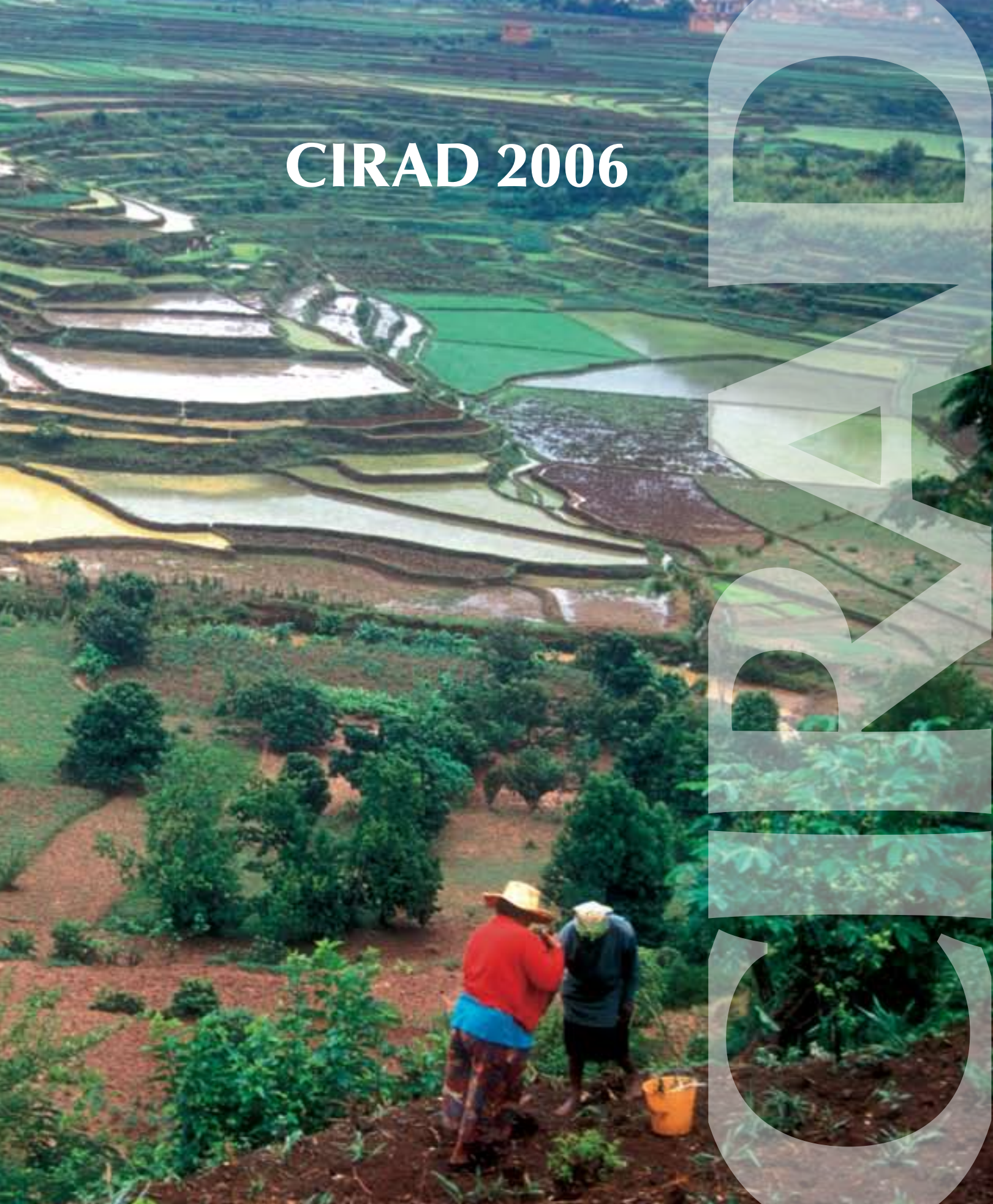
CIRAD 2006



CIRAD 2006

CIRAD, the Agricultural Research Centre for International Development, is a French agricultural research centre working for development in developing countries and the French overseas regions. It works throughout the tropics and subtropics, and most of its research is conducted in partnership.

It has a mandate to contribute to sustainable development in these regions through research, trials, training and the dissemination of scientific and technical information. Its expertise spans the life sciences, human sciences and engineering sciences and their application to agriculture, food, natural resource management and society.

CIRAD has three research departments: Biological Systems (BIOS), Performance of Tropical Production and Processing Systems (PERSYST), and Environments and Societies (ES). It is split into 59 units: 32 internal research units (UPRs), four service units (USs), 20 joint research units (UMRs) and three international research units (URPs).

It employs 1825 people, including 856 senior scientific staff members, and has an annual operating budget of 203 million euros.

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Foreword

Agriculture is now recognized as a key factor in development, as reflected in current World Bank policy; it provides almost half the global working population with jobs, contributes to harmonious landscape management, and helps conserve resources. These functions mean that agricultural research is now even more vital than before.

Research is now facing new challenges. According to the FAO, global divides are continuing to grow: although the world is richer overall, under-nourishment is increasing—it now affects more than 800 million people—and its global distribution is giving cause for concern. Expecting agriculture to supply energy and biomaterials, which is currently on the agenda, risks further exacerbating conflicts over agricultural land use. The weight of the global risks posed by emerging diseases has been confirmed by the bird flu crisis, and both decision-makers and society are banking on research to come up with solutions. As regards the South, with which CIRAD has strong, sustained links, the divides between and within countries are growing, to the extent that the term "the South" now covers a multitude of situations. Rich, poor and emerging countries need to work together if the major global issues are to be resolved.

In Spring 2006, the French government asked CIRAD and INRA to draw up a joint strategy with the aim of "building capacity in terms of expertise in agricultural research and renewable resource management for the benefit of developing countries". An agreement was signed with the Consultative Group on International Agricultural Research (CGIAR) in October 2006, with a view to boosting the synergies between the international system and CEMAGREF, CIRAD and INRA, in response to the Millennium Development Goals set by the United Nations, particularly that of alleviating poverty through sustainable development. In conjunction with the World Vegetable Center (AVRDC) and the International Society for Horticultural Science (ISHS), CIRAD launched the Global Horticultural Initiative in March 2006, with a view to making horticultural research for development more effective and more equitable.

In 2006, agricultural research in Montpellier was recognized as one of thirteen fields of excellence in France, with the project led by CIRAD, INRA and SupAgro being designated an advanced thematic research network (RTRA). The network centres on plant sciences, from gene to system, and combines biotechnical and socioeconomic approaches in tackling the issues facing temperate, Mediterranean and tropical countries. It is open to the whole of the scientific community in Montpellier and to its partners, and involves a total of 500 top-level researchers and teaching staff members. It has been allocated new resources that should enable it to confirm its central role on the international stage. CIRAD and INRA have also launched the Agrimonde prospective study, to run for two years.

At the end of the year, CIRAD restructured its departments and renewed its mode of governance, while keeping its research units at the heart of its operations. It cut the number of departments and confirmed their scientific vocation. Each new department now centres on a specific set of objectives and questions: plant and animal genes and organisms, for its Biological Systems Department; production and processing systems for its Performance of Tropical Production and Processing Systems Department; and resource management and territorial dynamics for its Environments and Societies Department. Scientific strategy is now the keystone of its operations; it is established collectively, by the Director General, Director of Research and Strategy and Directors of Department. The Director of Research and Strategy also oversees the various regional offices, to ensure a single programming rationale that takes account of scientific, partnership and geographical considerations. Lastly, 2007 is also due to see the launch of a public interest group: the *Initiative française pour la recherche agronomique internationale*, a joint tool built by CIRAD and INRA to support programming decisions on a global level.

The results presented in the report are a concrete reflection of CIRAD's scientific work, but also of its activities in terms of training and information. Working in partnership has been a priority for CIRAD from the outset, and is still central to its philosophy, enabling it to tailor its research operations and expertise to its commitment to development.

Patrice Debré
Chair, Board of Trustees

Gérard Matheron
Director General

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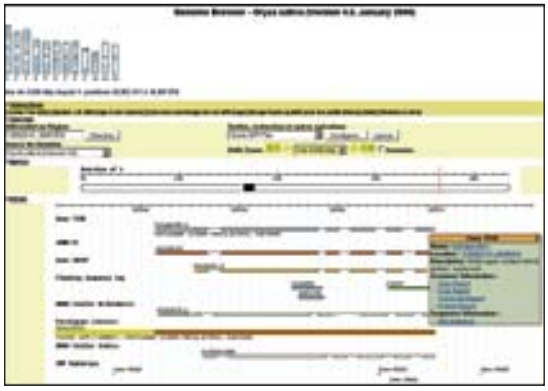
Understanding...

... OryGenesDB, discovering the function of rice genes

The complete rice genome sequence has now been mapped. It comprises 40 000 to 60 000 genes. The next step is to determine its biological function, through functional genomics studies. To facilitate these studies, CIRAD has recently set up a database, containing all the essential information on the rice genome, in particular the flanking sequence tags (FSTs) around the integration sites of mutagenes present in insertion mutant collections. These tags serve to pinpoint gene functions by linking the gene and the phenotype directly, in a reverse genetics approach.

In addition to its agricultural merits, rice has the advantage of having a small genome and similarities with other cereals in terms of sequences and genetic organization, which makes it a model plant for studying monocots. Sequencing of its genome was completed in December 2004. This revealed an unexpected abundance of genes: around 40 000 to 60 000, compared to just 27 000 for *Arabidopsis thaliana,* the model species for dicots. The next step is to determine the functions of all these genes, through functional genomics studies.



A graphic interface for surfing the genome

What genomics has to offer

To determine these functions, several studies have been undertaken, based on integrational mutagenesis. This method enables the random insertion of an identifiable DNA fragment, DNA-T or transfer DNA (or a transposable element) into the genome. When the fragment is integrated into a gene, it may alter the gene's function and trigger a change in the corresponding character. The mutated gene is located thanks to the inserted element, and its function pinpointed through the affected character. The systematic identification of insertion sites calls for large-scale sequencing using the integrated mutagenic elements.

A collection of 30 000 ADN-T lines and 40 000 FSTs has been compiled at CIRAD as part of the Génoplante project. Likewise, various international laboratories have also built up mutant collections. An integrative database, OryGenesDB, which contains all these resources along with the main genomic data on rice, has been developed to exploit this information.

A comprehensive information system

The aim of the OryGenesDB information system is to enable molecular geneticists to find insertion mutants for worthwhile genes quickly, and to pinpoint as many annotations linked

Rice, a model plant for studying monocots
© J.E. Taillebois/CIRAD

to those genes as possible, through a reverse genetics approach, from sequence to phenotype.

The heart of the system is the Genome Browser generic software, a web application for visualizing genomic annotations. It has a user-friendly graphic interface that allows users to surf the genome and visualize all the available genomic annotations. The software's system of reference corresponds to rice pseudomolecules, or chromosomes, from the Institute for Genomic Research (TIGR) website. In addition to FSTs, various items of information, such as full-length DNA, expressed sequence groups for several cereals (wheat, maize, barley, sorghum and sugarcane), molecular markers and expression data, have been integrated into the system in the form of annotation layers. Complementary tools have also been developed, to facilitate information searches and visualization: searches by accession number, keyword, conserved protein domain or sequence homology. The search result can then be stored as an Excel file.

An indispensable tool for exploring gene function

To simplify and intensify rice genome functional analyses, two other databases, developed in parallel, are to be coupled with OryGenesDB. Oryza Tag Line (OTL) is the phenotype equivalent of OryGenesDB. It lists all the morphological and physiological data gathered on DNA-T insertion lines. Coupling these two bases will enable the rapid identification of the effect of a mutation in a given gene, by looking into the morphological and physiological characteristics of the corresponding plants. Lastly, to exploit the mass of information gathered on *Arabidopsis thaliana,* a new database, Greenphyl, has been compiled. It serves to classify all the sequences from rice and *Arabidopsis* in families, and includes an automatic tool that determines the most likely functional equivalents in the two species.

OryGenesDB is now the central database for rice gene functional analyses at CIRAD. It is widely used by the international community. Its power and simplicity should also make it an indispensable tool for exploring the function of genes of agricultural interest in other cereals.

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The development of OryGenesDB was funded by the European Commission (Cereal Gene Tag Project CT-2001-01453) and the "Generation" Challenge Programme (Rice Stress Mutants Project).

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Website

http://orygenesdb.cirad.fr

Genes involved in coffee quality

Sucrose plays a vital role in coffee organoleptic quality. A team from CIRAD and the Agricultural Institute of Paraná (IAPAR) in Brazil has recently identified the genes responsible for sucrose accumulation in coffee beans. This is a new step along the way to producing exceptional coffees.

To maintain their incomes, growers are increasingly banking on producing quality coffee. However, improving coffee beverage quality means knowing more about the biological processes—flowering, fruit ripening, etc—that determine end product characteristics. Some compounds (sugars, fats, caffeine, etc) are known to play a role in coffee quality. Their accumulation in the plant, and particularly in the beans, is a determining factor. Sucrose is considered to play a crucial role in coffee organoleptic quality, since its breakdown during roasting releases several aroma and flavour precursors.

An enzyme responsible for sucrose accumulation

Since 2001, CIRAD and the Agricultural Institute of Paraná in Brazil (IAPAR) have been working on joint research into how coffee beans ripen. They have characterized the key enzymes in the sucrose metabolism during coffee bean development. The researchers involved used molecular biology and biochemistry techniques in their work, supported by the University of Campinas in Brazil (Unicamp).

Their work showed that an enzyme, sucrose synthase, is responsible for sucrose accumulation in coffee (*Coffea arabica*) beans. Unlike in other plants, invertases play only a minor role in this metabolism. Sucrose synthase exists in the form of at least two similar proteins with the same biological function—isoforms—, but which are coded by two different genes: *Sus1* and *Sus2*.

Expression of those genes was analysed within the various tissues of developing coffee beans (pulp, perisperm and endosperm). The results showed that sucrose accumulation in coffee beans, towards the end of ripening and just before picking, is controlled by isoform Sus2. Isoform Sus1, for its part, seems to be involved in sucrose breakdown and thus in energy production. In effect, its expression is systematically detected during the early stages of cell division and expansion in young tissues.

Early markers of quality

A second phase comprised a study of the nucleotidic diversity of these genes, so as to account for the variations in bean sucrose content between the various *Coffea* species or within the same species. The genes were mapped and tested to determine their role in that variability. The aim was to identify early markers of sucrose content that would guarantee end product quality.

The first application of these results was a study of the relations between shading, which is known to improve coffee quality, and sucrose metabolism enzymes. To this end, IAPAR set up a field trial. The results showed that sucrose synthase and sucrose phosphate synthase, another enzyme in the sucrose metabolism, show greater enzymatic activity in the beans of coffee trees grown in the shade than in those grown in full sunlight. In the case of sucrose synthase, this activity is correlated with the increase in *Sus2* gene expression seen in the beans of shaded plants. However, the final sucrose content of the beans is not higher for shaded plants. The quality of shaded coffee may thus result from the reorientation of the sugar metabolism towards the synthesis of other compounds, such as fats, which may also be involved.

The sucrose accumulated in the beans is one of the organoleptic compounds in coffee
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The coffee paradox

This book begins with an observation. International trade has grown dramatically in the last two decades, and trade is an important source of revenue in developing countries. Yet while many low-income countries have long produced and exported tropical products, they are still just as poor.

Through a study of the global coffee value chain, the authors look again at the constraints on developing countries that export commodities. To this end, they address what they call the "coffee paradox"—the coexistence of a coffee boom in consuming countries and of a crisis in producing countries—and demonstrate that the coffee paradox originated from the fact that the coffee that farmers sell and the coffee bought by consumers are increasingly different. Consumers are not paying for material quality, but for symbolic attributes, and as long as coffee farmers and their organizations do not at least partly control this "immaterial" production, they will keep receiving low prices. The book looks beyond case studies, and thus contributes to a critical, modern analysis of the commodity chain.

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Coffea arabica being grown on terraces in Espírito Santo, Brazil © P. Marraccini/CIRAD

● ● ● Sugarcane smut: genetic diversity of the fungus and genetics of resistance

Smut is found in every zone in which sugarcane is grown, except for Papua New Guinea, which strangely enough is where the ancestral domesticated species Saccharum officinarum *originated. Recent studies have provided a clearer picture of the genetic diversity of the fungus and the genetic determinism of sugarcane resistance.*

Sugarcane smut is a disease caused by the fungus *Ustilago scitaminea,* whose genetic diversity is very limited outside Asia. Control of the disease could centre on breeding resistant varieties, but the genetic determinism of that resistance is not known. A new strategy was recently adopted in the hope of identifying the chromosome

regions involved. It is based on a study of the associations between markers and resistance, and the results so far are very promising.

A single lineage is behind the disease outside Asia

Sugarcane smut takes the form of a whip-like smutty growth (a smut whip) at the tip of infected canes, which may release large numbers of spores. The specific structure of the genetic diversity of the fungus has now been studied on a global scale, using microsatellite markers. It transpires that the major share of the diversity is found in certain populations from Asia. The genetic diversity of populations from the Americas and Africa, on the other hand, is extremely limited, and all the non-Asian strains studied proved to originate from the same genotype. These results suggest that gene flow between continents is rare, since a single lineage, which originated in Asia, has spread worldwide, probably through the accidental transfer of infected cuttings. Outside Asia, using resistant varieties should thus be a sustainable, effective way of controlling the disease. In Asia, given the variability of the pathogen, it would be a good move to characterize the available resistance sources more clearly, particularly those in the wild species *S. spontaneum*.

Identifying the associations between markers and resistance

Modern sugarcane varieties stem from a few interspecific hybridizations of *S. officinarum* and *S. spontaneum* at the start of the 20th century, in India and Indonesia, the results of which have since been intercrossed a limited number of times to give the varieties we know now. There has thus been a marked founder effect likely to lead to linkage disequilibrium (LD). This LD, which is a measure of the non-random association of alleles to distinct loci, is more or less marked in cultivated plants depending on the history of their domestication and their reproductive regime. In sugarcane, a marked LD was confirmed by monitoring the behaviour of AFLP (Amplified Fragment Length Polymorphism) markers whose position on reference genetic maps was known: significant associations between markers could be detected at distances of anything up to 20 cM and more, although the mean degree of LD fell considerably if the distance between markers was more than 5 cM. The structure of the LD means that it may be possible to locate worthwhile genes by analysing the associations between markers and characters across the genome.

Sugarcane smut takes the form of a whip-like smutty growth at the tip of infected canes
© J.-C. Girard/CIRAD

It was on the basis of this observation that the genetic determinism of smut resistance was explored, within a cultivar population comprising two subpopulations, one highly resistant and the other highly susceptible to smut. A study of the associations between the presence or absence of markers and resistance revealed chromosome regions linked to resistance. Some of them correspond to QTLs (Quantitative Trait Loci) detected during a genetic mapping study conducted on a controlled cross between a resistant cultivar (R 570) and a susceptible clone (MQ 76-53).

Studies of associations are looking particularly promising for sugarcane. They complement the studies conducted using QTLs, which are complex in this highly polyploid plant.

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Vanilla aroma and images

During fruit ripening, the glucovanillin that has accumulated in green vanilla beans is hydrolysed by a glucosidase, which releases vanilla aroma. However, there is some debate about the location of these two compounds within the bean. Using cellular imagery and the latest spectral deconvolution techniques, it will now be possible to identify these two metabolites very precisely in situ, and eventually to improve bean postharvest processing techniques.

Cellular imagery is currently being revolutionized by the development of in situ marking techniques and improvement in microscope performance, which has really gathered speed in the past decade. It is now possible to analyse the spectral composition of the light in each pixel of an image. Spectral deconvolution, based on this analysis, uses powerful algorithms to decompose a complex emission spectrum into elementary spectra that are recorded as controls. The system was initially developed for biologists wanting to trace several proteins labelled with different coloured tags within the same tissue.

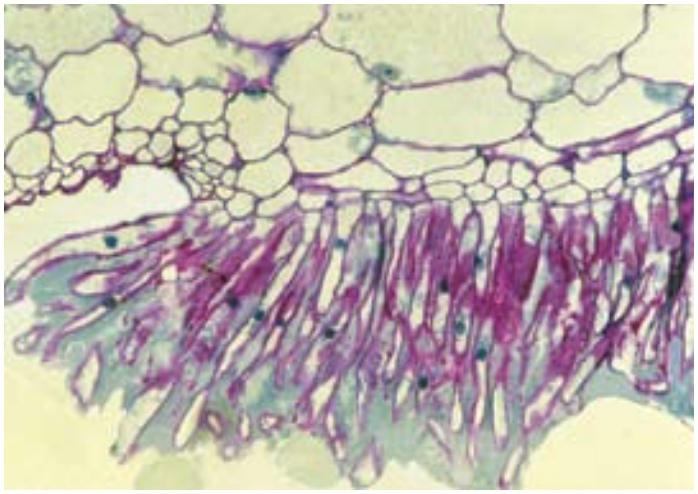
The histocytology and plant cellular imagery platform has used this technique for the in situ location of vanilla bean secondary metabolites with different degrees of fluorescence: vanillin and its glucosylated precursor, glucovanillin. During bean ripening, the glucovanillin that has accumulated in green vanilla beans is hydrolysed by a glucosidase, which releases vanilla aroma.

Vanilla flower
© P. Lachenaud/CIRAD

Locating vanillin precisely within the bean

Purified vanillin and glucovanillin powder samples were observed under a confocal microscope, and their respective emission spectra were recorded. These control spectra were used to analyse the fluorescent light from a bean section and find the pixels in the image that contained one or other spectrum or both spectra superimposed on each other. It also proved possible to distinguish the zones of the image and the section that corresponded to glucovanillin from those that corresponded to vanillin.

Glucovanillin accumulates mainly in the internal part of the bean, more precisely in the placentas, the secretory papillae, and around the seeds, within the bean cavity. Vanillin, for its part, is found in the placenta cells and around the seeds. Experiments



Histocytological section of a vanilla bean
© J.L. Verdeil/CIRAD

conducted on numerous controls confirmed this location. They demonstrated the power of spectral deconvolution to locate secondary metabolites in situ, but also its limitations.

These experimental data offer new prospects for adjusting bean postharvest processing methods. In effect, the method used in producing countries, which is the result of a long tradition, is entirely empirical. Under these conditions, it is almost impossible to diagnose the origin of any quality defects found correctly. This work is an essential stage on the road to a better understanding of how vanilla quality evolves during processing.

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● ● ● Silicon boosts sugarcane resistance to borers

The African stalk borer Eldana saccharina *is one of the main sugarcane pests. A study by CIRAD and SASRI, in South Africa, has shown that silicon plays a role in sugarcane resistance, by triggering its natural defences, and that this role is more pronounced in the event of water stress. This work has opened the way for a new agrobiological control method.*

With 20.4 million hectares in 2005, sugarcane plays a major role in the global economy. Moreover, it has recently seen unprecedented development to produce bioethanol, a biofuel for which demand is almost certain to grow in the coming years. However, plantations are under attack from numerous insects, several of which cause considerable damage. In particular, this applies to lepidopteran borers such as *Eldana saccharina* (Pyralidae), whose caterpillars bore into sugarcane stalks, causing losses in terms of both sugar and biomass. The economic impact is significant: estimates in Réunion show that an infestation rate of more than 90% of affected canes (20% of internodes with holes) causes losses of up to 30 tonnes a hectare in susceptible varieties.

Limiting the damage on susceptible varieties

Chemical control against this type of pest is difficult to implement since the larvae and caterpillars that cause the damage are sheltered inside the stalks. Moreover, biological control, which has been tested on *E. saccharina* for many years, has failed to give any conclusive results. Research

Eldana saccharina caterpillars bore galleries in canes, causing severe sugar and biomass losses
© R. Goebel/CIRAD

is now centring on identifying the agronomic factors that slow the borer's development. In partnership with SASRI (South African Sugar Research Institute), CIRAD recently conducted a three-year research programme in South Africa, one of the world's leading sugarcane producers

The results obtained in pot trials are convincing: silicon treatments significantly reduce the damage caused by the borer, regardless of the variety, with or without water stress. In the case of susceptible varieties and with water stress, damage is kept at very low levels, equivalent to those measured in resistant varieties, irrespective of water stress conditions. It is now estimated that applying silicon to susceptible varieties prevents the loss of 20 or even 30% of the sugar yield, not counting the biomass losses caused by the insect. On the other hand, silicon applications do not modify stem hardness or sugar quality.

A new agrobiological control method

In the event of water stress, the active role played by silicon in the plant's defence system could be put down to changes in silicon concentration and structure in the plant's tissues. These changes apparently reinforce the barrier effect against larva penetration, without affecting tissue hardness. One other possibility is that silicon may strengthen the plant's natural defence mechanisms, whether chemical or physiological. However, those defence mechanisms have yet to be fully elucidated. Experiments are planned, notably with the University of Kwa-Zulu Natal, in South Africa, to study the role of silicon within the plant. The aim is to locate the silicon deposits in the stalk that are involved in the barrier effect and to determine the nature of that barrier.

These results suggest that it should eventually be possible to extend the use of this agrobiological control method to all sugarcane producers. The cane production areas of South Africa are particularly concerned: 60% of the region's soils are deficient in plant-available silicon, a deficiency that is sometimes compounded by a lack of water, which increases infestation levels. There are hopes of controlling the borer more effectively in the field by applying calcium silicate, including on susceptible varieties. Field trials are planned for 2007 and 2008, before extending the results to producers.

In South Africa, 60% of soils are deficient in silicon available to sugarcane
© R. Goebel/CIRAD

This research was awarded the Kynoch prize for the best contribution at the South African Sugar Technologists' Association Congress in Durban (South Africa) in July 2006.

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At-risk landscapes and tsetse fly behaviour: the bases for vector control strategies

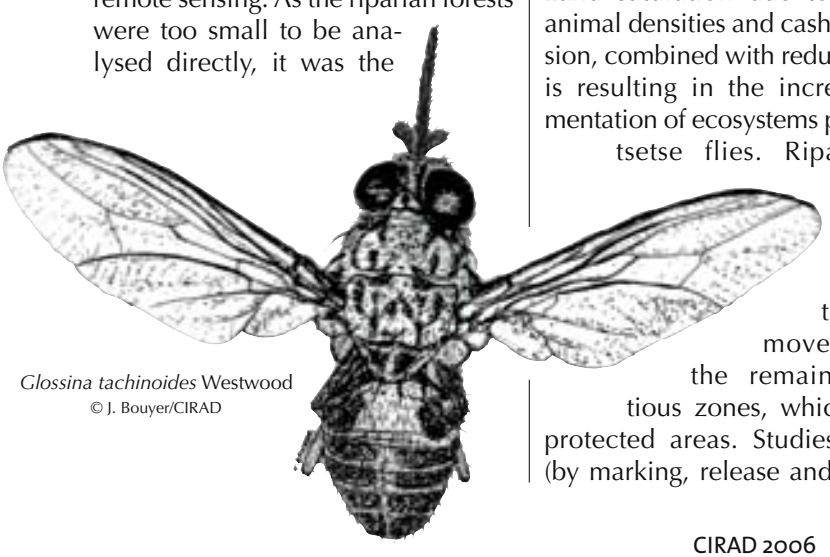
In sub-Saharan Africa, animal trypanosomoses transmitted by tsetse flies have considerable economic consequences for the animal production sector. To control these diseases, it is vital to understand the ecology of tsetse flies, and particularly the factors that affect their vectorial capacity. Studies are under way, primarily in Burkina Faso, to determine these factors.

In Burkina Faso, trypanosomoses are primarily transmitted by two tsetse fly species that live along streams and rivers: *Glossina palpalis gambiensis* and *G. tachinoides*. Studies of at-risk landscapes, and also of how the flies feed, are making it easier to target vector control strategies more effectively, on both a landscape and an animal scale, and to transfer a control technique used against ticks to tsetse flies.

Identifying at-risk landscapes

An initial series of studies concerned the relations between riparian plant ecotypes and tsetse fly densities in Mouhoun, a region in the Mid-West of the country. The landscapes along the river were analysed by spatial remote sensing. As the riparian forests were too small to be analysed directly, it was the surrounding pixels that were examined on images from the Landsat 7 TM satellite (30 m by 30 m pixels). These analyses pinpointed certain properties of the riparian belt, such as the degree of disturbance or the ecotype, by identifying clusters of similar neighbourhoods and comparing them with field surveys. The risk of cyclical trypanosome transmission was then estimated by calculating the entomological inoculation rate, which was equal to the relative density of the vectors multiplied by the percentage of infectious tsetse flies. This analysis served to locate trypanosome risk zones by considering these principal components of vectorial capacity over the whole of the Mouhoun loop, ie a 702-kilometre hydrographic network. It enabled the definition of three at-risk landscapes.

Land saturation due to increasing animal densities and cash crop extension, combined with reduced rainfall, is resulting in the increasing fragmentation of ecosystems propitious to tsetse flies. Riparian belts have thus become corridors enabling the flies to move between the remaining propitious zones, which surround protected areas. Studies of spread (by marking, release and recapture), population genetics and geometric morphometrics serve to quantify those movements and provide a clearer understanding of target population structure, their degree of isolation and their size.



Glossina tachinoides Westwood
© J. Bouyer/CIRAD

Such studies, prior to vector control operations, are intended for major control projects on a whole-population level (also called area-wide management), notably under the Pan-African Tsetse and Trypanosomiasis Eradication Campaign (PATTEC). They serve to confine operations, but also to set up barriers to isolate more vulnerable subunits that may be attacked in succession.

Trophic behaviour and vector control

A study of the vectors themselves, and particularly of how they feed, revealed two determining specificities for trypanosomosis epidemiology and control. Firstly, the existence of a learning period, which steers trophic preferences towards the first host encountered. This discovery casts doubt on current epidemiological models, which do not take account of this factor and consider the trophic preference of individuals—one of the components of vectorial capacity—to be constant. Secondly, it observed tropism, which prompts tsetse flies to attack the ends of the members

on cattle. This result has an immediate practical application: adapting an acaricide-insecticide foot bath in order to develop an integrated control strategy against both the tick *Amblyomma variegatum* and tsetse flies, which are the main vectors in the subhumid zones of West Africa. The technique is currently being practised in periurban zones of Burkina Faso, and demonstration foot baths are to be installed in neighbouring countries (Mali, Benin, Ghana, Chad, Cameroon, Central African Republic). Besides animal trypanosomoses, tsetse fly behaviour also has an impact on the epidemiology of sleeping sickness, and vector control centring on epicutaneous treatment of pigs has been organized in Guinea.

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Treating cattle using an acaricide-insecticide foot bath, in Burkina Faso © J. Bouyer/CIRAD

Partners

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A fruit and vegetable polyphenol composition table

Polyphenols, which are primarily found in fruit and vegetables, are the object of growing interest for their potential role in preventing certain diseases. However, there had never been a table giving the polyphenol compositions of foods eaten in France, until a vast project was launched to produce such a tool, to be used in future epidemiological studies.

Polyphenols have been the object of growing interest over the past decade or so, on the part of nutritionists, epidemiologists, agrifood firms and consumers. They have much better antioxidant properties than vitamins, and could play a role in preventing numerous degenerative diseases such as cancer and cardiovascular disease. However, there had never been an overall study of total polyphenol intake in the daily fruit and vegetable

diet in France. A vast project was thus launched in order to compile a polyphenol database and composition table.

Health benefits that are difficult to estimate

Researchers have only recently shown an interest in the health benefits of polyphenols. One of the major obstacles to studies is their significant structural diversity. Several thousand molecules have been identified in higher plants. Several hundred are found in the edible parts, which mostly contain one or more generally several phenolic molecules.

Moreover, the data currently available on food polyphenol composition are both sketchy and scattered. It was thus impossible for the researchers to estimate daily polyphenol consumption in France from dietary surveys.

The assumption that polyphenol consumption could reduce the risk of chronic disease has been looked at in several prospective studies, albeit only concerning consumption of certain types of flavonoids. While several studies have observed a beneficial effect on cardiovascular disease and cancer, others have failed to see any impact. However, it may be that the flavonols and flavones studied did not fully reflect the whole range of flavonoids consumed, much less the whole range of polyphenols. There were thus not enough data to draw any conclusions, hence the need for a composition table containing data on the total intake of polyphenols in the daily fruit and vegetable diet.

A better understanding of consumption

In all, 162 vegetable, 71 fruit and 85 tea samples were analysed for total polyphenol content. The results were added to a database that was subsequently used to establish a composition table for fresh foodstuffs, with a value for each product.

One of the first studies conducted using the table concerned daily polyphenol consumption in France, which was estimated based on existing data from the Secodip database on fruit and vegetable purchases by a panel of 2 000 households, and the Suvimax database on actual fruit and vegetable consumption in the country. The analysis revealed that the main fruit sources of polyphenols in the French diet are apples, strawberries and grapes, while the main vegetable sources are potatoes, lettuce and onions. Total polyphenol consumption from fruit is two to three times higher than from vegetables, while apples and potatoes combined account for almost half the polyphenols consumed in France.

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Potatoes, lettuce and onions are the main vegetable sources of polyphenols in the French diet © J. Weber/INRA

Preserving

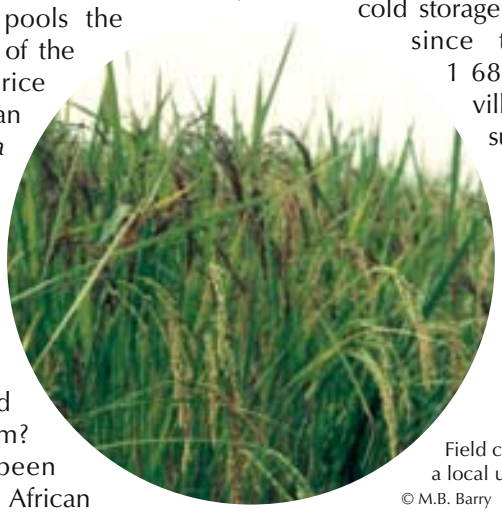
Local Guinean rice varieties: diversity, dynamics and preservation

The genetic diversity of crop species is often assumed to be threatened by pressure from human activities and the introduction of improved varieties. The results of a study of local rice varieties in Guinea seem to contradict this assumption.

Fewer crop species, fewer cultivated varieties per species, less diversity within each variety are three 'symptoms' of the erosion of biodiversity in crop fields. It is commonly assumed that the massive use of improved varieties instead of local varieties and anthropogenic pressure are the prime factors underlying this genetic degradation. Is this a cliché or reality? The only way to find out is to monitor changes in crop genetic resources. An assessment was thus carried out on local rice varieties in Guinea, a country that pools the genetic diversity of the two cultivated rice species, the African species *Oryza glaberrima* and the Asian species *O. sativa*. Are local rice varieties disappearing? What strategies should be implemented to preserve them? CIRAD has been working with its African partners since 2000 to come up with answers to these questions.

Stable or even slightly greater diversity

A molecular marker analysis was conducted to compare the genetic diversity of rice samples collected in six Guinean villages in 2003 with that in samples collected during a survey mission undertaken in 1980 in the same villages and kept in cold storage in Montpellier since then. Around 1 680 farms in 79 villages were also surveyed to draw up a national inventory of rice varieties grown by farmers between 1996 and 2001.



Field cropped with a local upland rice variety
© M.B. Barry

The survey results contradict the alarmist view that genetic erosion is under way. From 1980 to 2003, the number of available rice varieties and the genetic diversity remained stable, or even increased slightly. The number of varieties increased by 10% over the 1996-2001 period.

Diversity typical of subsistence farming conditions

The number of rice varieties ranged from 1 to 15 per farm and 4 to 40 per village, depending on the region, more than 80% of which were local varieties. With this extent of varietal diversity, villages were able to withstand changing agroecological conditions while fulfilling needs for a diverse range of rice uses. However, around 90% of the varieties inventoried were grown by only a few farmers, so there is a serious risk that they could disappear. Another important factor is that each local variety was found to be the sum of many pure lines and,

for a given variety, the proportion of these lines varied between farms. This multiline structure could be explained by the way farmers manage their rice varieties, ie frequent exchanges and replacement of varieties and seed, and cropping and seed production practices that promote genetic mixing and recombination.

Diversity can only be preserved in the field

In situ, on-farm conservation seems to be the only truly efficient way of preserving the diversity of local rice varieties, and this strategy is in line with agricultural development priorities. It would actually be impossible to sample all the lines that make up each local variety and maintain them ex situ in a cryobank, for instance. To organize this conservation, scientists studied rice diversity partitioning on several scales (region, village, farm, field) using different descriptors ranging from common names to molecular markers. The results showed that a single village may pool the equivalent of 70% of the regional diversity. A more in-depth analysis revealed that sometimes 50% of the genetic diversity of a village could be found on a single large farm. A small number of villages and farms could thus encompass the genetic diversity of an entire region such as Maritime Guinea. Genetic diversity patterns throughout the country could therefore be assessed on this basis.

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Agroforestry and coffee growing: enhanced sustainable production

How can a coffee crisis be overcome without necessarily boosting production? By enhancing production and focusing on quality. This is the main finding of CASCA, a large-scale project involving CIRAD in Central America. The results provide the scientific basis for improving coffee-based agroforestry system management, while promoting top-quality coffee and increasing producers' incomes.

Coffee has been the main export product in Central America for more than a hundred years. Coffee cropping provides income for around 300 000 producers. However, since 1999, the sector has been faced with a major crisis: coffee markets have collapsed as a result of overproduction worldwide, especially in Brazil and Vietnam. The CASCA* project was launched in this setting, with the aim of reducing producers' vulnerability to price volatility. The project was run by CIRAD and four partners, viz. CATIE, CEH, Promecafé and UNA. More than 25 scientists and 35 students were involved, including 25 Latin Americans, over a 5-year period.

Measuring photosynthesis on a coffee tree leaf
© P. Vaast/CIRAD

In this region, about 70% of coffee plantations are managed under

In agroforestry systems, production is lower but of better quality: coffee trees under *Gravilea robusta* © P. Vaast/CIRAD

shade trees at different degrees of intensification. However, the trend over the last 30 years has been to modernize coffee production: cropping practices have been intensified and shading has been reduced. To improve their incomes, farmers must now focus on the quality of their coffee, diversifying production and developing environmental services via agroforestry systems. Viable alternatives to intensive monocropping were therefore needed to promote sustainable management practices.

Over the five-year project period, data was collected from about 900 farms in three countries: Costa Rica, Guatemala and Nicaragua. Several avenues of research were explored, especially the effects of agroforestry systems on coffee cropping, the environmental impact of coffee production, and improving farm incomes.

Better quality coffee

Coffee growers generally know what forest species to intercrop with their coffee trees to provide shade, but these species are often poorly managed: the tree density is seldom adapted to the shading required for good vegetative growth and coffee tree production, and fertilizer applications do not always meet the joint needs of the coffee crop and the shade trees. Scientists have thus designed models that will help farmers determine the most suitable shade tree species and densities according to the lighting requirements of the coffee crop. They also assessed the impact of shading on the physiology and quality of coffee, especially on photosynthesis, carbon allocation between production and vegetative development, flowering and fruit load. Shading, like highland growing conditions, provides a microenvironment that is ideal for coffee berry growth. It delays pulp ripening, thus increasing bean size and enhancing beverage quality. Yields are lower but more stable between years and the coffee of better quality.

A tradeoff between production and protecting the environment

Coffee plantations cover an area of a million hectares in Central America and have a major environmental impact. These plantations are often located in very fragile mountain ecosystems in the Mesoamerican Biological Corridor, where biodiversity is particularly high. Studies were conducted to quantify this impact by assessing the effects of shade trees and their management on soil fertility and the amount of nitrogen available for coffee crops. Scientists identified fertilization practices that fulfilled cropping needs while not upsetting ecological balances. The results showed that by reducing fertilizer requirements, agroforestry systems help reduce nitrate loss through leaching, and therefore groundwater contamination. Moreover, growing shade trees within coffee plantations increases carbon levels in the biomass, surface litter and soil, thus increasing carbon sequestration.

Diversified income sources

The scientists looked finally at farmers' incomes. The aim was to simulate the impacts of several cropping scenarios and their effects on coffee production costs and on the economic sustainability of farms. The simulations revealed that timber and firewood are major income sources, especially in lowland regions: wood accounts for 30-50% of coffee growers' income in Costa Rica and Guatemala. This revenue could be increased further if farmers were to obtain certification and labels for the coffee they produce (sustainable, organic coffee, etc). However, modifying practices to comply with technical standards and the certification process generates additional expenditures.

A new project called CAFNET** has just been launched to obtain more in-depth results. It concerns Central America, East Africa and India and is aimed at promoting coffee-based agroforestry systems for the goods and environmental services they provide. The project should help coffee growers' cooperatives improve their organizational and marketing

capacities and adapt crop management sequences so as to qualify for coffee certification, a process that has multiplied in recent years.

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* CASCA (Sustainability of Coffee Agroforestry Systems in Central America: coffee quality and environmental impacts).

** CAFNET (Connecting, enhancing and sustaining environmental services and market values of coffee agroforestry in Central America, East Africa and India).

Website

http://www.casca-project.com

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Invasive plants: threatening biodiversity in Réunion

Biological invasions represent a substantial threat to biodiversity in island environments. In Réunion, where there is an especially high level of endemic flora, it is essential to protect natural plant communities against introduced plants that have become invasive. Since the 1990s, CIRAD has been analysing the mechanisms by which these plants propagate, their impact and ways of controlling them. The goal is to provide environmental managers with efficient ways to deal with these exotic invaders.

In Réunion, the rate of introduction of new plants has been increasing at an incredible pace over the last 30 years. Around a hundred plants have become invasive and are threatening natural plant communities. In addition to chemical, mechanical and soon biological control measures, it is crucial to intervene prior to invasions in order to prevent the introduction of potentially invasive species or to regulate the spread of plants already present on the island.

Acting before infestation

Analyses conducted under the EU POSEIDOM* programme led to the identification of around fifty potentially invasive plants, which are to be banned to avoid introductions into the French overseas departments. Thirty-four of the ornamental species grown on the upper slopes of Réunion are highly invasive. It is essential to deal with these plants as early as possible considering their incredible spreading potential.

The Étang du Gol, which was completely covered by a mixture of water hyacinths (*Eichhornia crassipes*) and water lettuce (*Pistia stratiotes*) in early 2006, is a particularly eloquent example. In March 2006, hurricane Diwa cleared almost 99% of the lagoon by flushing it out and washing all of its aquatic flora into the ocean, but eight months later it was again totally overrun with invasive plants, to the detriment of the entire aquatic ecosystem. These aquatic plants are estimated to produce some 250 tonnes of biomass per hectare every fortnight, thus ruling out the possibility of mechanical control. Such situations should be dealt with by biological measures, which have already proved their efficacy in many tropical countries.

Integrating all landscape compartments

It is also vital to take account of the movement of species between the

Recolonization of the Étang du Gol by invasive aquatic plants

From top to bottom: three weeks prior to hurricane Diwa, one month and eight months after the hurricane

© T. Le Bourgeois/CIRAD

different landscape compartments, ie forests, grasslands, cropland and inhabited areas. For instance, grasslands, which contain a high proportion of exotic species (80%), can play a major role in plant flows between landscape units, depending on how well they are managed. Grazing herbivorous livestock in sensitive areas like the upper slopes can be an interesting environmental management strategy. In addition to its socioeconomic functions, this activity ensures that the landscape remains open and attractive while controlling invasive plant species.

Recent work carried out under the PASTOFOR** rangeland management project highlighted that productive well-kept grasslands help maintain biodiversity in surrounding natural environments by limiting the spread of invasive species. Otherwise, grasslands in which weeds are not sufficiently controlled are a threat to neighbouring natural environments. The interfaces between different environments considerably facilitate the circulation and development of invasive species: rational joint management of natural environments and rural areas is the only way of keeping them under control.

Accounting for all propagation mechanisms

Classifying invasive plants according to their ecological impact and ability to colonize new areas has facilitated the task of defining the operational priorities effectively. It is also, however, necessary to gain further insight into how these species spread in different ecological settings and environmental management conditions. For instance, the false pepper tree (*Schinus terebenthifolius*) grows from seed in humid environments and from suckers under dry conditions. Similarly, the giant bramble (*Rubus alceifolius*) bears fruit in lowland areas but only propagates vegetatively at elevations above 1 000 m.

On the basis of these overall results, it is now possible to take efficient measures to control invasive plants that threaten the island's biodiversity. All possible strategies should be combined, including preventing introductions, conducting control treatments and restoring degraded environments.

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* POSEIDOM (Programme on options specific to the remote and insular nature of French overseas departments).

** PASTOFOR (Management of pastoralism on the fringes of highly protected natural environments).

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Prospects for irrigated farming in the Mediterranean region

Water is a rare, saline, irregularly distributed and coveted commodity in Mediterranean countries, and a major concern for the agricultural sector in this region. A seminar organized within the framework of the EU WADEMED project enabled an assessment of the current status of irrigated agriculture in North Africa, while exploring new forms of cooperation.

In North African and European countries, modernization of family farming was substantially stepped up during the second half of the 20th century. This is particularly true of irrigated agriculture. Farmers north of the Mediterranean were able to boost their yields while reducing production costs and obtaining better quality products, mainly through a reorganization of the farming profession. In North Africa, new forms of professional organization are emerging, some of which are government-backed while others have been prompted by local initiatives.

Since 1995, CIRAD has been participating in a regional cooperation initiative involving scientists, water management administrators and agricultural professionals (commodity cooperatives, water management associations, etc). During a seminar held in Cahors (France) within the framework of the EU WADEMED project, current trends in the irrigated agricultural sector in North Africa were analysed, especially from the standpoint of institutional reforms and professional organizations. It mustered North African and French farmers, scientists, heads of institutions and agricultural organizations and commercial stakeholders: discussions thus focused on existing problems and ongoing initiatives to address those problems, and a consensus agreement was reached by the end of the seminar.

Strengthening the organization of the farming profession

With social change and trade globalization, North African countries need to boost their agricultural performance in a context of a redefinition of government support. Irrigation is the key to achieving this goal. But how can the performance of this agriculture be reconciled with the social imperatives of small-scale family farming, which prevails in irrigated areas? The involvement of the farming profession in building strong institutions is crucial.

The analyses revealed that farmers' cooperatives and associations in Tunisia, Algeria and Morocco participate in subsector organization and providing social services in rural areas: road development, setting up local health clinics, creation of nursery schools and training of farmers' children. These professional agricultural organizations help farmers to corner a greater share of the profits. They offer support to farmholdings to improve technical and economic performance and help manage the hydraulic infrastructure, while also providing clout in negotiations with market stakeholders, public and local authorities.

With market liberalization and the redefinition of government support, the future of irrigated family farming depends on the recognition and strengthening of these professional agricultural organizations via partnerships between the public, private and professional sectors. This is now essential for rural development, for linking farmers with national and international markets and for efficient water management.

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The Mitidja plain, on the outskirts of Algiers, supplies the capital with peppers and others vegetables. Glasshouse cropping is booming in Algeria
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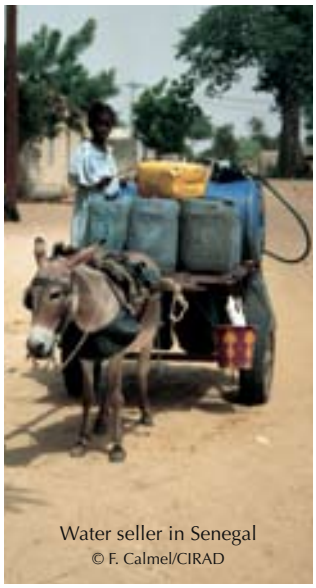
Website

www.wademed.net

Water governance

Sustainable management of water resources is a key to alleviating poverty and ensuring food security, yet efficient water governance has proved difficult to achieve in practice. The book *Water governance for sustainable development* reviews recent changes in governance, institutions, economics and water policies, with special emphasis on South African case studies. It examines how these elements have shifted from quantitative, supply-driven, centrally controlled management to more demand-sensitive, decentralized and participatory approaches. The case studies highlight the problems encountered in implementing new policies, often linked with cost recovery, between-sector water resource allocation, management and privatization of water services.



Water seller in Senegal
© F. Calmel/CIRAD

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For further information

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Pig farming in the Red River Delta

The Red River Delta is a broad region of intensive agriculture in Vietnam. Livestock production is expanding at a dramatic pace, with pig farming representing a key factor for economic development. Pig rearing leads to a risk of water and soil pollution, which can in turn be detrimental to human health. How can the environmental impact of pig farming be managed while not undermining the competitivity of the pig farms? How can the spatial and societal constraints of this type of livestock production be allowed for in development policies?

The Red River Delta region has a population of 18 million people, with densities exceeding a record 1 200 inhabitants per square kilometre, while hosting many activities that are essential to the northern Vietnamese economy. The high industrial, agricultural and population growth rates are now seriously straining natural resources. Livestock production is growing dramatically in most provinces in this region to fuel the economy, with pig farming at the forefront of this development. In Thai Binh province, production increased from 700 000 pigs in 2000 to 1.2 million in 2006 in response to high domestic and world demand for pork. Agricultural services in Thai Binh are managing a national programme for the development of lean pork

production. The aim is to support 1 600 pig farms and 16 400 family farms in the province so as to be able to produce 1.4 million pigs by 2010, and 500 000 tonnes of top quality carcass meat a year.

Better pig farm waste management

In this setting, a large-scale EU-funded project (E3P) was launched to promote the development of pig farming, waste management and environmental protection. This project was undertaken within the framework of the PRISE consortium (research on livestock production systems), in collaboration with seven Asian and European organizations. It resulted in a multidisciplinary assessment of the livestock production and waste management situation in Thai Binh province, along with the development of a highly documented local database on the topic.

This assessment was based on a set of analyses and surveys carried out under the project: collecting local agricultural statistical data, classifying pig farming units, assessing their environmental impact, and conducting a survey of stakeholders' viewpoints. A geographical information system (GIS) and an agricultural assessment tool were developed. The GIS is used to present actual or simulated regional organic matter balances, in the form of thematic maps, according to development scenarios predicted for 2010. The assessment tool is used to evaluate surplus fertilizer elements derived from livestock waste on different scales, fertilizer needs for crop fields, and nutrient requirements in fish-farming ponds. Environment-friendly waste processing and management procedures were developed on the basis of these results. The use of modelling to combine the agricultural assessment tool and the GIS is one of the unique features of the work undertaken in this project.

Pens cleaned daily on a pig farm © V. Porphyre/CIRAD

Tailored waste treatment systems

The project findings triggered demand from development stakeholders. The Thai Binh popular committee would now like to build waste treatment systems tailored to the size of farms. A project will be launched in 2007 to focus on agricultural standards to enhance organic matter use and on conditions required to meet the needs of processed (energy, compost) and recycled (agriculture, aquaculture) organic matter subsectors. It will also concern modelling of regional nutrient and biomass flows, along with a scientific support component to assist the Vietnamese partners in dealing with any issues concerning interactions between pig farming and the environment.

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Website

http://pigtrop.cirad.fr/en/worldwide/asie_VN_Asiaproeco.htm

Safeguarding endangered animal species in Vietnam

In the mountains of Vietnam, traditional livestock species and wild bovids have long been isolated. They are now threatened by the opening up of these regions, so a large-scale multidisciplinary study is being devoted to them. This should give rise to new strategies to promote and preserve these species while enhancing living conditions for rural communities, especially herdswomen, in these deprived regions.

Mountainous areas of Vietnam were isolated for several decades for geographical and historical reasons, and the wild and domestic animals found there were preserved. Under the BIODIVA* project, and in partnership with Vietnamese research organizations, CIRAD has been conducting several operations since 2004 to inventory, analyse and safeguard these now threatened animal genetic resources. These multidisciplinary operations combine field activities and a more fundamental genetic analysis approach.

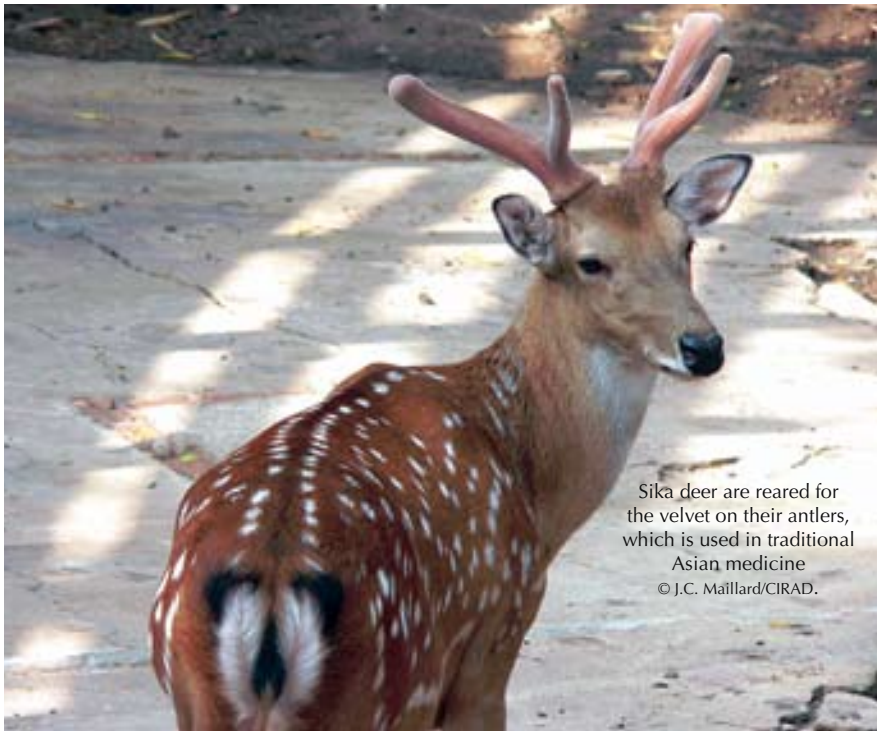
Inventories were carried out and 2 000 questionnaires processed to assess the biodiversity of endemic domestic animal species. The aim was to define the zootechnical traits of the animals along with the socioeconomic features of traditional livestock production systems. Molecular tools were used for the genetic analysis of 7 000 georeferenced biological samples from livestock collected during the inventory surveys. The data were analysed using a software program designed specifically for thematic mapping of animal populations.

Vietnamese sika deer now only found in captivity

Vietnamese sika deer (*Cervus nippon pseudaxis*) are very economically and traditionally important as the velvet from their antlers is used in traditional Asian medicine. This subspecies is now only found in captivity, and there is a substantial risk of genetic drift due to inbreeding and interspecific crossing. Data on Vietnamese sika deer growth and feeding patterns, etc, were collected and analysed using software designed specifically for deer management. These data will be used to draw up a management strategy adapted to Vietnamese sika deer rearing. Village workshops were also held to train more than a thousand farmers in good practice and rearing techniques.

Reproductive cloning to save large wild bovids from extinction

A dual conservation approach has been adopted to manage remaining populations of large wild bovids. It is hoped that somatic cloning in the laboratory will be effective for preserving two endangered species, the saola (*Pseudoryx nghetinhensis*) and gaur (*Bos gaurus*). Successful results have been obtained through in vivo reproductive cloning of the saola in bovids, and numerous embryos have been obtained. Preimplantation



Sika deer are reared for the velvet on their antlers, which is used in traditional Asian medicine
© J.C. Maillard/CIRAD.

tests must now be carried out in different potential recipient species. However, trials conducted by INRA have already shown that the embryos develop normally for up to 20 days after implantation in a bovid uterus. This promising approach could be extended to other endangered bovid species such as the gaur.

The in situ approach is focused on the gaur (*Bos gaurus*), the banteng (*Bos javanicus*) and the wild water buffalo (*Bubalus arnee*), which are highly threatened in Vietnam. The aim is to draw up appropriate management plans to ensure effective conservation of these species. It is thus necessary to quantify the number of animals left in the remaining herds. Here again molecular tools are used: more conventional approaches are not possible because of the very low number of animals involved. Non-invasive DNA samples from faeces are being collected in the field for subsequent analysis. Individual genetic markers are then used to assess demographic traits in these populations. Modelling and analysis of their viability should highlight the demographic risk factors and the most effective way of boosting population numbers.

A regionwide conservation strategy

Local pilot projects aimed at preserving and promoting this animal diversity are also under way. Six microprojects have already been planned concerning animal populations of interest for various reasons: productivity, prolificacy, adaptation to specific environments, resistance to certain diseases, reduced populations, etc. Another microproject concerns the development of Vietnamese sika deer farming in Nghe An and Ha Tinh provinces, with the installation of a pilot byproduct production, packing and marketing unit (velvet, meat, etc). These microprojects are due to be launched in 2007.

These results are crucial for the entire region. Two other countries in the Indochinese Peninsula, Laos and Cambodia, whose animal biodiversity must also be inventoried and preserved, are to be associated with this initiative.

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* BIODIVA (Conservation and promotion of endemic domesticated and wild animal biodiversity in mountainous areas of Vietnam)

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Among other things, the BIODIVA project should serve to safeguard and promote local domestic races: Tay goatherd and her herd of goats in the mountains, Ha Giang Province © J.C. Maillard/CIRAD

Sharing

KASSA, new research issues concerning conservation agriculture

Conservation agriculture relies on the simultaneous use of three principles: reducing, if not abandoning, soil tillage, keeping the soil covered and rotating crops. It is intended to produce better while conserving natural resources. Between 2004 and 2006, the KASSA project coordinated by CIRAD took stock of the available scientific knowledge on the topic, in Europe, North Africa, Asia and Latin America.

In 1990, fewer than 10 million hectares were being cultivated worldwide according to the principles of conservation agriculture. The area now totals more than 95 million hectares, of which 44% are in Argentina, Bolivia and Brazil. In India and Pakistan, the area cultivated in this way jumped from 400 000 hectares in 1998 to 2.2 million in 2005. Systems inspired by conservation agriculture are being developed in Estonia, the Czech Republic, Ukraine and the Maghreb. However, while conservation agriculture enables farmers to save on energy, machinery and labour, it has a variable impact on yields and its implementation is largely dependent on the local natural, socioeconomic and cultural context. The KASSA* project, which involved scientists from 22 institutions, 5 non-governmental organizations and a private enterprise, in 18 countries worldwide, provided a clearer idea of its merits and limitations.

Direct seeding of beans on a wheat straw cover
© M. Raunet/CIRAD

Strong but inconsistent progress

More and more farmers in a growing number of countries are adopting conservation agriculture. This trend has been marked in the major producing and exporting countries of South and North America and in Australia. Europe, however, is lagging behind. What are the reasons for this disparity? There are various constraints that may discourage farmers from embarking upon conservation agriculture or, at the very least, mean that they only adopt part of the technology. Certain types of soils (those that are susceptible to compaction, wet, etc) or climates (very humid, cold or arid) do not lend themselves to the practice. Permanent soil cover and crop rotation in particular are supposed to protect the soil against erosion and control weeds, pests and diseases, but they mean increased costs for farmers: crops grown in rotation do not always find market outlets, soil cover fosters pest and disease development in some

cases, hence the sometimes intensive use of pesticides, and suitable plants and varieties are still in short supply. Moreover, in systems that are already highly productive, such as in Europe, introducing conservation agriculture does not significantly modify yields, and its only advantage is the reduction in production costs. Lastly, the lack of knowledge, suitable machinery and innovation systems that would make it possible for the various players to both acquire and share knowledge and know-how is a major handicap.

Topics for further study

It is thus still necessary to develop and improve the technology and adapt it to the various favourable situations. Moreover, numerous research topics also require further study, such as the impact of such techniques on soil biological, structural and chemical functioning, the carbon and nitrogen balance and soil fertility in general. It is also important to ascertain the consequences of the pollutants, heavy metals and pesticides used for biodiversity and for soil, water and food chain quality, and the social and economic repercussions of the practice. More generally, while the short-term benefits are sufficiently clear for conservation agriculture to have found its rightful place now, there are still many questions concerning its positive or negative impact in the longer term.

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Website

http://kassa.cirad.fr

Biological approaches to soil systems

Direct seeding on an oat straw cover in Brazil © R. Pirot/CIRAD

Several CIRAD agronomists were involved in preparing and writing the book *Biological approaches to sustainable soil systems,* a compilation of the experiences of 102 researchers from 28 countries in innovative conservation agriculture systems and their implications for soil biology. The book includes five chapters on the results obtained by CIRAD and its partners in Madagascar, Brazil, Vietnam and Gabon, on direct seeding systems with permanent crop cover and on the principles behind these systems, which are based on understanding how soils function and fostering biological activity.

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For further information

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Training in the impact of organic matter management

In both industrialized and developing countries, there is growing interest in recycling organic matter in farming. How can we assess the agricultural and environmental impact of this practice? CIRAD and its partners have developed indicators suited to tropical areas and reliable, easy-to-use simulation models. To disseminate them, it has also established a training course for students from developing countries, with the possibility of modifying both the content and site of the course.

CIRAD has recently established a training course in the agricultural and environmental impact of organic matter management. The aim is to take stock of the ways of using organic matter depending on the situation—urban or rural areas, industrial zones, intensive animal production or organic farming zones—and examine the advantages and ecological risks—water quality, pollutant transfers, changes in the soil, greenhouse gases and carbon sequestration, and the mineral load of certain types of effluent. The course also covers measurement methods for use in the field and the laboratory (organic matter, water, soils, plants, gases) and indicators for determining the status of and forecasting the changes in the organic matter used. Its originality lies in the fact that it takes account of the specificities of developing countries (the logistical, ecological and regulatory aspects), and also in the analysis and measurement methods proposed, which are tailored to the limited technological capacities of such countries.

The course is intended for researchers, engineers, agricultural and environmental technicians and, more generally, anyone involved in agricultural or agroindustrial development or conservation. It alternates talks, supervised study and field trips, and encourages participants and tutors to discuss their experiences.

Training for researchers, engineers and technicians working in agriculture and the environment © R. Oliver/CIRAD

A pilot session was held in Montpellier in October 2006, with contributors from CIRAD, INRA and IRD. The participants came from New Caledonia, Senegal, Mali, Madagascar, Cameroon and Burkina Faso. The session served to define a framework for the training course. For instance, the participants stressed the need for talks, on a local level, between the various players involved in organic matter management, and the importance of training tutors and of integrating this type of course into the higher education sector. Lastly, they determined two levels, depending on the target audience: a scientific course for tutors, centring on specific topics (agricultural production chains, periurban agriculture, animal production, etc), and technical tools; and another, more general course for decision-makers, looking at the role of agriculture, energy requirements, environmental risks, legislation and applying research results for development.

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For further information

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Observatories, backing up collective action

Information is a key element in an ever-changing agricultural world. Shared, reliable, up-to-date information is vital in coordinating activities, implementing collective operations and more generally managing rural territories. Observatories are a means of structuring and compiling that information. CIRAD has recently tested a new approach in France for building such observatories.

The future of agriculture, its economic viability, its integration into a fragile environment and its relations with civil society are now vital issues for every stakeholder in the rural world, in both industrialized and developing countries. Reliable, rationalized information is indispensable in responding to these issues and adapting to future change.

However, from one situation to another, the information available may be comprehensive, sketchy, scattered, incomplete or poorly structured; in any event, it will at least need reformatting. A new way of structuring, sharing and disseminating information has recently been developed: observatories. What are the conditions, methods and resources required for setting up observatories? How can they be made operational? Through a series of case studies in France, CIRAD has recently tested and validated an innovative approach for establishing strategic observatories.

Why observatories?

Observatories make it easier to understand and manage the relations between agriculture and territory. They provide an opportunity for players to explain, both individually and collectively, how they see their territory, and to construct representations of it.

Haymaking on the Millevaches Plateau:
emergence of new practices and new cultivated systems © Y. Clouet/CIRAD

The approach centres on the belief that through a process of discussion and negotiation, players can work together to define the directions to take and the resources required. The data collected and disseminated by observatories improve and "objectivize" the information used and thus support the decisions and negotiations required for collective action.

To assess the feasibility of such an approach, a method was developed and tested in two zones: the Aume-Couture basin in Charente, where the central issue was water quantitative management, and the Hien Valley, in Isère, where the issues were biodiversity and water quality. At each site, a territory was defined around a collective operation centring on a specific issue. Rural stakeholder groups were set up to build an observatory, laying the foundations for an information system.

An approach based on consultation

The approach comprises five stages. The first is to characterize practices within the various production systems in the territory, before analysing players' requirements in order to determine the structure of the observatory: type of information to be gathered, processing procedures, and modes of dissemination to players. The next step is to define the priority issues and choose the levels

of observation and the links between them, so as to build the information system. Lastly, it is important to assess how the observatory fits in with existing organizations and its impact on negotiating processes.

The feasibility study concluded that the approach was relevant, highlighting the extent to which players were involved and the importance of formalizing how the different players expressed their objectives and points of view. There are plans to introduce the method in other situations in both industrialized and developing countries, and to extend its use.

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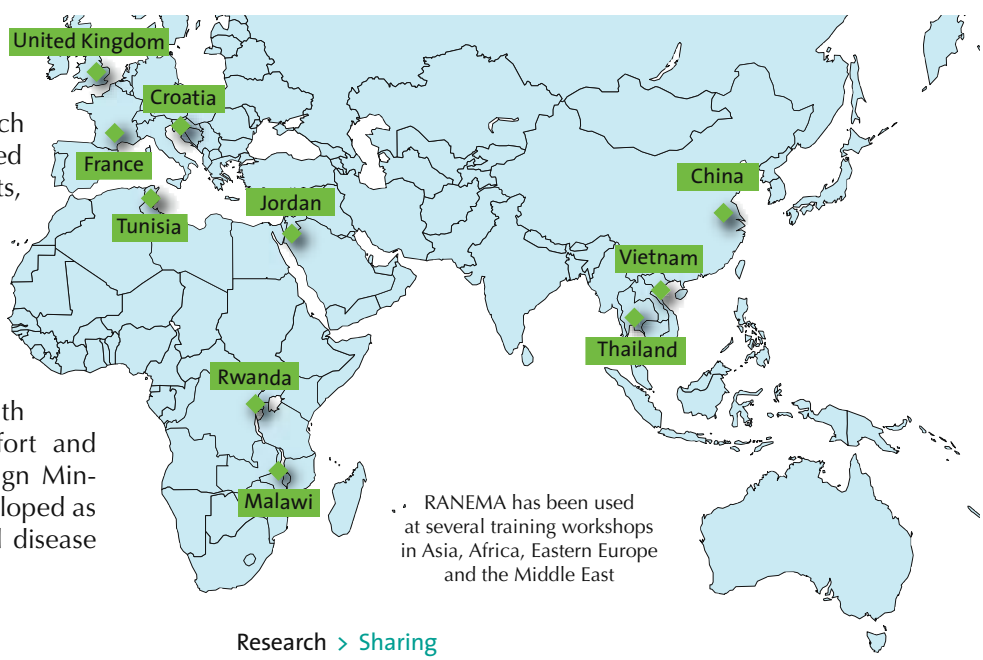
RANEMA, a computer-assisted learning tool in epidemiology

E-learning is a response to cuts in study and training grants. Moreover, it enables the building of partnerships with establishments in developing countries. A training module of this type, a refresher course in animal disease epidemiology (RANEMA), has been developed, based on simulation activities. It can be used either alone, for e-learning, or as part of a traditional training course.

E-learning is growing in importance. It is a response to the constraints now facing traditional training, such as cuts in the funding allocated for study and training grants, but also offers new possibilities for building partnerships with establishments in developing countries. A computer-assisted learning (CAL) tool, RANEMA, designed in partnership with the Ecole vétérinaire d'Alfort and funded by the French Foreign Ministry, has recently been developed as a refresher course in animal disease epidemiology.



RANEMA has been used at several training workshops in Asia, Africa, Eastern Europe and the Middle East

Interactive and recreational training

The module is largely based on an applied veterinary epidemiology handbook, *Epidémiologie appliquée à la lutte contre les maladies animales transmissibles majeures,* by B. Toma *et al.* (1999). It centres on simulation activities aimed at stimulating and encouraging students. The central scenario is simple: the student is a veterinary surgeon working for the veterinary services in a virtual country, Ranema; to do his job correctly, he needs to refresh his knowledge of epidemiology through a range of activities. The module may be offered alone, for e-learning, or as part of a traditional training course, hence reducing the amount of theoretical training required. It is a new, interactive and recreational way of acquiring basic epidemiology skills.

In 2005 and 2006, the RANEMA module was used at several training workshops on bird flu, organized by the FAO in Asia, Africa, Eastern Europe and the Middle East, and by the OIE, in Southeast Asia. It is now available in two languages (English and French) and different versions (teaching packs for use in part-face-to-face training). It can be used via a platform for e-learning. Work is continuing to develop new modules on more specific aspects and on other language versions. Moves are also being made to train tutors, assess the impact of the training course and simulate how an epidemiological surveillance network operates, by applying multi-agent models.

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Growing crops in town: a response to urbanization

Urban agriculture plays a vital socioeconomic role, particularly for the most underprivileged. Projects in Africa and Asia are trying to ensure that this type of activity is recognized and to reconcile the conflicting interests of the different players involved in its development.

By 2025, half the population in Asia and Africa will be living in towns. This urban population explosion sets stiff challenges for the towns concerned: growing food requirements, increasing waste and effluent generation, and rising poverty rates.

Muea market, Cameroon
© L. Parrot/CIRAD

Urban and periurban agriculture can help solve these food and ecological problems.

According to the FAO, in 2005, this type of agriculture supplied food for almost 700 million urban dwellers, in other words a quarter of the world's urban population. It supplies markets with a range of products, creates jobs, and makes towns greener. However, urban agriculture is under many threats, notably competition for land between agricultural, resi-

dential and industrial uses, and the use of imports to satisfy demand from supermarkets.

Raising awareness of the issues of urban agriculture

It is important that local and national public bodies, private urban development players and the agricultural sector realize the issues involved in this type of farming. The aim is to reconcile the different stakeholders and their often conflicting interests. To this end, CIRAD and its partners have launched two projects—one (SUSPER*) on developing periurban agriculture in Southeast Asia, in Cambodia, Laos and Vietnam, and the other (supermarket component of M4P**) on supermarkets and the poor, in Vietnam—and organized a workshop on promoting urban and periurban agriculture in West and Central Africa, in late 2005, in Yaounde, Cameroon.

Generally speaking, this research has shown that to ensure sustainable urban agricultural activity, the various stakeholders, particularly town councils, need to realize the functions of this type of agriculture. It is also vital to ensure that the authorities recognize producers and producers' groups.

The Yaounde workshop enabled a discussion of experiences in Africa. In Benin, talks between the government and the Cotonou communal producers' union have resulted in the allocation of 400 hectares to market gardeners. In Uganda, the Mayor of Kampala passed by-laws in 2005 to allow urban dwellers to cultivate land and rear animals within the city. These various experiences prompted the Cameroonian farmers at the workshop to set up a coalition for the promotion of urban and periurban agriculture in Africa, with the support of researchers.

Vegetable growing on the fringes of Hanoi, Vietnam © P. Moustier/CIRAD

The coalition is intended to foster dialogue between farmers and town councils.

Technical solutions for commercial production

It is also necessary to improve the skills of the private- and public-sector staff involved in this sector, so as to ensure sustainable food supplies. The SUSPER project has enabled four Asian cities (Hanoi, Ho Chi Minh City, Phnom Penh and Vientian) to respond better to local demand for vegetables and make the switch to commercial production. Technical solutions have been found in order to satisfy market demand and boost farmers' incomes, such as out-of-season production. New vegetable sanitary quality certification systems have been tested, and an economical daily price information gathering and dissemination system has been developed to facilitate talks between producers and traders.

In Vietnam, the M4P project has enabled an assessment of the impact of supermarket development on poor populations, seen as both consumers and traders. Supermarkets account for less than 5% of food distribution, but they are expanding at a rate of more than 15% per year. This is having many adverse consequences for poor consumers: they have limited access to supermarkets due to their higher prices and to transport constraints, and cannot find work in the sector, which offers many fewer jobs than traditional markets or street sales. Moreover, poor producers cannot supply supermarkets due to the demands they make in terms of consistency and quality and of the time they take to pay. However, certain producers' organizations allow small-scale producers to develop the taste and sanitary quality of their products and reward that quality with a seal of approval, hence enabling such producers to gain a foothold in the sector, ensuring higher, more stable incomes than traditional supply chains.

The increasing urbanization of agriculture means that the agricultural sector needs to be more professional and to look more closely at the requirements of urban inhabitants. It is increasingly necessary to raise awareness among urban authorities, for social, sanitary and land management reasons.

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Open access to scientific knowledge

In 2006, CIRAD signed an agreement with the French universities, "grandes écoles" and research organizations, covering the establishment of a joint national platform to make scientific documents available online. This was an unprecedented step towards easier access to information, from which the entire scientific community stands to benefit.

CIRAD has joined the worldwide drive to open up documentary archives by signing the Berlin declaration on open access to knowledge and a national draft agreement for the establishment of a joint platform to make scientific documents available online. In addition to CIRAD, all the French universities and "grandes écoles", through their Conference, and seven research organizations—CEMAGREF, CNRS, INRA, INRIA, INSERM, the Institut Pasteur and IRD—are involved in this national initiative, aimed at ensuring easier access to scientific information.

A joint open archive for French organizations

Alongside scientific journals, the Internet has provided a means of direct communication between researchers. French organizations keen to establish such a means of disseminating and promoting their researchers' scientific results have opted to launch a joint platform for depositing those results. The instrument, which is linked to other open archives worldwide, satisfies the criteria for open access. It uses HAL (*hyperarticle en ligne*), a software tool developed by the CNRS Direct Scientific Communication Centre.

The open archives principle was inspired by this new form of scientific communication between researchers, which is called direct because it is the author who is in charge of providing open, free-of-charge access to his or her publication. An open archive allows authors to make their work known quickly and their parent organizations to improve their image by offering universal, free-of-charge access to the publications deposited. Moreover, publications deposited this way are automatically open to peer review, which may prompt authors to produce and post updated versions of their publication.

International visibility for scientific results

CIRAD researchers can now deposit their publications on the HAL platform and link them to their research unit. A set of references corresponding to the main scientific fields covered by HAL means that authors can also link their publications to a research topic or topics. The self-archived text can be accessed freely and free-of-charge via the Internet within 24 hours. In addition to the HAL interface and those of open archive harvesters, the communication protocol on which HAL is based enables users to search and visualize content via conventional search engines. Any publication deposited has a permanent Internet address and a guarantee of its storage.

A CIRAD-specific interface for consulting the HAL open archive enables users to view on line all the references and scientific documents deposited by CIRAD researchers or research teams involving CIRAD on the Internet. By the end of 2006, 233 scientific documents concerning CIRAD had been deposited.

These institutional archives, along with new publication and dissemination tools such as open-access e-theses and e-newsletters, facilitate access to researchers' results by ensuring that they can be consulted free of charge on line. This is a novel communication facility that should benefit the entire scientific community, in both North and South.

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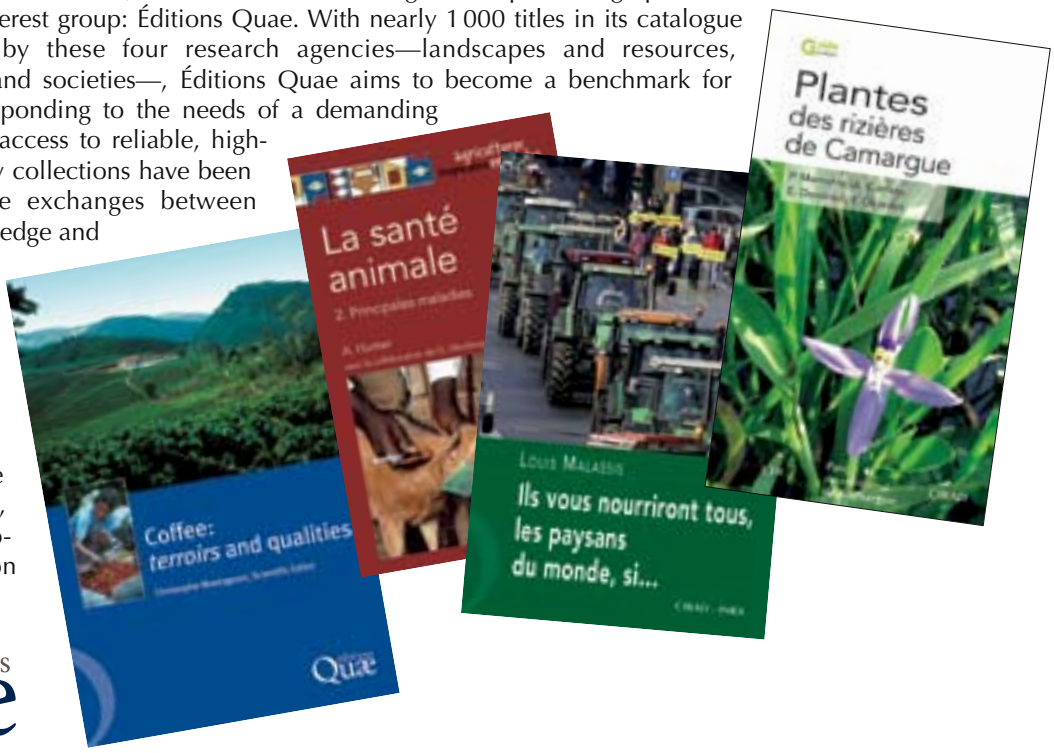
Éditions Quæ, CIRAD's new publishing house

On 1 July 2006, CIRAD, CEMAGREF, IFREMER and INRA merged their publishing operations to form an economic interest group: Éditions Quae. With nearly 1 000 titles in its catalogue in the fields covered by these four research agencies—landscapes and resources, the environment, food and societies—, Éditions Quae aims to become a benchmark for scientific publishing, responding to the needs of a demanding readership who require access to reliable, high-quality information. New collections have been launched, to encourage exchanges between scientists, transmit knowledge and know-how, contribute to public debate and make research results universally available. The catalogue, collections, and services to authors and booksellers can all be accessed via the www.quae.com website, the Éditions Quae promotion and distribution facility.



éditions Quæ

Innovating

A universal early diagnostic test for anthurium bacterial blight

Anthuriums are grown in Réunion for their beautiful heart-shaped, deep-coloured flowers. However, a bacterium has been threatening anthurium production since 1997. A sensitive, reliable and quick molecular tool is now available to detect this bacterium.

The first symptoms of bacterial blight in anthurium are watersoaked leaf spots that turn yellow and necrotic. The infection can rapidly become systemic and kill the plant. This infectious disease, caused by the bacterium *Xanthomonas axonopodis* pv. *dieffenbachiae*, almost entirely wiped out the anthurium industry in the West Indies in the 1980s. The bacterium was accidentally introduced into Réunion in 1997 through contaminated plants from the Netherlands. An eradication campaign was launched, with the destruction of all plants in infected nurseries and a ban on sales. Anthuriums could then only be imported as micropropagated plantlets, with an 18-month quarantine period. CIRAD launched a research programme in conjunction with the Réunion Plant Protection Service and stakeholders in this sector. The aim was to find more effective ways of inspecting imported plants.

Anthurium with severe bacterial blight symptoms, grown in a shaded nursery
© I. Robène-Soustrade/CIRAD

A specific and sensitive detection tool

This tool was developed in two stages. The first aim was to build a collection that was representative of the global genetic and pathogenic diversity of the bacterium. Bacterial cultures from all areas where the disease was prevalent were collected and analysed. The results showed that the bacteria that infect Araceae (the family to which anthuriums belong) form a genetically heterogeneous group, but not all of them are able to infect anthuriums. The diversity was analysed using two techniques, viz. amplified fragment length polymorphism (AFLP), which is used to compare pairs of individuals for a large number of traits in the genome, and tests to measure pathogenicity in various plants of the Araceae family.

Subsequent work was focused on developing a reliable, universal detection tool capable of detecting all bacterial strains that may cause the disease, regardless of their geographical origin. Conclusive results were obtained: the tool was found to be specific (it does not detect non-pathogenic strains) and sensitive, ie it detects strains even if the plants are only slightly infected and have no obvious symptoms.

Rapid diagnosis and shorter quarantine

Detection is based on the polymerase chain reaction (PCR) gene amplification technique to detect one of the genes of the bacterium. It was thus first necessary to identify a large number of potential target genes in the genome of the bacterium, to determine which genes were specific, and then to check, via the DNA sequence, that the target gene was actually unique and corresponded to one of the bacterium's indispensable functions. Nucleotide primers were then selected in the target DNA sequence in order to develop a specific PCR test. Then amplification of the target sequence by this test was checked for all strains pathogenic to anthurium.

The tool has a wide range of applications. It is now possible to diagnose infections quickly, and also on a larger scale to monitor nurseries and check imported plants as they enter the country. Moreover, the quarantine period imposed on importers could be shortened by half. The tool can also be applied under certification schemes aimed at producing disease-free plant material. Patents have been taken out in France and the Netherlands. Lastly, there are plans to have the tool approved as an official diagnostic method by the European Plant Protection Organization (EPPO).

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This project was funded by the French Office de développement de l'économie agricole des départements d'outre-mer (ODEADOM, Ministry of French Overseas Regions) and the European Agricultural Guidance and Guarantee Fund (EAGGF).

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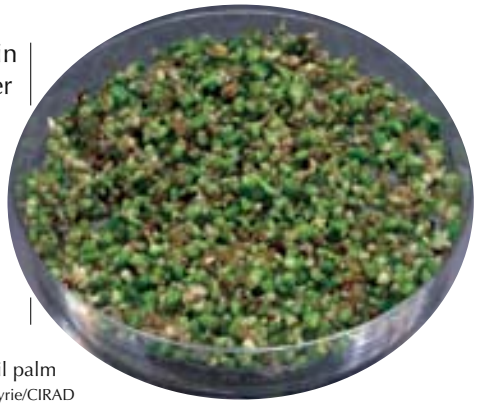
Patent FR2848222 registered in France in 2002, and extended to the Netherlands (NL1024929C).

● ● ■ Oil palm micropropagation: a second-generation procedure

The sustainability of oil palm plantations depends partly on the quality of the plant material: it must be high-yielding, adapted to local cropping conditions and disease-resistant. Oil palm clones can meet these requirements but their propagation is still complicated. CIRAD is therefore currently developing a new procedure for rapid propagation of high performance clones.

Oil palm is a prime source of vegetable oil worldwide: palm oil and palm kernel oil, which are both extracted from the fruit, account for around 30% of world vegetable oil production, with 37 million tonnes produced in 2005. This production depends mainly on the quality of the plant material, ie it has to be high-yielding so as to generate sufficient profits, adapted to local cropping conditions, and resistant to the main diseases affecting oil palm in order to guarantee a return on growers' investments. Commercial oil palm varieties are hybrids between heterozygotic parents, which means that there is high genetic variability between individuals within the same family. This variability can be



First stages of young oil palm plantlet development © A. Labeyrie/CIRAD

exploited by selecting and then cloning individuals with the best qualities. This cloning can only be performed via in vitro culture to tap the somatic embryogenesis potential of this plant. The first cloning procedures developed in the world involved cultures on static gel media. However, these methods were expensive to perform, production capacities were scant for many interesting genotypes, and it was hard to obtain true-to-type clones.

In 2001, in collaboration with the Agricultural Services and Development (ASD) company in Costa Rica, CIRAD began developing a new cloning procedure based on propagation of embryogenic suspensions in liquid medium.

A new clone production procedure

After five years of partnership, a new procedure involving embryogenic suspensions in liquid medium was developed. The conditions required for large-scale production were established. The process is highly productive—50 000 plants/l of suspension can be produced within a few months—so production can be efficiently streamlined.

A key feature of this process is that production can be predicted for given areas, resources and times. Moreover, a very broad genetic base can be tapped, including backcrossing of certain interspecific hybrids, which is impossible to achieve by conventional methods. Micropropagated plantlets were produced to assess different steps of the production process, and over 10 000 palms were planted in order to check the quality of the produced material and to begin laying the foundations for clone conformity management.

A pilot-scale test

A pilot-scale test project to be carried out in collaboration with IRD and partners in developing countries was submitted to and accepted by the French national research agency (ANR). This project will be undertaken in 2007 and 2008. The aim is to produce 100 000 micropropagated plantlets that will be used to assess all economic aspects concerning implementation of the procedure and to monitor variations in plant quality by biochemical marker analysis.

Oil palm growers have shown growing interest in clones, especially since this material can readily meet their specific needs, including resistance to certain diseases and producing oils with very specific features. This programme should ultimately provide them with reliable high-yielding oil palm clones.

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A joint venture to manage an oil palm seed garden in Thailand

Germinated oil palm seed
© T. Durand-Gasselin/CIRAD

Oil palm cropping is developing at a sharp pace in Thailand. In support of this development, CIRAD and INRAB, which are linked by a common interest programme signed in 2001, suggested that the United Palm Oil Industry Public Company (UPOIC) set up a seed garden that would benefit from recent research results. The genetic improvement programme managed by CIRAD and partners provides key support in this initiative. The seed garden should begin producing by around 2015 and will be managed by the Siam Elite Palm company, a CIRAD-UPOIC joint venture. This company has been approved as a priority foreign investment by the Thai Board of Investment.

UPOIC is the largest palm oil company in Thailand, with over 7 000 ha of oil palm plantations. However, the company buys 40-50% of the palm fruits it processes from smallholders. UPOIC would now like to supply these growers with top quality oil palm planting material, which would boost their income and enable UPOIC to achieve higher palm oil yields.

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A genetic technique for sex control in tilapia

Tilapia is the world's second-ranking aquaculture fish species, with over two million tonnes produced yearly. However, only male populations should be reared to ensure cost-effective production. So far, this could only be achieved through hormonal inversion methods. CIRAD is currently assessing new alternative techniques, especially genetic sex control.

Males grow faster than females © J.F. Baroiller/CIRAD

When rearing tilapia, at any level of intensification, it is essential to only rear males due to the high sexual dimorphism and impressive reproductive potential of this fish species. Cost-effectiveness is maximized if the reared population includes under 5% female fish. Most male monosex populations are currently produced by hormonal inversion, despite the many concomitant consumer- and environment-related issues, ie food safety, human health, water quality and biodiversity. CIRAD is investigating new techniques that are more consumer- and environment-friendly, including genetic control and modulation of water temperatures in rearing ponds.

Identifying sex chromosomes

Sex control studies are especially hard to perform in tilapia since its sex chromosomes are not morphologically differentiated enough to analyse them by simple cytogenetic techniques, and no specific molecular markers are available. CIRAD is participating in an international research programme launched recently to identify sex chromosomes in *Oreochromis niloticus* and *O. aureus*, the two main tilapia species used in aquaculture. The aim is to place sex-specific probes on the genomes of these two species using the fluorescent in situ hybridization (FISH) technique.

The results suggest that this species group is now at a pivotal point in its evolution in terms of sex determination. In *O. aureus,* major genetic sex determination factors were initially located only on the largest chromosome pair, which pools all of the traits of differentiating sex chromosomes. Minor genetic factors then appeared on a small chromosome pair in some individuals or populations. These minor factors gradually became paramount with respect to sex determination, to the detriment of the major factors borne by the large pair. The final phase was noted in some *O. niloticus* individuals or populations for which the large chromosome pair had no major sex determinants, ie they were located only on the smallest pair, which had not yet acquired traits associated with its subsequent sex chromosome status.

Achieving genetic sex control

Sex determinants are located on one or two chromosome pairs, depending on the sex determination evolution stage of the reared individuals or populations, which partially explains the observed sex-ratio deviations. The thermosensitivity of sexual differentiation could also explain these deviations. This factor likely facilitated the transition between two contrasting sex determination systems, ie female and male heterogamy, and gave rise to a new pair of sex chromosomes in *O. niloticus*.

Once these sex chromosome markers and their locations are validated, a technique will quickly be developed to determine the sexual genotype of the parents, which is essential for genetic sex control in tilapia.

Temperature and sex differentiation

Further research was conducted to identify sex differentiation thermosensitivity markers. In some progeny, a ten-day high temperature (34°C) treatment was found to produce mainly male populations (up to 100% males), but the treatment had no effect on other populations. Studies have shown that thermosensitivity traits are heritable and borne by both parents. On the basis of these results, CIRAD set up a collaborative project with a German team to identify thermosensitivity markers in temperature-insensitive and -hypersensitive tilapia lines using genomic procedures.

A sex chromosome study in the two species will be conducted under a new research project, and a large-scale programme will be set up to sequence the ends of 35 000 probes spanning the tilapia genome, while also completely sequencing its genome within the framework of the Cichlid Genome Consortium.

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● ● ■ Rinderpest and peste des petits ruminants: a future treatment centring on interfering RNA

Rinderpest and peste des petits ruminants are still serious virus diseases even though a vaccine is available. A new generation of antiviral agents which inhibit the replication of the morbilliviruses that cause these diseases has just been developed on the basis of the RNA interference mechanism. This could pave the way to the development of therapeutic vaccines to treat infected animals.

Rinderpest affects domestic cattle, buffaloes and yaks, but also sheep, goats and some pig races, along with a whole range of wild species. Despite a blanket preventive vaccination campaign that has almost completely eliminated the disease worldwide, there are still some persistent infection hotspots in Somalia, but no curative treatment. Peste des petits ruminants is prevalent in Africa, on the Arabian Peninsula, in the Middle East and India. The available preventive vaccines are effective but heat sensitive, and again there is no curative treatment.

Since early 2005, CIRAD has been developing a new method to control these diseases based on a novel molecular genetics technique: RNA interference. This natural biological mechanism enables multicellular organisms to control the expression of some of their genes. The process

involves short RNA fragments (interfering RNAs) capable of silencing proteins genetically encoded by the DNA prior to their translation. These interfering RNAs specifically bind to the target messenger RNA, leading to its degradation and thus inhibition of the corresponding protein.

Interfering RNA inhibits virus replication by more than 80%

CIRAD scientists recently identified three synthetic interfering RNAs that can inhibit peste des petits ruminants and rinderpest virus replication by over 80% in vitro. They target the messenger RNA of the nucleoprotein gene of the causal viruses, thus blocking the virus propagation process. A patent application was filed on these results in December 2005.

The second phase of the research has now begun and involves in vivo tests of this new generation of antiviral agents in infected animals. A virus vector, which usually serves as a vaccine, will be used to transfer interfering RNAs in infected animals. If virus replication is actually found to be inhibited in infected animals, safe and effective therapeutic vaccines against rinderpest and peste des petits ruminants could be developed.

These very promising results immeasurably boost the prospects in terms of animal health. They could be of interest concerning other viruses such as bird flu or African swine fever. For this latter disease, using RNA interference as a control method would be a major step forward since no preventive vaccine is currently available.

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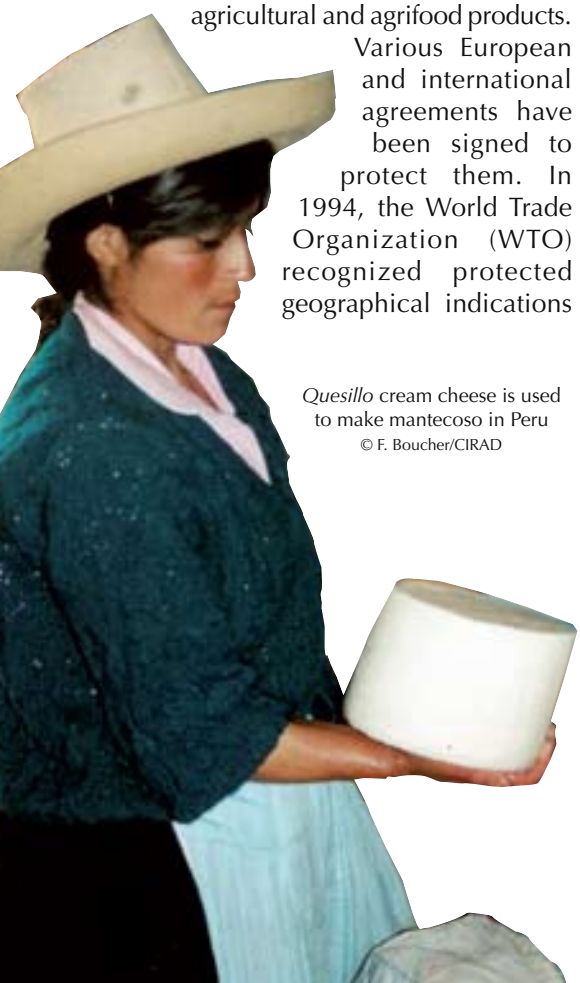
A patent application was filed on these results on 21 December 2005 (n° 0513029), with an international extension (n° PCT/FR2006/002819).

Gum swab from a sick goat for diagnosis of peste des petits ruminants in India
© G. Libeau/CIRAD

Geographical indications in emerging countries

Antigua coffee from Guatemala, Peruvian mantecoso, Mamou pepper from Guinea, Karoo lamb from South Africa, Surin Hom Mali fragrant rice from Thailand, Darjeeling tea... referring to unique agricultural and agrifood products by the name of the place where they were harvested or manufactured is a long-standing custom in many parts of the world. Emerging countries are now aware that recognizing such reputations could help them maintain and promote their products and are thus setting up effective legal regulatory mechanisms. CIRAD is supporting several of these countries in this initiative.

Origin products have existed for centuries on every continent, but the geographical indication (GI) concept is quite recent. It was first transcribed into law in France in the early 20th century. In 1935, the French Institut national de l'origine et de la qualité (INAO) was assigned the responsibility of overseeing designations of origin (AOCs), which recognize the heritage value of certain agricultural and agrifood products. Various European and international agreements have been signed to protect them. In 1994, the World Trade Organization (WTO) recognized protected geographical indications as a fully-fledged intellectual property right, on the same level as patents and trademarks. Geographical indications, which designate products with a given quality, reputation or other characteristic essentially attributable to their area of origin, have become a key element in world trade discussions.



Quesillo cream cheese is used to make mantecoso in Peru
© F. Boucher/CIRAD

Emerging countries are beginning to adopt the geographical indication concept. In an increasingly open market setting, these countries are now aware that the GI label could help them promote their unique products better on domestic and export markets. Effective legal control mechanisms must therefore be set up, while identifying and selecting potential GI products. CIRAD signed an agreement with INAO in 2004 and is now supporting several countries in this initiative.

Geographical indication potential in South Africa and Brazil

In South Africa, no specific legislation has been passed to protect geographical indications. However, prompted by the realization that certain local resources are specific to these areas, a national debate began in 2004 on the advantages of developing the GI approach. Two projects coordinated by the University of Pretoria and CIRAD were launched in South Africa and Namibia. The aim is to study the potential of geographical indications for providing access to markets and promoting rural development, while also serving as a biodiversity conservation instrument. This initiative concerns several products: rooibos and honeybush infusion plants, Karoo lamb, Candeboo mohair, Kalahari melon seed oil and Karakul fur. Discussions between professional, institutional and research stakeholders were initiated through meetings and workshops. The rooibos tea issue is quite advanced, and a dossier has been compiled with a view to national and then European certification.

In Brazil, geographical indications have been recognized since 1996 under federal law, but GIs are just recently being promoted. CIRAD is supporting Brazilian partners in conducting research on conditions required for the development of this distinctive label and its role in protecting export products and promoting local commodity chains. Stakeholders have been exchanging their experiences. Specific studies were conducted to support producers in GI development or management for products like Vale dos Vinhedos and Urussanga wines, São Joaquim apples and Florianópolis oysters.

Geographical indications more recognized in Indonesia and India

In Indonesia, the most renowned regional products, such as Toraja coffee and white Muntok pepper, are regularly exported. However, traders in exporting countries often register the geographical names as trademarks without offering producers any financial benefits. The Indonesian government therefore decided to set up a legal framework to recognize these geographical indications and to launch a pilot project on coffee. A project on Kintamani arabica coffee from northern Bali is being coordinated by the Indonesian Coffee and Cocoa Research Institute (ICCRI) and local authorities in association with CIRAD and INAO. This has generated substantial stakeholder involvement in favour of the GI concept and the certification specifications have been drawn up. In this situation, growers and processors have worked together to draw up common regulations for production and for determining the boundaries of protected areas, which is clear evidence that geographical indications strengthen the rural development process.

India—an emerging country with a prominent role in international trade negotiations—is also implementing active policies to promote GI recognition. Under the adopted legal framework, agrifood products as well as certain textiles and handicrafts may be protected under geographical indication labels. CIRAD and its partners are interested in comparing the development of geographical indications in Southern Europe and in this country, which has an Anglo-Saxon legal tradition. They are also assessing new GI objectives, such as the protection of biodiversity and traditional skills and know-how. GI specifications could thus be designed to consolidate ancient environment-friendly practices.

Finally, a comparative analysis with the situation in Europe and in several countries worldwide is being conducted to highlight the scientific basis for international recognition of geographical indications.

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The national and European certification dossier for rooibos tea from South Africa has already been compiled
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Anticipating

Agrimonde: agriculture and food worldwide in 2050

A major challenge facing world agriculture in the coming decades will be to find ways to boost production sustainably so as to be able to lastingly fulfil sharply increasing needs for food and nonfood goods. What future patterns could be possible in France, Europe, and all major regions worldwide, especially in the tropics? How can agricultural research help to meet this challenge? The Agrimonde prospective study, managed jointly by INRA and CIRAD, should provide answers to these questions, while fuelling discussions on the future of French public research and highlighting key orientations that could enhance its position within the international scientific community.

Current trends—world population growth, changes in food systems in emerging countries, growth in demand for bioenergies and other nonfood products, and the decline or degradation of natural resources—will upset the national supply and demand balance. Effectively preserving the world's natural resources while alleviating poverty and inequality is a major challenge for sustainable development, as well as for global geopolitical equilibria and relationships between industrialized and developing countries.

A prospective study on patterns in 2050

The Agrimonde prospective study on agriculture and food worldwide in 2050 was launched in 2006 and will be continued in 2007 and 2008. The results should highlight the potential role of agriculture in different global change scenarios and identify fundamental issues that agricultural research will have to address. It will provide CIRAD and INRA with a tool to think ahead concerning these changes and to prepare for the future in terms of public research systems and priorities, and relative to their strategic position in the global arena.

Overall, the study is based on the results of the Millennium Ecosystem Assessment (MEA), an international initiative conducted between 2001 and 2005 under the aegis of the United Nations to assess ecosystems and prospective changes. This will dovetail with current prospective agricultural research being carried out under the International Agricultural Assessment of Science and Technologies for Development (IAASTD) initiative launched by the UN and the World Bank in 2002.

A brainstorming platform

In the light of the variety of analyses and information available on world agriculture and food, Agrimonde aims primarily to serve as an instrument for discussions on prospective changes in current settings. The focus is especially on the possible roles of research, public policies and international regulations.

A key phase is the strategic analysis of MEA change scenarios. This involves comparing the different agricultural and food production and consumption scenarios in order to assess the environmental, economic and political implications, which in turn will determine future issues facing agricultural research. Many parameters concerning both consumption and demand come into play. The critical

analysis involves unravelling and reconstructing current scenarios so as to highlight and then overcome potential shortcomings and failures. Analyses and thoughts on these scenarios will be thoroughly discussed in a final phase, and give rise to recommendations and prospects for using this platform for further applications.

Agrimonde should help scientists gain deeper insight into the implications of major expected changes and make optimum use of their expertise, especially in the increasing number of international task forces that have been formed in recent years. INRA and CIRAD thus intend to target their scientific strategies and strengthen their participation in major international discussions so as to be able to better address the agriculture and food related issues of the future.

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A market on the East coast of Madagascar

Emerging diseases: a research challenge

Climate change, ecological imbalances and trade intensification are triggering the development of new diseases and an upsurge in known disorders affecting plant, animal and human health. New operational strategies are needed to deal with recent pest and disease crises. Prediction, early detection, early warning and preventive studies on diseases that could be problematic in the future are now essential.

Emerging diseases are having an increasing impact on human, animal and plant health. These are new diseases with unknown causal agents, or known diseases whose modes of transmission, expression or adaptation to host organisms have suddenly changed to the extent that they induce more serious symptoms, or diseases transmitted by pests (insects, rodents, etc) that have managed to colonize new previously disease-free areas. These are often tropical diseases capable of inducing major outbreaks, especially in developing

CIRAD is studying the role of migrating birds in spreading the avian influenza virus: blue-winged teals fitted with small Argos transmitters, in Mali © P. Poilecot/CIRAD

countries where health and crop protection systems are often ill-prepared to cope with such crises.

CIRAD is a key player in research on emerging diseases. Its overall strategy in dealing with this issue combines surveys, studies on epidemiological cycles, risk analysis and the development of diagnostic and control tools. CIRAD scientists have long been conducting field research in developing countries, so they have acquired in-depth knowledge of the endemic areas of most of these diseases. They can also call on a network of partners in the Mediterranean region, Africa and Southeast Asia, further strengthened by close collaborations with institutions in industrialized countries. CIRAD can thus use its own skills and experience and those of its partners to respond quickly when new problems arise, while also foreseeing risks of emergence of new biological pests and diseases.

Renowned experience

For several years, CIRAD has been conducting research in the field of animal health, while contributing to disease surveillance and participating in teaching and training sessions on Rift Valley fever, West Nile fever, African swine fever, bluetongue and avian influenza. Since the beginning of the highly pathogenic avian influenza crisis, its scientists have been studying the role of migratory birds in propagating the highly virulent H5N1 virus, and several sampling campaigns have already been undertaken.

CIRAD is renowned for its coordination experience, especially in international projects such as the Pan African Programme for the Control of Epizootics (PACE) and the Emerging Diseases in a changing European Environment (EDEN) project. Through its environmental approach to diseases, its researchers can assess relationships between wildlife and domestic animals and health ecology issues. CIRAD has access to highly efficient tools in this field, including technical platforms specializing in the analysis of remote sensing data and high-speed diagnostic analysis techniques.

Pest and disease control experience

Emerging diseases are a major concern in the pest and disease control sector. Problems associated with plant pests can lead to excessive pesticide treatments and even food shortages. CIRAD is here again involved in analysing pest colonization patterns worldwide and risk management conditions (see following section on Huanglongbing disease).

CIRAD's diagnostic, epidemiological, modelling and integrated pest

management studies carried out in a broad range of settings should help to predict associated risks and enable responses to problems as soon as they arise. For instance, CIRAD is participating in a West Indian network to monitor black Sigatoka disease in banana so as to hamper the introduction of this banana pathogen, which is currently approaching the Lesser Antilles, and to control it quickly if detected. CIRAD's involvement in the European Network for the Durable Exploitation of Crop Protection Strategies (ENDURE) will facilitate the integration of research systems in developing countries into this European network.

The animal health and crop protection issues to be dealt with are substantial. A joint methodical assessment of concerns in these two fields using the same diagnostic, epidemiological, modelling, prediction and risk management tools is essential: a mutually beneficial approach.

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Websites

EDEN (Emerging Diseases in a changing European Environment):
http://www.eden-fp6project.net

ENDURE (European Network for the Durable Exploitation of Crop Protection Strategies):
http://www.endure-network.eu

Emerging pest and disease risks: citrus Huanglongbing disease

Diaphorina citri rearing cage in an insectarium
© F. Gatineau/CIRAD

Huanglongbing disease affects all citrus fruits. The causal agent is *Candidatus* Liberibacter sp., a phloem-limited bacterium transmitted by psyllid insects. This disease is native to Asia and Africa, but has also just been identified in Brazil and USA, where it is now a serious threat to citrus fruits—the world's top fruit crop in terms of production value. CIRAD is investigating new methods to eradicate this serious disease.

So far, Huanglongbing control strategies have been focused on eradicating or reducing populations of the insect vectors, *Diaphorina citri* and *Trioza erytrea,* through pesticide or biological control methods, and on preventive control, since no natural resistance or tolerance to the disease has been detected in cropped or wild *Citrus* varieties. However, *Candidatus* Liberibacter sp. transmission by these vectors is a key step in the epidemiology of this disease. Control or even eradication of this disease could be possible without this highly specific entomophilous transmission.

In the light of recent advances in the study of insectborne diseases and in insect genetic transformation techniques, CIRAD is focusing research on a control strategy based on modifying the bacterial transmission capacity of the insect vectors rather than on trying to eliminate or reduce their populations. A series of preliminary studies have already begun on cellular mechanisms that enable translocation of the bacterium in psyllid tissues and on direct or indirect germ-line transgenesis of the insect vectors.

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For further information

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Indicators

Indicators

The year 2006 was one of transition for CIRAD, between the establishment of its research units in 2005 and the restructuring of its departments, which took effect in 2007. The contractual agreement signed between CIRAD and the French government for the period 2001-2005 has now expired, and no new contract was signed in 2006. The indicators for 2006, which are more or less the same as for the previous agreement, cover the most significant aspects of CIRAD's operations and, in some cases, the changes that have occurred over the past six years. However, in view of the restructuring operation at CIRAD and the introduction of a new human resources information system, not all the indicators are available.

Human resources and changing skills

Human resources

Overall staff numbers are down slightly on 2005, from 1 850 to 1 825. This trend, which has been marked since 2002, does not concern every category, since from 2001 to 2006, the number of senior staff members increased by 57 and that of intermediate staff members by 31, while the number of junior staff members fell by 122 **(figure 1)**. The level of qualifications among CIRAD staff members changed significantly over the period, as a result of CIRAD policy of improving skills.

Numbers have fallen most in metropolitan France, with 31 fewer staff members, while numbers overseas have increased by six. This has primarily benefited the French overseas regions and Latin America; the number of staff members assigned to Africa is down five **(figures 2 and 3)**.

The number of missions rose in 2006, by 8.7 full-time post equivalents, primarily in favour of Asia and Oceania (+6.3) and Africa (+3). Overall, the number was down 14.1% on the 2002 figure **(figure 4)**.

Compared to 2001, numbers are down in Africa (–21) and the French overseas regions (–12), but have risen elsewhere, as a result of CIRAD's diversification policy, particularly in favour of Asia and Oceania (+9).

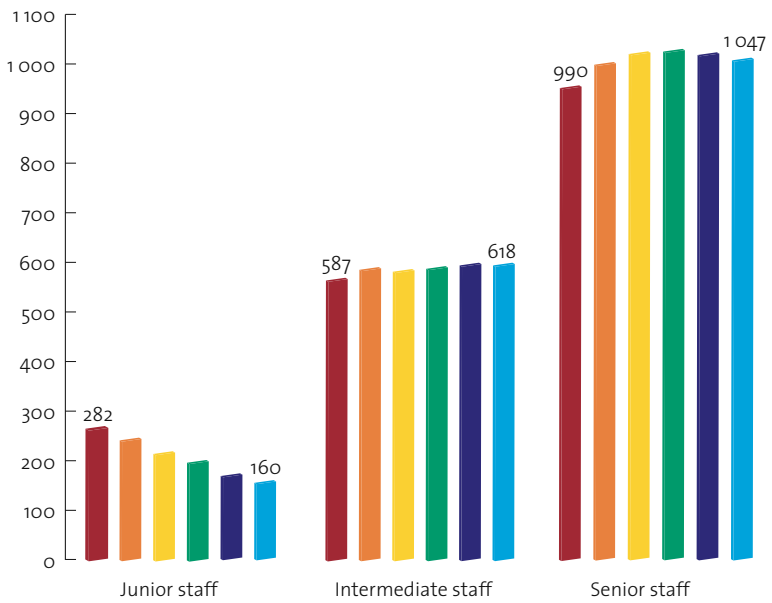

Figure 1. Staff numbers and distribution

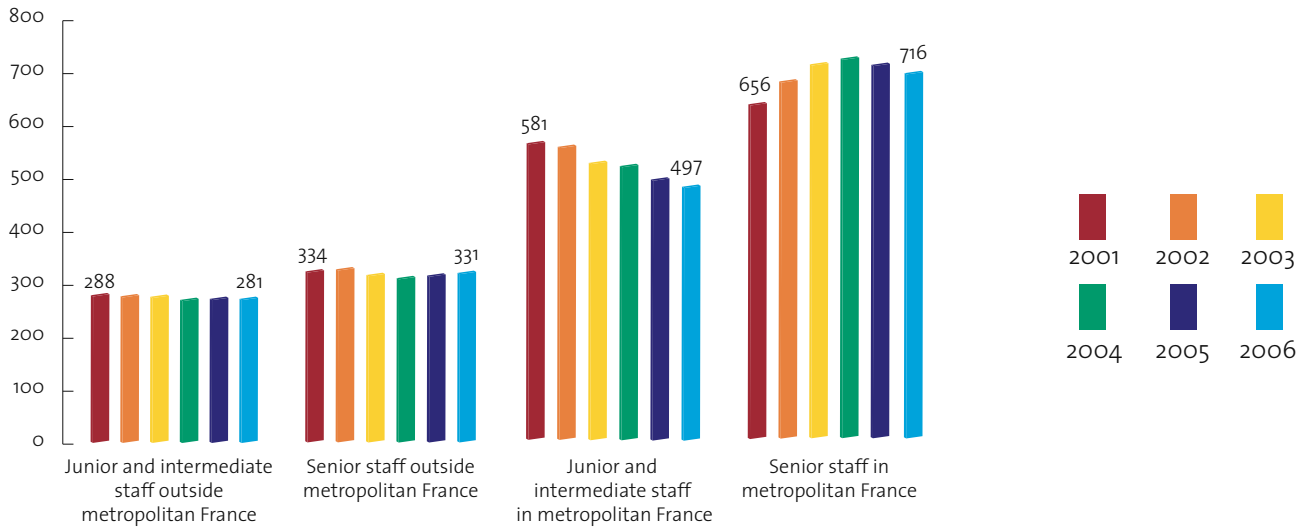

Figure 2. Location of CIRAD staff

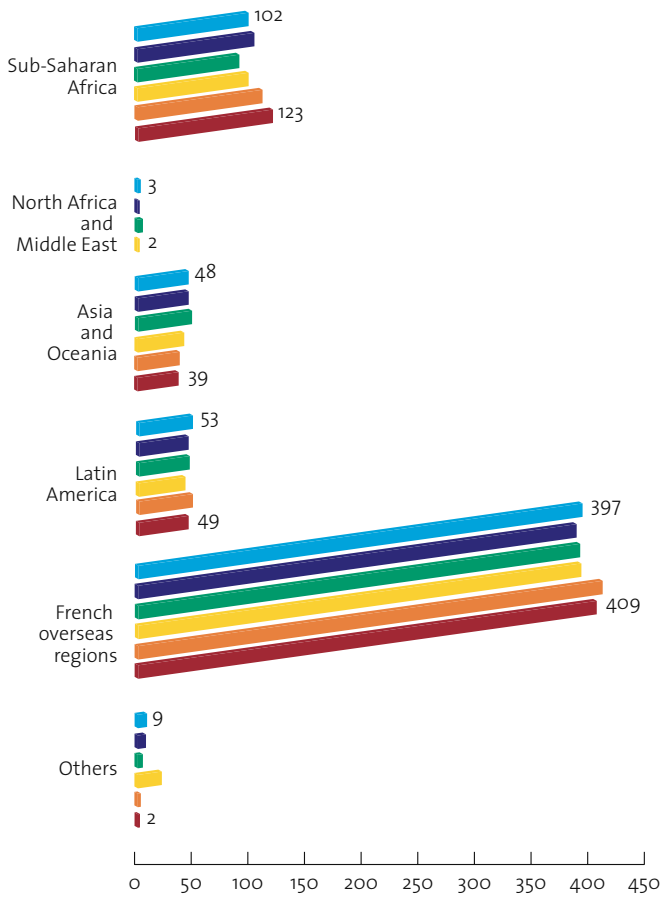

Figure 3. Distribution of assignments (numbers)

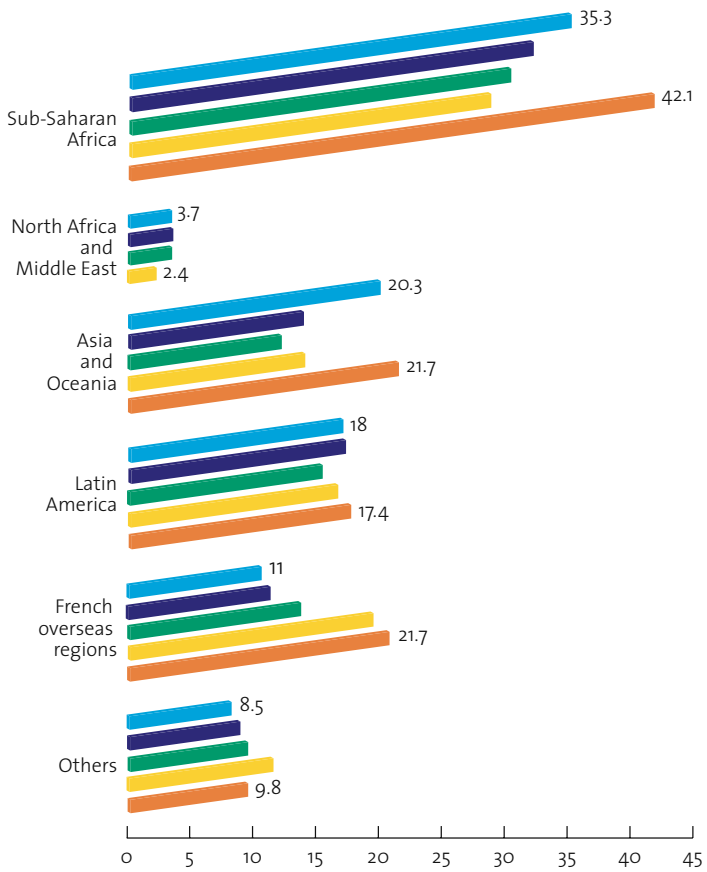

Figure 4. Missions, in full-time post equivalents

CIRAD employs 788 senior scientific staff members, supported by 36 associates, including eight assigned by INRA and 11 by the Ministry of Agriculture. The Foreign Ministry provides CIRAD with ten technical assistants for development (ATDs). While CIRAD is supported by researchers from other organizations, it also contributes to research operations at 11 CGIAR (Consultative Group on International Agricultural Research) centres, to which it assigned 20 researchers in 2006.

The number of researchers of European origin has fallen slightly, and indeed slightly faster than overall senior staff numbers, with a drop of 0.2% in percentage terms. Since 2000, the number of researchers from Europe has nevertheless risen from 24 to 37, in other words from 2.6 to 3.5% of the total **(figure 5)**.

Despite the overall fall in numbers, the proportion of women among senior staff members again increased in 2006. The number of female senior staff members rose from 266 in 2005 to 274 in 2006, reaching 26.2% of the total **(figure 6)**. The proportion has been increasing steadily since 2001, at a rate of almost 1% per year.

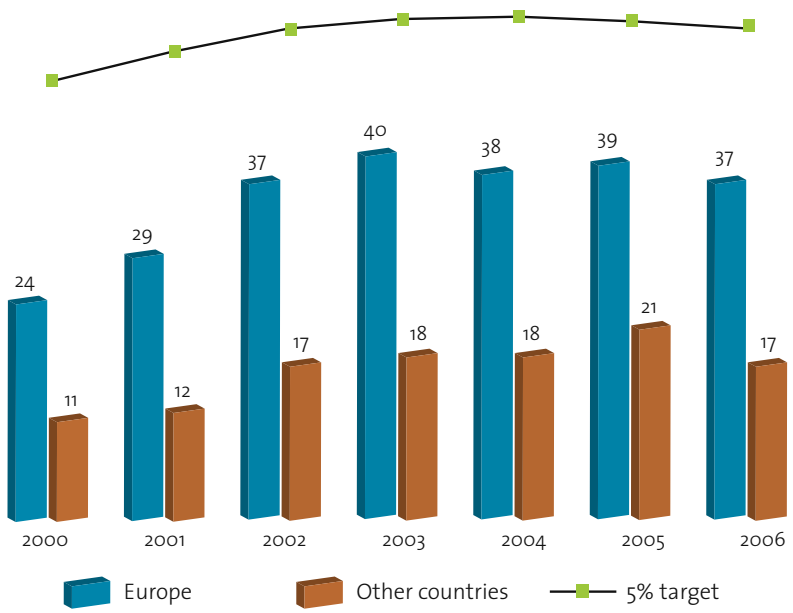

Figure 5. Changes in the number of senior staff members and target for senior staff members from the European Union

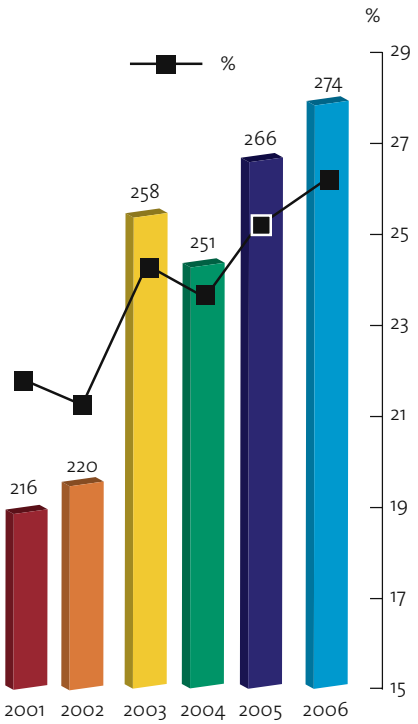

Figure 6. Changes in the number of women on the senior staff

Changing skills

The number of directors of research (HDRs) is up to 8.9% of the total senior scientific staff. The proportion of PhD holders has also increased, to more than 50%. For 2006 compared with 2001, the percentage of PhD holders was more or less stable (around 50%), with a 1.8% increase in the proportion of HDRs **(table I)**.

Table I. Scientific qualification levels from 2001 to 2006

	2001	2002	2003	2004	2005	2006
Senior scientific staff	818	842	899	878	878	856
PhD holders						
number	408	419	465	439	436	430
percentage	49.9	49.8	51.7	50.0	49.7	50.2
HDRs						
number	58	67	72	68	75	76
percentage	7.1	8.0	8.2	7.7	8.5	8.9

Policy on scientific operations and partnerships

Partnerships

Federative projects

There are now six federative projects in France involving several CIRAD departments and other research centres, higher education establishments and technical centres: ARPEGE (plant root architecture: environmental and genetic factors), ORYZON (rice, from gene to field and field to gene), ECOFORBAC (forest ecosystem management and conservation in the Congo Basin), GRENAT (tools for evaluating and managing the environmental risk linked to use of waste and pollutant products in agriculture), LABELSUD (product qualification and certification), and DURABILIS (sustainable agriculture and sociotechnical innovations). There are also numerous European and international partnerships.

There are 13 programmed thematic projects (ATPs) involving researchers from several departments and units over a period of around three years. These projects imply collective calls for proposals, selection and reporting.

Joint research units

The situation as regards joint research units (UMRs) has not changed in 2006. CIRAD is associated with 20 UMRs, with 200 staff members on assignment, ie more than a quarter of the total CIRAD senior scientific staff. In 2001, CIRAD was involved in just 12 UMRs, assigning 128 scientists or 15.6% of its total scientific staff **(figure 7)**.

European projects

The 6th European Community Framework Programme for Research and Development (FP6) was completed in 2006. CIRAD adapted rapidly to the changes in this programme in relation to its predecessors, resulting in increased involvement on its part and a greater contribution to its contractual resources from European projects (see figure 14 on the origin of contractual resources).

Of the seven projects chosen in 2006 for European Community funding, four were coordinated by CIRAD **(table II)**. Among other operations, CIRAD is involved in the ENDURE network of excellence, which was founded to ensure durable exploitation of crop protection strategies as part of an ecofriendly approach. It has thus been able to consolidate its own research topics and associate its partners in developing countries.

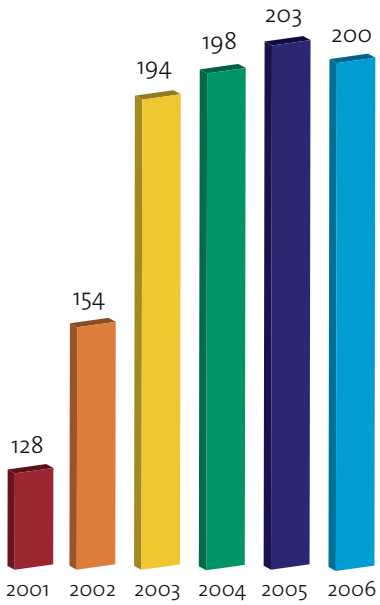

Figure 7. Changes in the number of CIRAD researchers working for joint research units

Table II. European projects selected in 2006

European Network for the DURable Exploitation of crop protection strategies (ENDURE)	Contact: J.L. Sarah (BGPI, PVBMT, Banana, Plantain and Pineapple Cropping Systems, DIC) Coordinator: INRA
Promoting European Traceability Excellence and Research (PETER)	Contact: N. Zakhia (IATE) Coordinator: Chambre de commerce et d'industrie du Gers
Quantification, understanding and prediction of carbon cycle and other GHG gases in sub-Saharan Africa (Carbo-Africa)	Contact: J.P. Bouillet (Functioning and Management of Tree-Based Planted Ecosystems) Coordinator: CIRAD
Integrated water resources management by the implementation of improved agro-forestry concepts in arid and semi-arid areas in Latin America (WAFLA)	Contact: F. Forest (Direct Seeding and Cover Crops) Coordinator: Technologie Transfer Zentrum, Bremerhaven (TTZ, Germany)
Unravelling pathogenicity of *Xanthomonas albilineans,* the pathogen causing leaf scald disease of sugarcane (Xagenomics)	Contact: P. Rott (BGPI) Coordinator: CIRAD
Agricultural Innovation in Dryland Africa (AIDA)	Contact: D. Clavel (Agrobiodiversity in Savannah Environments) Coordinator: CIRAD
Integrating Social Science Research into Cotton Reform Implementation lined with the international outlook (ISSCRI)	Contact: M. Fok (Cotton Farming Systems) Coordinator: CIRAD

Research platforms in partnership and international research units

There are six overseas research platforms in partnership, bringing together researchers and resources from various organizations at a given geographical site, working on a common topic related to development issues **(table III)**. The aim is to provide those researchers with an ideal long-term environment in which to conduct their research and maintain their position in the international scientific community. This fosters the production of quality scientific results, the creation of development tools and the training of young researchers of various origins. In addition, there is also a will to centre operations on partnerships, taking care to ensure that each and every partner has an equal say in the decisions made. Partners are involved from the outset, and projects are written into national research programmes. The transfer of skills and access to information are priorities and the publication and shared use of results are encouraged.

Table III. Research Platforms in Partnership

Markets and Agriculture LInkages for Cities of Asia (MALICA), Vietnam	Partners: Asian Institute of Technology (AIT, Thailand), Information Center for Agriculture and Rural Development (ICARD, Vietnam), Institute of Agricultural Economics (IAE, Vietnam), Institute of Sociology (IOS, Vietnam), Research Institute for Fruits and Vegetables (RIFAV, Vietnam), Vietnam Agricultural Science Institute (VASI, Vietnam)
Intensification of animal production systems (PRISE), Vietnam	Partners: Hanoi Agricultural University (Vietnam), National Institute for Veterinary Research (NIVR, Vietnam), National Institute of Animal Husbandry (NIAH, Vietnam), Vietnam Agricultural Science Institute (VASI, Vietnam)
Integrated management of family agriculture in humid agroforestry systems (Grand Sud Cameroun), Cameroon	Partners: Institut de recherche agricole pour le développement (IRAD, Cameroon), Universities of Yaounde I and Dschang (Cameroon)
Savannah ecosystem management (GESED), Mali	Partners: Institut d'économie rurale (IER, Mali), Institut polytechnique rural (IPR, Mali)
Tree-based agroforestry systems, Costa Rica (April 2007)	Partners: Centro Agronómico Tropical de Investigación y Enseñanza (CATIE, Costa Rica), Centre for Agriculture and Bioscience International (CABI, United Kingdom), Instituto Centroamericano de Administración de Empresas (INCAE, Costa Rica), Programa Cooperativo Regional para el Desarrollo Tecnológico y la Modernización de la Caficultura de Centroamérica (Promecafé, Guatemala, Costa Rica)
Production and conservation in partnership, Zimbabwe (April 2007)	Partners: Centre national de la recherche scientifique (CNRS, France), National University of Science and Technology (NUST, Zimbabwe), University of Zimbabwe (UZ, Zimbabwe), French Embassy

There are also three international research units (URPs) in Madagascar and Senegal **(table IV)**, associating teams from CIRAD with staff from other research and higher education establishments, with a similar status to joint research units. This status boosts the teams' integration into national higher education and research systems, their visibility on the international stage and their recognition in relation to academic standards.

Table IV. International Research Units

Sustainable Farming and Rice Cropping Systems (SCRID)	Partners: Centre national de la recherche appliquée au développement rural (FOFIFA, Madagascar), University of Antananarivo
Management of Madagascan Forests and of Their Biodiversity (Forests and Biodiversity)	Partners: Centre national de la recherche appliquée au développement rural (FOFIFA, Madagascar), University of Antananarivo
Pastoralism	Partners: Institut sénégalais de recherches agricoles (ISRA, Senegal), Centre de suivi écologique (CSE, Senegal), Ecole nationale d'économie appliquée (ENEA, Senegal), Cheikh Anta Diop University (UCAD, Senegal)

Regional scientific coordination centres

These are inter-country coordination units governed by regional economic communities and associating national agricultural research systems. PRASAC, the *Pôle de recherche agronomique des savanes d'Afrique centrale*, is thus a specialized tool affiliated to CEMAC, the Economic and Monetary Community of Central African States. The unit is based in N'Djamena, Chad, and receives an annual grant from CEMAC. It is also funded by the Foreign Ministry and the African Development Bank, and coordinates research operations by the national structures in Cameroon, Chad and the Central African Republic.

There are four regional centres and national centres with a regional responsibility working with CIRAD in Africa: CIRDES, the *Centre international de recherche pour le développement de l'élevage en zone sub-humide*, in Burkina Faso; CARBAP, the *Centre*

africain de recherche sur la banane plantain, in Cameroon; CERAAS, the *Centre d'études et de recherches sur l'adaptation à la sécheresse*, in Senegal; and UR2PI, the *Unité de recherche sur la productivité des plantations industrielles*, in Congo.

Scientific and technical publications

The figures concerning scientific and technical publications by CIRAD researchers were drawn from the Agritrop database, the CIRAD reference base in terms of institutional publications and reports. These data concern the base as of 31 January 2007. Due to the time that elapses before actual publication, only 50 to 70% of 2006 publications had been recorded by then, which is why the data were extrapolated for all the analyses below.

The total number of publications (journal articles, books, book chapters, conference proceedings and papers, and theses) has fallen slightly since 2001 **(figures 8 and 9)**. This reduction is primarily due to a fall in the number of papers presented at conferences since 2003. However, the number of articles published in journals has been rising steadily, with a significant increase in the number of publications in ISI impact-factor journals **(figure 10)**.

For the period 2005-2006 (not extrapolated), 482 articles were published in ISI impact-factor journals. Of those, 415 (86%) were written jointly with authors from outside CIRAD, primarily from universities or research organizations in Europe (94%) or Africa (30%) **(figure 11)**.

The co-authors came from a wide variety of organizations. However, at least 40% of these articles were published with at least one academic, based in Europe (48%), Africa (18%), North America (13%), Asia (13%) or South America (10%). Besides universities, the organizations most widely represented in these joint publications were INRA, CNRS and IRD.

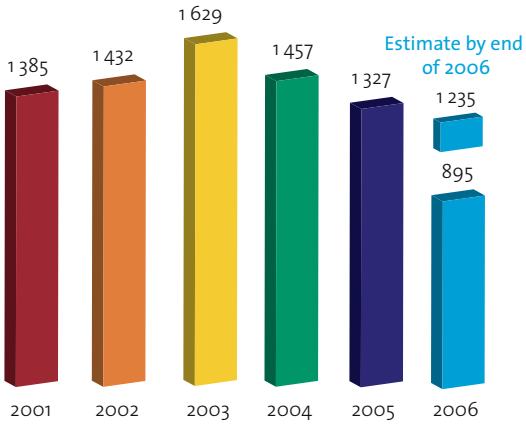

Figure 8. Changes in the total number of publications

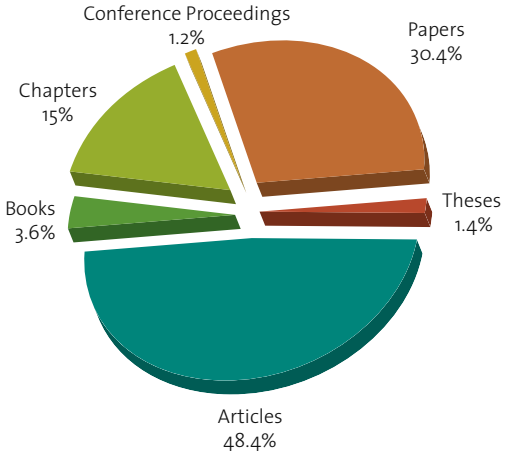

Figure 9. Distribution of publications recorded in 2006, according to type of document

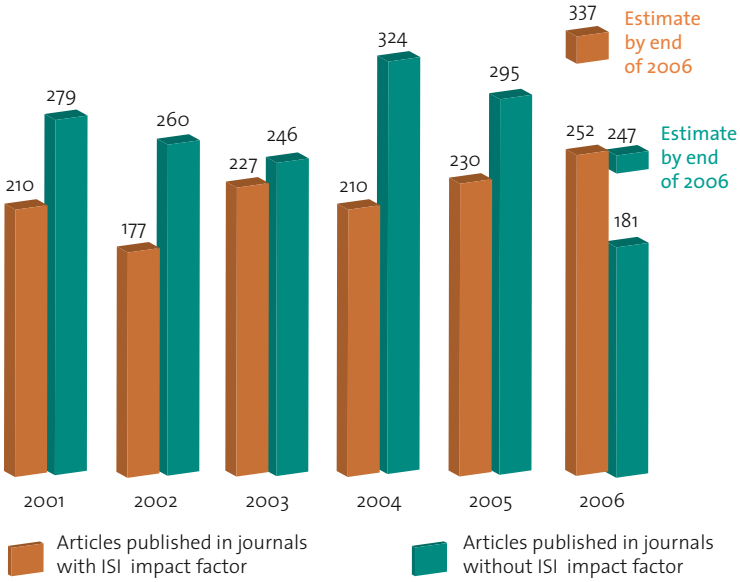

Figure 10. Changes in the number of articles published in periodicals

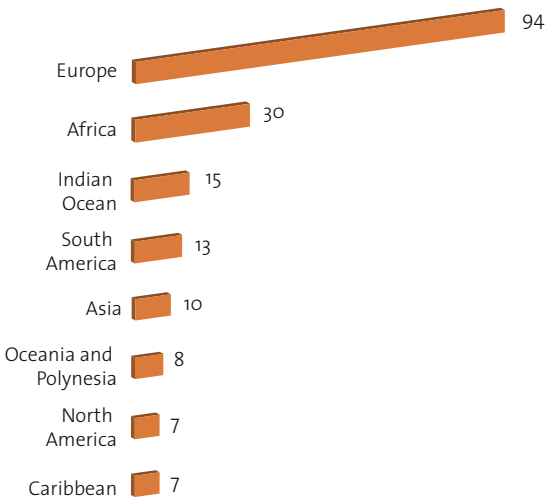

Figure 11. Geographical origin of co-authors of articles published in ISI impact-factor journals

Technology transfer and development

CIRAD has a portfolio of 35 patents, half of them held jointly with at least one partner. By the end of 2006, it had registered 33 softwares, 51 plant variety protection certificates (PVPC), ten brands, a design and a dossier technique secret (trade secret).

Financial resources

Coverage of operating costs by the public service operating budget (SCSP) was up from 62.3% in 2005 to 62.4% in 2006 **(figures 12 and 13)**.

Contractual resources were also up: 53.5 million euros in 2006 as against 47.4 million in 2005 **(figure 14)**. Once again, this was primarily due to the increase in European Union funding, from 16.1 to 19.3 million euros (19.9% more than in 2005). All the other sources of funding also increased, but to a lesser extent. After a previous fall, French public funding increased for the third year running, albeit failing to reach the 2002 figure.

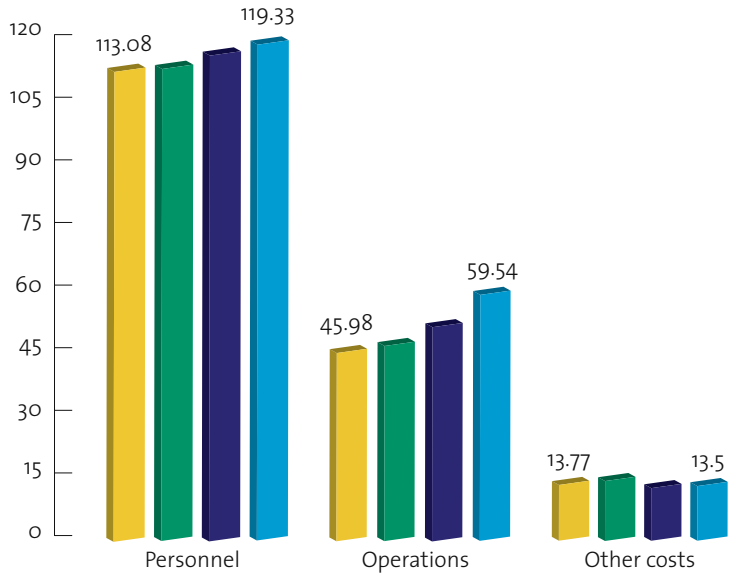

Figure 12. Operating costs (million euros)

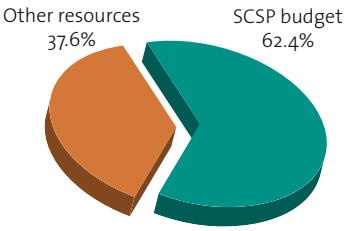

Figure 13. Cost coverage by the public service operating budget (SCSP)

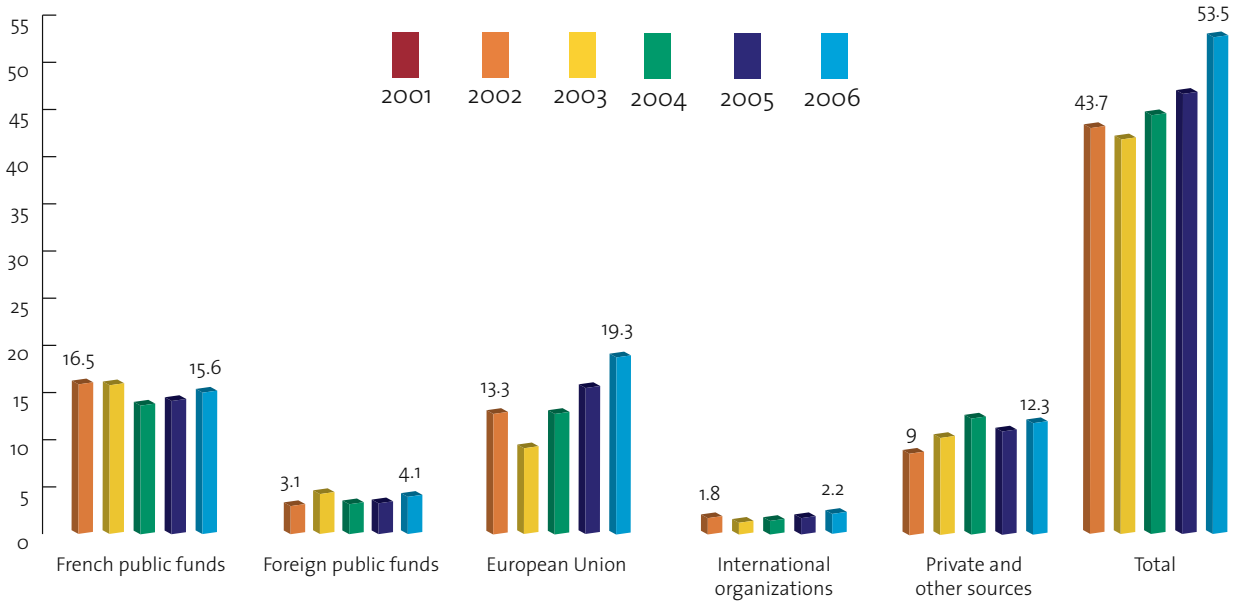

Figure 14. Origin of contractual resources (million euros)

Quality policy

The purpose of quality control schemes in the research sector is to guarantee the traceability of operations, improve the reliability of results and ensure that operations and laboratories satisfy standards. The primary aim is the collective improvement of scientific production processes, and this concerns every research player, including management and research support staff.

Nine structures (including eight research unit laboratories), representing some 360 employees (20% of the total staff), have now embarked upon a level-4 certification or accreditation procedure in the hope of gaining the approval of third-party organizations, under the ISO (International Organization for Standardization) system **(table V)**.

CIRAD's quality policy concerns its operations and laboratories in metropolitan France and the French overseas regions, and also installations run jointly with foreign partners. Specific operations have been launched to raise awareness and inform people about quality control schemes and train them in how to use quality control approaches and tools. These various operations, which fit in with CIRAD's overall strategy, serve to boost the credibility of its research teams by improving the quality of their work.

Table V. Certified or accredited structures

Structures (research unit concerned)	Type of standard	Numbers
Already certified in 2004		
• Agricultural analysis laboratory, Montpellier	ISO 9001	21
• Agricultural analysis laboratory, Réunion	ISO 9001	8
• Wood preservation testing laboratory, Montpellier	CTBA* certification (ISO 17025)	8
Certified in 2005		
• Wood preservation testing laboratory (Production and Processing of Tropical Woods), Montpellier	ISO 17025 (COFRAC accreditation)	8
• Environmental management system at Baillarguet (Animal Production and Veterinary Medicine Research and Service Units), Montpellier	ISO 14001	180
Certified in 2006		
• Natural rubber quality laboratory (Quality of Tree Crop Products), Montpellier	ISO 9001	4
Certification or accreditation pending		
• Animal health laboratory, Montpellier	ISO 17025	43
• Animal health laboratory, Guadeloupe	ISO 17025	10
• UMR: Biology and Genetics of Plant-Pathogen Interactions for Integrated Protection (BGPI), Montpellier	ISO 9001	74

* CTBA: Centre technique du bois et de l'ameublement.

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Organizational chart in April 2007

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* UMR: Joint Research Unit • UPR: Internal Research Unit • URP: International Research Unit • US: Service Unit

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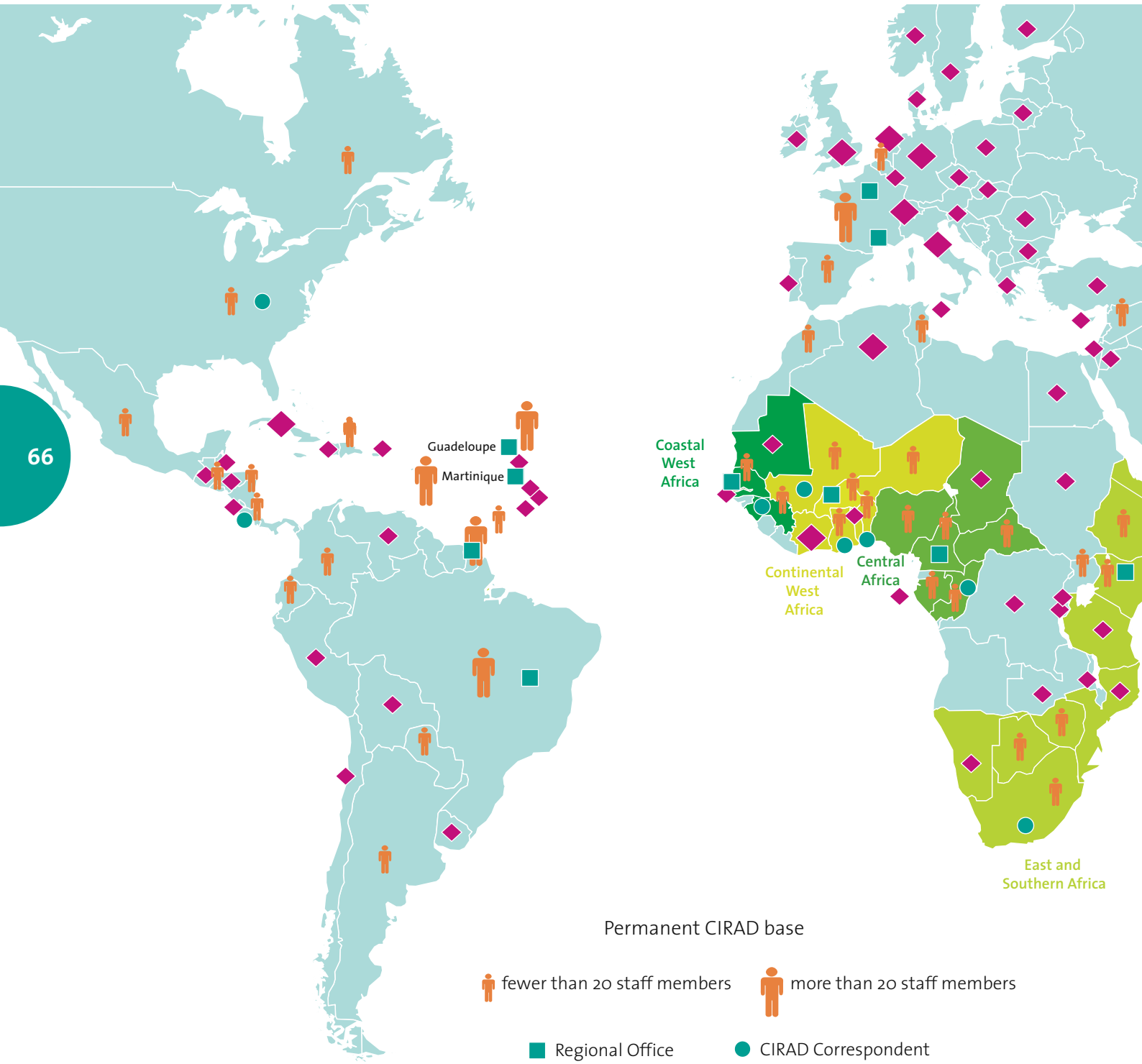

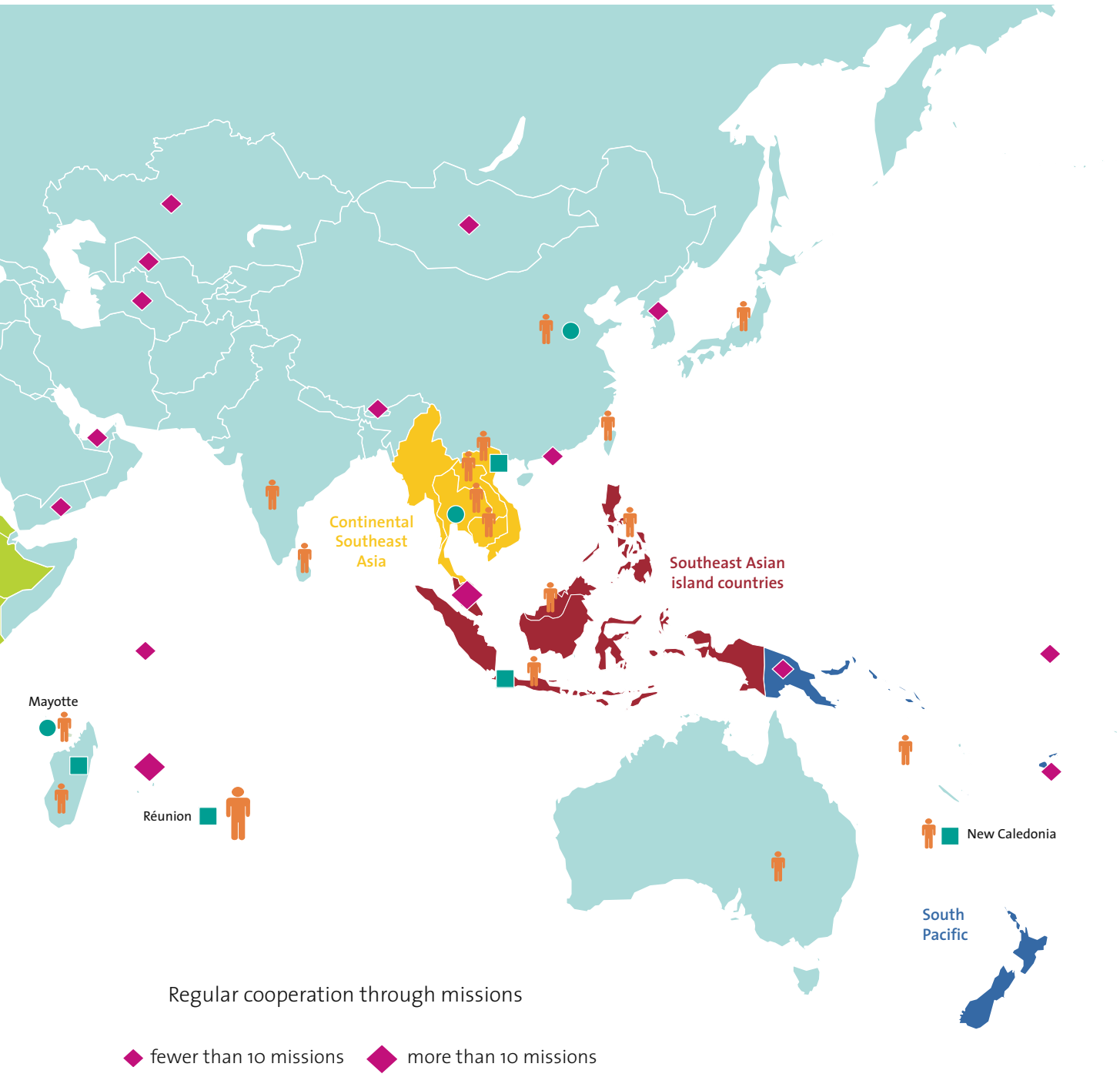
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Réunion
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South Pacific
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fewer than 10 missions
more than 10 missions

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