agro Montpellier, INRA, IRD
PIA	Polymorphisms of agricultural value	J.C. Glaszmann	Agro Montpellier, INRA
AMAP	Botany and informatics of plant architecture	D. Barthélémy	UM2, CNRS, EPHE, INRA
BGPI	Biology and genetics of plant-parasite interactions for integrated pest management	J.L. Notteghem	Agro Montpellier, INRA
CBGP	Population biology and management centre	S. Morand	UM2, Agro Montpellier, INRA, IRD
LSTM	Tropical and Mediterranean plant symbiosis laboratory	B. Dreyfus	Agro Montpellier, INRA, IRD
Ecologie des forêts en Guyane	Forest ecology in French Guiana	M. Fournier	ENGREF, INRA
System	Tropical and Mediterranean cropping system functioning and management	J. Wéry	Agro Montpellier, INRA
ERRC	Ruminant production in warm regions	F. Bocquier	Agro Montpellier, INRA
CIRED/UMR 8568	International environmental and development research centre	J.C. Hourcade	EHESS, ENPC, CNRS
Innovation	Innovation, technical change, apprenticeship and coordination in the agricultural and agrifoods sectors	F. Dreyfus	Agro Montpellier, IAMM,CNEARC, INRA
PVBMT (Réunion)	Plant stands and biothreats in tropical environments	B. Reynaud	University of Réunion
DGPC	Diversity and genomes of cultivated plants	S. Hamon	Agro Montpellier, INRA, IRD
SAGERT	Agrarian systems and sustainable management of agricultural use of tropical and Mediterranean resources and territories	P. Jouve	CNEARC, ENGREF

UM2: University of Montpellier II

Table 8. Number of senior researchers in joint research units

	Annual Crops	Tree Crops	FLHOR	EMVT	Forêt	TERA	AMIS	General management	Total
BEPC	-	8	1	-	1	-	5	-	15
PIA	11	13	1	-	6	-	13	1	45
AMAP	-	1	-	-	4	-	19	-	24
BGPI	5	2	-	-	-	-	11	-	18
CBGP	1	1	-	-	-	-	1	-	3
LSTM	-	-	-	-	4	-	1	-	5
Ecologie des forêts en Guyane	-	-	-	-	6	-	-	-	6
System	16	4	3	-	-	-	7	1	31
ERRC	-	-	-	11	-	-	-	-	11
CIRED/UMR 8568	-	-	-	-	-	-	4	-	4
Innovation	-	-	-	-	-	5	-	-	5
PVBMT	3	-	3	-	2	-	8	-	16
DGPC	1	6	-	-	-	-	-	-	7
SAGERT	2	-	-	6	1	27	-	1	37
Total	39	35	8	17	24	32	69	3	227

Table 9. List of joint research units being validated in 2003

	Purpose	Head	Partners
MOISA	Markets, organizations, institutions and stakeholder strategies	J.L. Rastoin	Agro Montpellier, CIHEAM, INRA, IRD
CEFE	Centre for functional and evolutive ecology	B. Delay	Universities of Montpellier I, II, III Agro Montpellier, CNRS
ITAP	Information and technologies for agroprocesses	V. Bellon-Maurel	Agro Montpellier, ENSIA, CEMAGREF
Génie des Procédés	Bioproduct manufacturing process engineering	A.Grasmick	Universities of Montpellier I, II, ENSIA
IATE	Agropolymer engineering	S.Guilbert	Universities of Montpellier I, II, Agro Montpellier, ENSIA, INRA

Students received

Students from developing countries

In 2002, in metropolitan France, CIRAD received 449 students from developing countries, corresponding to the equivalent of 123 full-time posts (figure 1). On average, each CIRAD senior researcher in metropolitan France therefore supervised a student for one and one-half months.

Doctoral students

In 2002, CIRAD received 151 doctoral students, corresponding to a total of 1 134 man-months. Each staff member authorized to supervise research statistically supervised the equivalent of 1.41 years of doctoral studies (figure 2). In practice, some doctoral students received by CIRAD are also supervised by associate scientists. Conversely, other doctoral students are not listed as being received by CIRAD, but are nevertheless supervised by senior researchers belonging to the thesis panel.

French post-doctoral students

In 2002, CIRAD received nine post-doctoral students under the agreement signed with the Ministry for Research and New Technologies (nine in 2000, six in 2001). They were stu-

Figure 1. Number of students received in metropolitan France, by country of origin

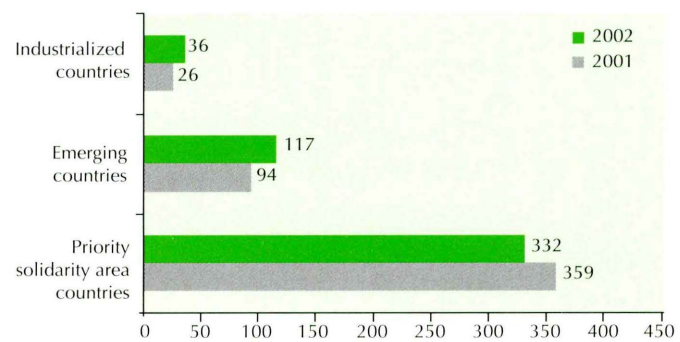
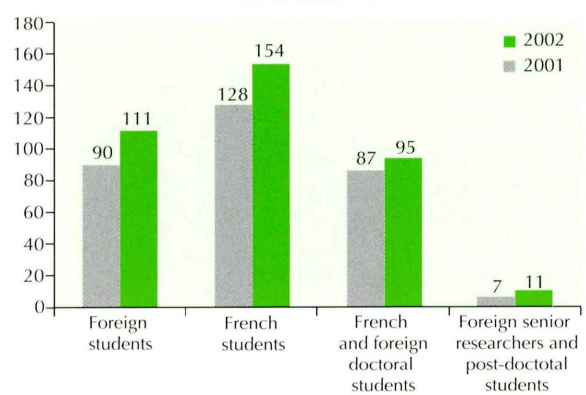


Figure 2. Students received by CIRAD (equivalent full-time posts)



dents holding doctorates obtained in laboratories other than at CIRAD, who were employed on 12-month short-term contracts that could be extended for 6 months, in the fields of crop protection (3), environmental agronomy (3), mathematics and informatics applied to agronomy (1), economics (2). Of the 15 post-doctoral students received in 2000 and 2001, 4 have since been recruited full-time by CIRAD.

Foreign senior researchers and post-doctoral students

In addition to the agreement on French post-doctoral students, signed with the French Ministry for Research in 2000, CIRAD also gives its departments financial incentives to receive foreign senior researchers.

In 2002, 18 senior researchers and post-doctoral students spent an average of 8.5 months with CIRAD research teams, compared with 13 the previous year. They came from 11 countries: Australia (2), Chile (1), China (2), Côte d'Ivoire (1), Ecuador (1), Egypt (1), Japan (1), Slovenia (1), Tunisia (1), UK (3), and the USA (4). These stays enabled the CIRAD teams to establish close ties with the universities and structures from which the foreign researchers came, which have, in some cases since, given rise to joint projects.

Human resources

Staff breakdown

The recent strategic restructuring has resulted in an increase in staff numbers, particularly senior staff (figure 3). At CIRAD, women now account for 21% of the total senior staff. CIRAD's achievements in terms of placing staff abroad were masked by the need to repatriate 15 members of staff from Côte d'Ivoire during the recent troubles.

Staff based outside metropolitan France, and overseas missions

The CIRAD staff members working overseas are mostly based in French departments and territories. Around 30% are senior staff (figure 4). The total number of equivalent full-time posts overseas is 728, including missions outside metropolitan France. Almost 60% of missions are to the French overseas departments and territories and over a quarter to the priority solidarity area.

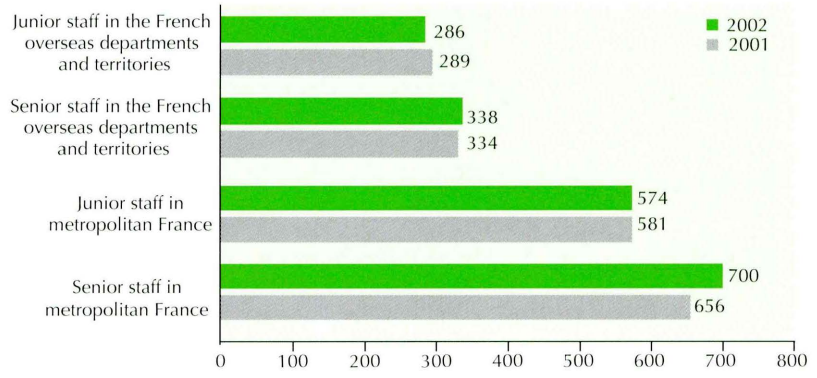
Financial resources

Operations

The share of CIRAD operating costs covered by State research and technological development funds was cut from 63.2% in 2001 to 61.9% in 2002 (figure 5).

This cut was primarily due to the deduction of 4.9 million euros from the budget for "fundamental support of units", with a view to setting aside funds for two major strategic invest-

Figure 3. Salaried staff numbers in 2001 and 2002



The data include staff on both short- and long-term contracts.

Figure 4. Staff and missions outside metropolitan France in 2002

ment projects (a genome study and crop protection building in Montpellier and the establishment's information system) and by the cancellation of a loan of 2 million euros.

Contractual resources

Contractual resources were up 2.3% between 2001 and 2002, from 42.7 million euros in 2001 to 43.7 million in 2002. Total growth over the period 1998-2002 was 15.6% (figure 6).

The rise in the proportion drawn from French State funds resulted from the increase in local authority funding, primarily under projects conducted in the French overseas departments and territories.

The drop in public funding from abroad was compensated for by an increase in European Union funding (EAGGF and ERDF), which was again primarily used in the French overseas departments and territories, through joint funding of State-regional programme contracts.

The drop in private funding can partly be attributed to the sale of the banana production sector of the Rivière-Lézarde station in Martinique in the second half of 2001.

Orders

The number of new contracts in CIRAD's portfolio was up 7.4% in 2002, when 503 orders were taken, for a total of 45.1 million euros.

Figure 5. Income and expenditure in 2002

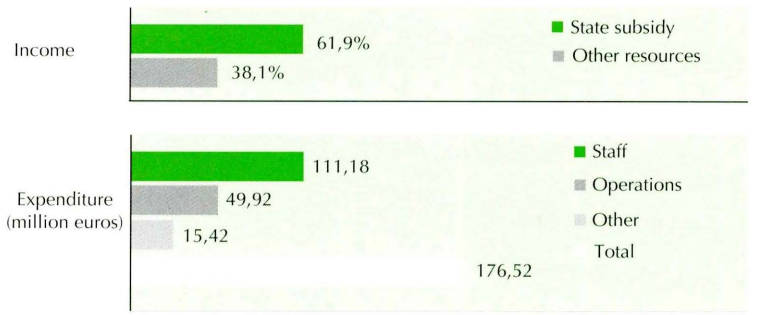
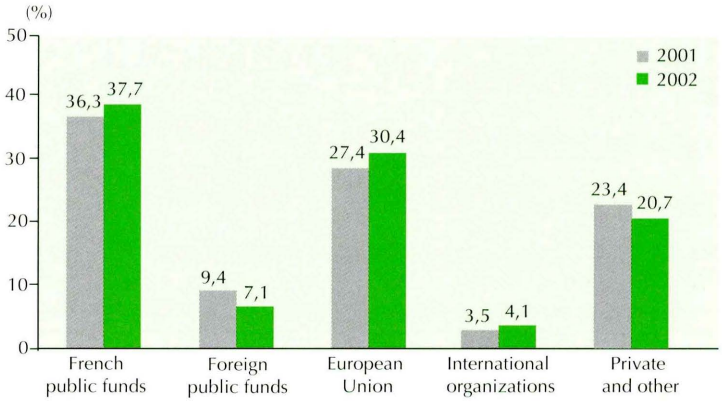


Figure 6. Contractual resource distribution per type of funding



Transversal projects

In additional to its internal interdepartmental projects and interorganizational thematic projects, CIRAD is also involved in numerous transversal projects, in particular in conjunction with INRA and CEMAGREF, and in projects financed by an INRA-CIRAD joint fund since 1999.

An INRA-CEMAGREF-CIRAD structure has been set up for research and expertise in terms of the multifunctionality of agriculture and rural areas (table 10). It aims to assess the concepts and instruments at play, and to analyse and study the relevant dynamics in detail.

A joint fund was set up in 1999 to finance scientific collaboration between teams from INRA and CIRAD. Since 2000, 33 projects have been selected (table 11), involving numerous INRA centres in metropolitan France as well as teams from the French overseas departments and territories.

Table 10. Projects under the INRA-CEMAGREF-CIRAD structure

	Leaders	Main Institutions	Associated Institutions
Institutional dynamics and emergence of multifunctionality: procedures for resolving conflicts linked to land	A. Torre	INRA	CEMAGREF
The side issues of international policy: are there agricultural multifunctionality-type policies in the Cairns Group and NAFTA countries?	B. Losch, D. Perraud	CIRAD	INRA
Agricultural multifunctionality in peri-urban areas: the range of ways of being a farmer, inserting farming into territorial development schemes	A. Fleury	ENSP	INRA, CEMAGREF, CESA
Agricultural multifunctionality as a link between market and non-market functions	D. Barthélémy	INRA	
Building an analysis approach at local level, based on a comparative structure in France and Brazil	B. Roux, P. Bonnal	INRA, CIRAD	Univ. Brazil, EMBRAPA
International distribution effects linked to the consideration of agricultural multifunctionality in national policy	R. Lifran	INRA	
Multifonctionality in the watersheds of northern Thailand: between the emergence of different points of view and external management	O. Barreteau	CEMAGREF	
Development models and territorial identity in the islands of the French overseas departments and territories	M. Piraux	CIRAD	INRA
Recognition of the complexity of production systems, reflection on farmer identity and status... The case of Mayotte	J.M. Sourisseau	CIRAD	

Table 11. INRA-CIRAD joint projects

	Leaders	Organizations
Projects selected in 2000		
Modelling of rubber tree physiological functioning	E. Gohet	CIRAD
Cropping systems and animal production effluents	P. Leterme	INRA
Comparison of mineral functioning in eucalyptus stands planted in savanna areas and in managed plots: impact of eucalyptus trees on savanna soil fertility. Case of Congo	J.P. Bouillet	CIRAD
Huanglongbing (HLB, ex-greening) of citrus fruits: contribution to establishing a control strategy to ensure sustainable high-quality fruit production	P. Cao-Van	CIRAD
Nitrogen and organic matter in integrated tropical market garden cropping systems	C. Langlais C. Gary	CIRAD INRA
Redistributive hydrological functioning in a banana-cultivated andosol system: consequences for local soluble input storage and flux	Y.M. Cabidoche	INRA
Identifying satellite DNA-type sequences in the coffee root-knot nematode *Meloidogyne exigua*, with a view to developing a specific diagnostic test	J.L. Sarah	CIRAD
Impact of mulch-based no-till systems on soil structure and organic matter: consequences for physical properties and nitrogen resources	F. Maraux	CIRAD
Characterization of tree crop systems practised on family farms	A. Leplaideur	CIRAD
Projects selected in 2001		
Recombinant vaccine against heartwater	I. Scwartz-Cornil	INRA
Transferability of local technique certification systems	P. Byé	INRA
Study of individual management of animal production effluents based on a general agricultural production system modelling and simulation package	F. Guerrin	INRA
Poultry feeding strategies in hot conditions	D. Bastianelli	CIRAD
Towards a decision-support system for control of the parasites affecting Arabica coffee trees	J. Avelino	CIRAD
Genetic approach to heartwood formation and its properties: extractable substances (flavonoids), colour and natural durability in four forest species	P. Vigneron	CIRAD
Role of small dairy firms in local development	J.P. Boutonnet	INRA
Controlling food product flavour quality: evaluation of new aromatic compound separation methods	M. Dornier	CIRAD
Modelling of epidemics of fungi responsible for leaf diseases	J. Carlier	CIRAD
Analysis of the factors governing the spread of the soybean front in Brazilian Amazonia	J.P. Bertrand R. Pasquis	INRA CIRAD
An integrated approach to forest dynamics: reproduction and dispersion, growth and competition	P. Dreyfus	INRA
Evaluation of the strengths and weaknesses of different coordination methods aimed at developing agricultural quality control systems in developing countries	P. Moustier	CIRAD
Projects selected in 2002		
Decision support for management of wild Atlantic salmon populations	E. Prévost	INRA
SACADEau: knowledge acquisition systems for decision support concerning water quality	M.O. Cordier G. Gascuel	INRA INRA
ADEBAL: decision support for brood cow rearing: herd management and production decisions	J. Agabriel	INRA
Combination of models and measurements made during the season for better decision-making	D. Makowski	INRA
Anticipation and management of irrigation	F. Garcia	INRA
Designing information and advisory systems. Application to the rationalization of treatments against rapeseed *Sclerotinia*	M. Cerf M. Taverne	INRA INRA
Tests of a model simulating sugar mill supply chains	P.Y. Legal L.G. Soler	CIRAD INRA
APSOOTEC: social forms of appropriation of technical advances and common practices: the case of the SEPATOU pasture management simulator	P. Geslin	INRA
Designing a model to analyse or intervene in the construction of a collective operation	C. Loyce	INRA
Building the negotiating space	P. Rio	INRA
Methodology of modelling	R. Martin-Clouaire	INRA

Organizational Chart of CIRAD in June 2003

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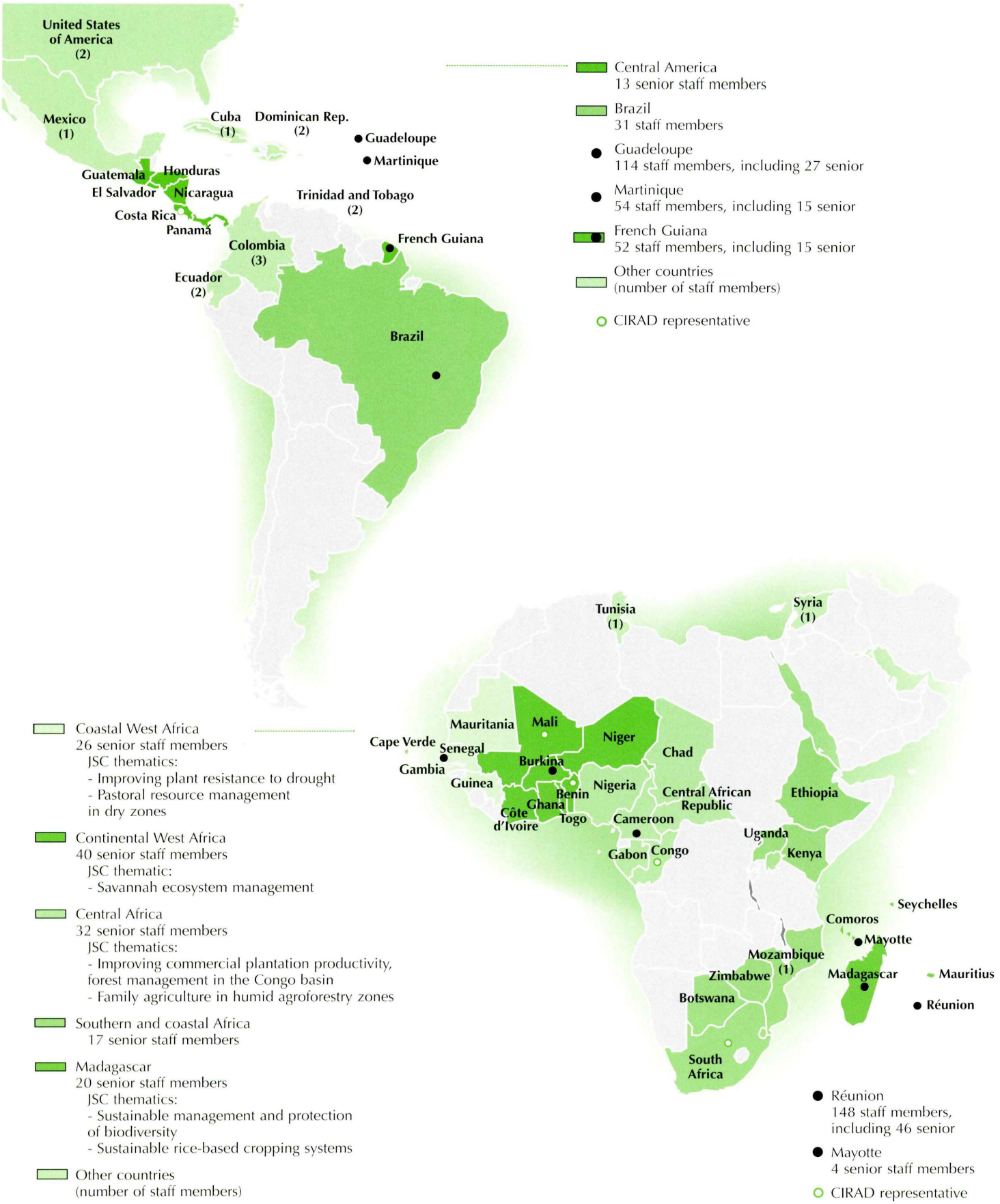
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Honduras
El Salvador
Nicaragua
Costa Rica
Panamá
Trinidad and Tobago (2)
Colombia (3)
French Guiana
Ecuador (2)
Brazil
Central America
13 senior staff members
Brazil
31 staff members
Guadeloupe
114 staff members, including 27 senior
Martinique
54 staff members, including 15 senior
French Guiana
52 staff members, including 15 senior
Other countries
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CIRAD representative
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Syria (1)
Mauritania
Mali
Niger
Cape Verde
Senegal
Gambia
Burkina
Chad
Guinea
Nigeria
Benin
Ghana
Côte d'Ivoire
Togo
Cameroon
Central African Republic
Ethiopia
Uganda
Kenya
Gabon
Congo
Seychelles
Comoros
Mayotte
Mozambique (1)
Zimbabwe
Madagascar
Mauritius
Botswana
Réunion
South Africa
Coastal West Africa
26 senior staff members
JSC thematics:
- Improving plant resistance to drought
- Pastoral resource management in dry zones
Continental West Africa
40 senior staff members
JSC thematic:
- Savannah ecosystem management
Central Africa
32 senior staff members
JSC thematics:
- Improving commercial plantation productivity, forest management in the Congo basin
- Family agriculture in humid agroforestry zones
Southern and coastal Africa
17 senior staff members
Madagascar
20 senior staff members
JSC thematics:
- Sustainable management and protection of biodiversity
- Sustainable rice-based cropping systems
Other countries
(number of staff members)
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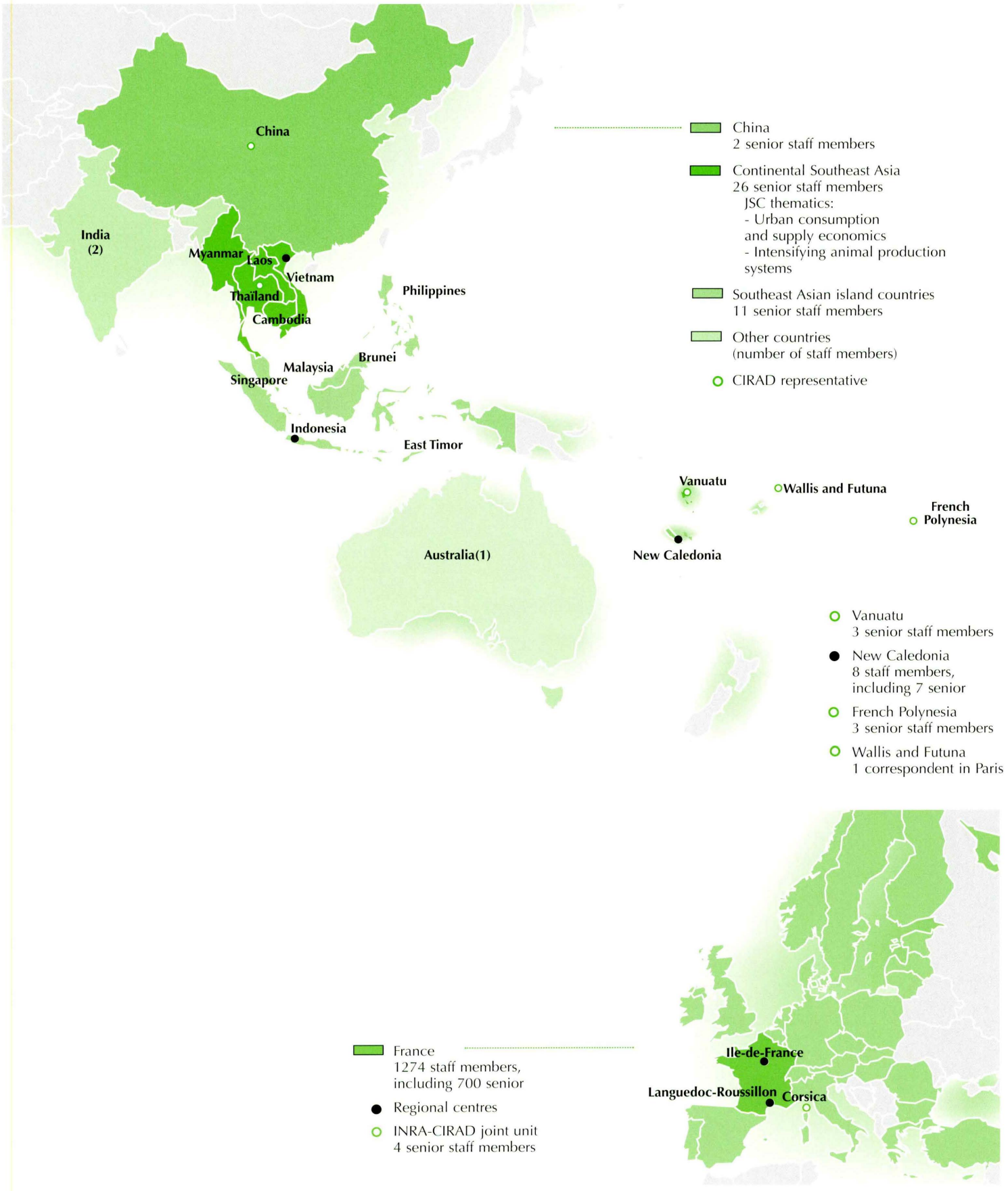
148 staff members, including 46 senior
Mayotte
4 senior staff members
CIRAD representative


China
India
(2)
Myanmar
Laos
Vietnam
Thailand
Cambodia
Philippines
Malaysia
Brunei
Singapore
Indonesia
East Timor
Australia(1)
Vanuatu
Wallis and Futuna
French
Polynesia
New Caledonia
China
2 senior staff members
Continental Southeast Asia
26 senior staff members
JSC thematics:
- Urban consumption
and supply economics
- Intensifying animal production
systems
Southeast Asian island countries
11 senior staff members
Other countries
(number of staff members)
CIRAD representative
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3 senior staff members
New Caledonia
8 staff members,
including 7 senior
French Polynesia
3 senior staff members
Wallis and Futuna
1 correspondent in Paris
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1274 staff members,
including 700 senior
Regional centres
INRA-CIRAD joint unit
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Corsica

List of acronyms and abbreviations

ACP, Africa, Caribbean and Pacific
AFD, Agence française de développement, France
AFLP, Amplified Fragment Length Polymorphism
AFSSA, Agence française de sécurité sanitaire des aliments, France
AGI, Agricultural Genetics Institute, Vietnam
Agro Montpellier, Ecole nationale supérieure agronomique de Montpellier, France
ASD, Agricultural Services and Development, Costa Rica
AVRDC, Asian Vegetable Research and Development Center, Taiwan
BFP, Bureau fédéral du plan, Belgium
BPTP, Sleman Agricultural Technology Research Workshop, Indonesia
CAOBISCO, Association des industries de la chocolaterie, de la biscuiterie et de la confiserie, Belgium
CARBAP, Centre africain de recherches sur bananiers et plantains, Cameroon
CBGP, Centre de biologie et de gestion des populations, France
CEFE, Centre d'écologie fonctionnelle et évolutive, CNRS, France
CEMAGREF, Centre national du machinisme agricole, du génie rural, des eaux et des forêts, France
CENAREST, Centre national de la recherche scientifique et technique, Gabon
CERAAS, Centre d'étude régional pour l'amélioration de l'adaptation à la sécheresse, Senegal
CES-KUL, Centre of Economic Studies, Katholieke Universiteit Leuven, Belgium
CFC, Common Fund for Commodities, Netherlands
CGIAR, Consultative Group on International Agricultural Research, USA
CIFOR, Center for International Forestry Research, Indonesia
CIRDES, Centre international de recherche-développement sur l'élevage, Burkina Faso
CNEARC, Centre national d'études agronomiques des régions chaudes, France
CNFRCG, Comité national français de recherche sur les changements globaux, France
CNIA, Comité national interprofessionnel de l'arachide, Senegal
CNRA, Centre national de recherche agronomique, Côte d'Ivoire
CNRS, Centre national de la recherche scientifique, France
COODETEC, Cooperativa Central Agropecuária de Desenvolvimento Technológico e Econômico, Brazil
CSAR, Centre for Soil and Agroclimate Research, Indonesia
CTBA, Centre technique du bois et de l'ameublement, France
CUFR, Centre universitaire de formation et de recherche, France
EAGGF, European Agricultural Guidance and Guarantee Fund
EARO, Ethiopian Agricultural Research Organization, Ethiopia
ECP, Ecole centrale de Paris, France
EHESS, Ecole des hautes études en sciences sociales, France
ENEA, Ecole nationale d'économie appliquée, Senegal
ENGREF, Ecole nationale du génie rural, des eaux et des forêts, France
ENSA, Ecole nationale supérieure agronomique, Senegal
ENSAM, Ecole nationale supérieure des arts et métiers, France
ENSIA, Ecole nationale supérieure des industries alimentaires, France
EPHE, Ecole pratique des hautes études, France
ERDF, European Regional Development Fund
FAO, Food and Agriculture Organization of the United Nations, Italy
FOFIFA, Centre of Applied Research for Rural Development, Madagascar
GEVES, Groupement d'étude et de contrôle des variétés et des semences, France
GIEC, Groupe international d'étude du climat, France
IAC, Institut agronomique calédonien, New Caledonia
IAM, Institut agronomique méditerranéen, Montpellier, France
IAV, Institut agronomique et vétérinaire Hassan II, Morocco
ICCS-NTUA, Institute for Communication and Computer Systems, National and Technical University of Athens, Greece
ICRA, Institut centrafricain de recherche agronomique, Central African Republic
ICRISAT, International Crops Research Institute for the Semi-Arid Tropics, India
IDDRI, Institut du développement durable et des relations internationales, France
IEPE, Institut d'économie et de politique de l'énergie, France
IER, Institut d'économie rurale, Mali
IFREMER, Institut français de recherche pour l'exploitation de la mer, France
IIFT, Instituto de Investigación en Frutales tropicales, Cuba
IITA, International Institute of Tropical Agriculture, Nigeria
ILRI, International Livestock Research Institute, Kenya
INAO, Institut national des appellations d'origine, France
INA-PG, Institut national agronomique Paris-Grignon, France
INERA, Institut de l'environnement et des recherches agricoles, Burkina Faso
INIBAP, International Network for the Improvement of Banana and Plantain, France
INRA, Institut national de la recherche agronomique, France

INRA, Institut national de la recherche agronomique, Morocco
INRAB, Institut national de recherches agricoles du Bénin, Benin
INRIA, Institut national de la recherche en informatique et en automatique, France
INSERM, Institut national de la santé et de la recherche médicale, France
IOPRI, International Oil Palm Research Institute, Indonesia
IPGRI, International Plant Genetic Resources Institute, Italy
IPTS, Institute for Prospective Technological Studies, Spain
IRAD, Institut de recherche agricole pour le développement, Cameroon
IRAL, Institut de la recherche agronomique du Liban, Lebanon
IRD, Institut de recherche pour le développement, France
ISIMI, Institut supérieur d'informatique et de modélisation et de leurs applications, France
ISRA, Institut sénégalais de recherches agricoles, Senegal
ITRAD, Institut tchadien de recherche agronomique pour le développement, Chad
IUCN, International Union for Conservation of Nature and Natural Resources, UK
IVIA, Instituto Valenciano de Investigaciones Agrarias, Spain
IWMI, International Water Management Institute, Sri Lanka
JSC, Joint Skills Centre
LIRMM, Laboratoire d'informatique, de robotique et de micro-électronique de Montpellier, CNRS, France
LRVZ, Laboratoire de recherche vétérinaire et zootechnique, Chad
MPOB, Malaysian Palm Oil Board, Malaysia
NRI, Natural Resources Institute, UK
OAU, Organization of African Unity
OIE, World Animal Health Organization, France
PACE, Pan-African Programme for the Control of Epizootics, Kenya
PCR, Polymerase Chain Reaction
PRI, Plant Research International, Netherlands
PUC, Pontifica Universidad Catolica de Chile, Chile
QTL, Quantitative Trait Loci
RCF, Recherche coton et fibres, Benin
RFLP, Restriction Fragment Length Polymorphism
RIFAV, Research Institute on Fruits and Vegetables, Vietnam
RIVM, Rijksinstituut voor Volksgezondheid en Milieu, Netherlands
SOCFINDO, PT Socfin Indonesia, Indonesia
SPC, Secretariat of the Pacific Community, Fiji
SYAL, Local Agrifood System
UR2PI, Unité de recherche sur la productivité des plantations industrielles, Congo
VARTC, Vanuatu Agricultural Research and Training Centre, Vanuatu
VASI, Vietnamese Agricultural Sciences Institute, Vietnam
WECARD, West and Central African Council for Agricultural Research and Development, Senegal
ZEW, Zentrum für Europäische Wirtschaftsforschung, Germany

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