



CIRAD
2007



CIRAD 2007





CIRAD is a French public establishment specializing in tropical and Mediterranean agriculture, placed under the joint authority of the Ministry of Higher Education and Research and the Ministry of Foreign and European Affairs.

Its operations encompass the life and earth sciences, social sciences and engineering sciences, applied to agriculture, forestry, animal production, food, natural resources and rural territories.

CIRAD has three scientific departments: Biological Systems (BIOS), Performance of Tropical Production and Processing Systems (PERSYST), and Environments and Societies (ES).

It has a staff of 1800, including 800 researchers. It works with more than 90 countries worldwide and has scientific platforms with a regional scope in the French overseas regions. It receives and trains almost 800 researchers and technicians each year.

It has a budget of 203 million euros, with two thirds provided by the French government.

© CIRAD, May 2008

ISBN: 978-2-87614-660-0

EAN: 9782876146600

Foreword

●●●●● As we write, the world is once again having to admit that agriculture, in its broadest sense, is the human race's only source of food, and also one of the keys to fair, balanced global development. How has the importance of rural development and of supporting the whole range of farmers—despite the complexity of the interactions between them—gradually come to be almost completely overlooked when deciding on the aid to be provided to the least advanced countries? Current events have borne out—if indeed that were necessary—the World Bank's recent analysis.

Nowadays, only a tiny part of development aid goes to support agriculture, despite the fact that the vast majority of the world's poorest people live in rural areas: several hundred million, according to FAO. This is a matter of grave concern for the international community. The situation at the start of the millennium is already worrying, so what will it be like in thirty years? In 2030, there will be between 8 and 9 billion mouths to feed worldwide, 2 to 3 billion more than today.

This is a huge issue for every type of farming system. Major technological progress will have to be made if those systems are to succeed in increasing yields despite growing environmental, energy, social and ethical constraints. Above all, the challenge is to guarantee food supplies for all the world's inhabitants. The current food crisis is not a supply crisis, but one of access to the food available, given the increasing fragility of the existing regulatory mechanisms on various levels.

CIRAD's mandate, history and current ambitions place it at the very heart of these issues: the aim is clearly to return agriculture to its rightful place in the fight against poverty and inequality.

The six priority lines of research CIRAD has chosen for the coming years—ecological intensification; biomass energy; food; animal health and emerging diseases; public policy; and rural areas—echo this belief. They fit in with the organization's strategic orientations, which the Board of Trustees approved unanimously at its December meeting, and are supported by its new structure.

The strengthening of links with INRA, which continued in 2007, is another step in this direction. The aim is to build a wide range of scientific expertise capable of responding to calls from political bodies and funding agencies in France, Europe and indeed the world over. The creation of the French Initiative for International Agricultural Research (FI4IAR) is proof of the two organizations' determination to play a heavyweight role on the international stage.

The results presented in this year's annual report naturally fit into the topics chosen under the above priority lines of research. They give an insight into the research being conducted by CIRAD's teams and their partners.

Ecological intensification of farming systems is the first of the six lines of research CIRAD has set itself. Biodiversity is the driving force behind ecosystems, enabling them to evolve and adapt. It acts as a link between the ecology of populations and exchange and flow dynamics within the biosphere. An in-depth understanding of these mechanisms is crucial to tomorrow's farming systems, which will have to save on inputs, work to preserve the environment and produce enough to feed all the world's inhabitants.

Health risks are at the heart of the news, with the emergence of epizootics linked to the appearance of biological mutations and increased global travel. These diseases are upsetting the balance built up over a long shared history between man and animals, which has ensured collective resistance, if not total protection. The consequences can be dramatic, on both a human and an economic level. One of the priorities of the strategic orientations is to understand the risks better so as to prevent and control them.

The same questions apply to plants, the challenge being to develop effective phytosanitary control strategies that do not harm the environment. Pesticides have come in for considerable criticism, both for the human health risks they pose and for the environmental damage and economic costs they generate. Finding ways of producing healthy food without adversely affecting the environment is also one of the topics chosen under the new strategic orientations.

Lastly, public policy is now taking greater account of the increasing scarcity of resources and the effects of climate change. Whether the aim is to fight poverty and inequality or manage resources and rural areas in a sustainable way, policies are now being based on specific research. Work is due to be stepped up in this field, to support future change. Where targeted agricultural research for development needs to be looking first and foremost is towards the world's poorest communities, which are the hardest hit by the above changes.

The strategic orientations set out in 2007 mark a new chapter in CIRAD's long history. 2008 looks like being a decisive year for our organization, with the implementation of a whole new strategy.

Foreword > 3

RESEARCH



Exploring and making effective use of biodiversity

A new model **to explain photoperiodism in African sorghum** > 10

Tapping **teak diversity** > 12

Key factors determining the **carotenoid composition in citrus fruit** > 14

Genetic resources of coffee in Ethiopia > 16

Network for plant genetic resource management in the West Indies > 16

A method **to improve plant selection accuracy** > 17

Timber production in French Guiana: what is the impact on the evolution of forest tree species? > 19

International group of scientific expertise on biodiversity > 21



Preventing and managing health risks

Geomatics and epidemiology: **animal diseases from above** > 22

Understanding and preventing **the emergence of bird flu** in developing countries > 24

Preserving fruits without using fungicides > 26

An entomotoxic albumin from peas **in transgenic rice** > 27

Cassiicolin, a toxin **produced by a pathogenic fungus of rubber trees** > 29

Fruit flies, a pest to be reckoned with **in the mango orchards of West Africa** > 31

The cotton aphid: an identity survey > 33



Preserving the environment

Coconut palm, tropical forests, **productivity and carbon flux** > 35

Oscar and Oswald, **computer-assisted weed identification tools** > 37

LIAMA celebrates its 10th anniversary > 38

Borates and vegetable oils—**promising wood preservatives** > 39

A new phytosanitary waste treatment technique > 40

Cotton pests in Mali—**making pesticide management more sustainable** > 41

Climate policies—what are the options? > 43

Woody species indigenous to Réunion—from propagation to planting > 44



Inventing the farming system of the future

- Can **the agroforests of Forest Guinea** be exploited sustainably? > 45
- Building sustainable production systems** in partnership in Brazil > 47
- Mafate, modelling and analysing matter flows** on a territory scale > 48
- Water governance on a catchment area scale** in South Africa > 50
- Resolving disputes over water** in periurban zones of Latin America > 51
- Strengthening producers' organizations in Costa Rica** > 54
- Contracts for **more profitable milk sales** > 56



Overseeing transformations of rural areas

- Olympe—decision support software for farmers** > 58
 - Development-oriented agriculture: a new World Bank report > 59
- Prototyping **innovative crop management systems** advised by experts > 60
 - Fragile states: birth of an international consensus > 61
- GAMEDE: a global model to assess farm operations** > 62
- Streamlining our approaches** to family farming > 64
 - Agri-food enterprises and poverty alleviation in sub-Saharan Africa > 65

CIRAD in a nutshell

- Indicators** > 68
- Partnerships** > 75
- Organisation in April 2008** > 79
- CIRAD worldwide** > 82

The image is a full-page abstract painting. It features a dense composition of palm fronds in various shades of green, from bright lime to deep forest green, with some areas of yellow and blue. The brushstrokes are thick and expressive, creating a sense of movement and texture. In the lower right quadrant, a glass of rum and cola is depicted with realistic shading and highlights, showing the liquid's reflection and the glass's rim. The overall style is reminiscent of mid-century modern tropical art.

RESEARCH

Exploring and making effective use of biodiversity



A new model to explain photoperiodism in African sorghum

Photoperiod sensitivity is a key adaptation of annual crop species in tropical regions. By this mechanism, their growth cycle can be tailored to climatic constraints, especially rainfall. The flowering date may thus be adapted to and independent of the sowing date, thus enabling the plants to avoid water stress at the end of the cycle along with biotic constraints. A new model that accounts for this mechanism has been developed within the framework of PhD thesis research at CIRAD.

●●●●● Many studies have focused on the complexity of the photoperiod sensitivity of sorghum, but none of them has given rise to the development of a single model that could explain this species' phenological plasticity and diversity. A recent study carried out at CIRAD led to the development of an innovative model called Impatience. The underlying concept is inspired from animal behaviour science—when there is an extended wait for a “good” environmental signal, the plant gradually lowers its day length requirements to trigger flowering. This very simple model has been successfully validated for a range of genotypes.

The model has already been implemented for genetic research, in addition to agricultural and ecological applications. In genetics, a plant phenotyping method was developed using this model to parameterize the sensitivity of varieties to the genotypic photoperiod. This plant characterization approach is of interest for molecular genetics studies, via quantitative trait loci (QTLs) or marker-assisted mapping, and thus for breeding genotypes adapted to specific climatic environments. The Impatience model has also been incorporated in the SarraH plant growth simulation model for agroecological applications. The resulting tool can be implemented to identify optimal areas for varietal adaptation by matching their photoperiodic responses to rainy season duration patterns in West Africa.

Moreover, it can be used to analyse the flexibility of cropping calendars according to the site and genotype, and to determine the yield potential and interannual variations.

This research has been underpinned by two complementary studies. The first aims to determine aspects of the agrobiodiversity of African sorghum varieties with respect to different environmental constraints. The second involves an analysis of crop yield build-up according to ideotypes favoured by breeding. The goal is especially to breed varieties that combine a specific photoperiod response profile and an improved harvest index so that the plants will be better adapted to climatic variations and give higher yields.

Due to their unique growth development patterns, photoperiod-sensitive sorghum varieties (generally large-sized) have a small panicle, which results in a low harvest index and poorer yield. Different but related sorghum varieties were compared and the results revealed that photoperiodism associated with a reduction in plant size and late leaf senescence led to a better assimilate distribution, thus boosting the harvest index while also markedly increasing crop yields and their stability. Studies are under way to validate these results with a more substantial dataset. If they confirm the initial trends, the foundations could be laid for a green revolution through breeding of new highly adapt-



Tapping teak diversity

Demand for teak is rising because of its resistance to degradation and aesthetic qualities. Asian natural forests from which this species originated are disappearing or now protected, so marketed teak comes mainly from plantations located in some 30 tropical countries worldwide. A study was carried out to assess how the environment affects teak tree growth and wood quality so as to ultimately be able to provide growers with planting material that will fulfil their specific needs.

●●●●● **The market value of teak** is continuing to rise as this wood is treasured for its resistance to degradation agents, along with its aesthetic and technological features. Natural teak forests in Myanmar, India, Laos and Thailand from which this species originated are disappearing or are now protected. Marketed teak therefore mainly comes from plantations covering an area of 3-4 million ha in Asia (Indonesia, India) and West Africa (Ivory Coast, Togo, Benin, Ghana), where the species was successfully introduced. Private companies have also recently set up intensive teak plantations in Latin America (Brazil, Colombia, Ecuador, Costa Rica), East Africa (Tanzania) and Australia.

CIRAD began research on teak genetics in Ivory Coast through provenance and silviculture trials. This led to the introduction of many teak provenances, while describing the behaviour of teak in plantation growing conditions and generating the first improved varieties. This research was aimed at gaining insight into how

the environment affects teak tree growth, architecture and wood quality. The ultimate goal was to be able to provide growers with planting material—seeds or clones—to suit their specific needs. The studies were focused on teak stands and wood specimens from Ivory Coast, Ghana, Togo, and more recently from Sabah, Malaysia. A few specimens from Myanmar, Brazil, Tanzania and Colombia were also analysed.

Expansion of teak clonal plantations

The first step was to assess tree variability in original teak stands on the basis of high economic impact criteria and to select individual trees that had all of the traits that are sought for seed propagation oriented teak breeding programmes. In addition, clonal plantations have been developed through propagation from cuttings and commercial microcuttings in collaboration with the Malaysian group Yayasan Sabah. These plantations are currently booming and replacing ordinary seed-propagated plantations that have a very low germination rate and are especially heterogeneous.

Teak growers are striving to maximize the return on investment of these clonal plantations by focusing on enhancing teak volume yields and wood quality. New criteria, such as wood physicochemical characteristics, have recently been added to standard criteria to refine the initial selection of individual trees. A study is under way to assess the impact of environmental conditions on the technological properties of teak



Wood samples
from good quality
six-year old teak clones
© O. Monteuis/CIRAD

Partners

Forestry Research Institute of Ghana (FRIG, Ghana), Société de développement forestier (SODEFOR, Ivory Coast), University of Lomé (Togo), Yayasan Sabah Group (Malaysia).

wood. This should ultimately give rise to new top quality varieties, some of which should be sufficiently versatile to be suitable for planting under various environmental conditions.

Wood durability—an essential quality feature

Teak is being logged at an increasingly younger age in plantations, and the wood quality is highly variable in terms of the proportion of sapwood and heartwood, colour, technological properties and resistance to degradation agents. For instance, according to European standards concerning resistance to wood-eating fungi, wood from natural forests are generally ranked in durability class 1 (highly durable) or 2 (durable), whereas it ranges from 1 to 4 (slightly durable) for plantation wood. The natural dura-

bility of wood, which is closely linked with the nature of some of its chemical constituents, depends on the age of the tree, the growing environment and its genome. Hundreds of teak samples from 5-40 year old trees and different origins were tested by CIRAD's wood preservation laboratory. The resulting database can be tapped to determine the natural durability classification of teak specimens using near-infrared spectrometry.

Other studies on growth modelling for yield estimation and molecular genetics studies, etc, have also been carried out in recent years in collaboration with partners in Ivory Coast, Togo and Ghana. The latter studies have already led to the development of a microsatellite marker library that should ultimately help to determine the geographical origins of teak trees on the basis of their DNA. Further studies are also planned on genetic marking for quality control during propagation, clonal identification with respect to commercial features, assessment of gene flows in seed plots and genetic control of target traits.

CIRAD has established many partnerships throughout the sector in several different countries and has gained expertise on teak genetic resources, so it is ideally qualified to conduct research on a broad range of topics concerning top quality teak wood production.

Contacts > Gilles Chaix, Genetic Diversity and Breeding of Forest Species (UPR)
Olivier Monteuis, Plant Development and Genetic Improvement (UMR DAP),
Nadine Amusant, Production and Processing of Tropical Woods (UPR),
gilles.chaix@cirad.fr

For further information

Chaix G., Goh D.K.S., Baillères H., Boutahar N., Monteuis O., 2007. New techniques for upgrading the selection of teak genotypes and their clonal propagation. *In: Processing and marketing of teak wood products of planted forests*, 25-28 September 2007, Peechi, India.

Goh D.K.S., Chaix G., Baillères H., Monteuis O., 2007. Mass production and quality control of teak clones for tropical plantations: the Yayasan Sabah Group and CIRAD joint project as a case study. *Bois et forêts des tropiques*, 293: 65-77.



An 18-month-old Malaysian teak clone planting, in Brazil
© G. Chaix/CIRAD



Key factors determining the carotenoid composition in citrus fruit

Citrus fruits have an especially high carotenoid content. Carotenoids give them their colour, taste and many nutritional qualities. Findings of a series of studies carried out by CIRAD revealed a correlation between the carotenoid composition of different species and the structure of genetic diversity within the *Citrus* genus.

●●●●● **Carotenoids are key factors responsible** for the organoleptic and nutritional qualities of citrus fruits. They form one of the largest plant pigment classes, and citrus fruits have an especially high and complex carotenoid composition. Over 100 different carotenoid molecules have been isolated in *Citrus*. CIRAD has carried out a series of studies on the carotenoid composition of different species and its links with the genetic diversity structure within the *Citrus* genus, the metabolic pathways of these compounds and the environmental conditions.

Substances with a broad range of properties

Carotenoids are responsible for the internal and external yellow, orange or red colour of citrus fruits. For instance, β -cryptoxanthin gives clementines and mandarin oranges their typical bright orange colour, whereas lycopene gives some pummelo varieties their red colour. The carotenoid composition of citrus fruits is therefore one of the main factors responsible for the organoleptic quality of fresh citrus fruits and juices.

Carotenoids are also micronutrients with many different biological functions. Carotenoids include provitamins A, ie vitamin A precursors that are essential for vision, epithelial tissue preservation, bone growth and reproduction. In developed countries, 25-35% of dietary vita-

min A is supplied via carotenoids through fruit and vegetable consumption, while this figure reaches as high as 82% in developing countries. Carotenoids are also antioxidants and thus able to prevent some cancers and cardiovascular diseases. Finally, lutein and zeaxanthin, which are xanthophyllic carotenoids, occur in orange and mandarin pulp and have an important role in vision, especially in the prevention of age-related macular degeneration.

Diversity associated with the history of citrus crops

CIRAD's research findings have shown that the carotenoid composition of citrus fruits is structured in three groups: the first includes mandarins and sweet and sour oranges; the second, grapefruits and pummelos; and the third, citrons, lemons and limes. This organization, which is very close to the overall genetic structure of the *Citrus* genus, suggests that the genetic differentiation that gave rise to the interspecific carotenoid content structure took place before the formation of secondary species—oranges, pummelos, lemons, limes and sour oranges—from three basic taxa of cultivated forms, ie mandarins, pummelos and citrons.

Carotenoid biosynthesis pathways are well known in plant species. Expressed sequence tags (ESTs) of genes encoding enzymes in this pathway have been isolated and sequenced

Partners

Corsica Regional Council,
Institut national de la
recherche agronomique
(INRA, France),
Instituto Valenciano de
Investigation Agrarias
SIVIA (Spain), University
of Corsica.

for different species, including citrus fruits. CIRAD studies have shown that the interspecific carotenoid content diversity structure in citrus fruits is associated with five key steps in this biosynthesis chain. The mandarin and orange group is the only one to explore all the carotenoid biosynthesis pathways with a high level of provitamin A components. Very little carotenoid synthesis takes place in the citron group. Apart from lycopene, they do not synthesize xanthophylls, and stop at β -cryptoxanthin on the other chain branch. Genotypes of the pummelo group only synthesize carotenes: phytoene, phytofluene, lycopene and β -carotene, generally in low quantities. These findings suggest that steps that occur in the upper part of the chain are limiting for the grapefruit and citron group. Steps catalysed by lycopene cyclases (LCy b and LCy e) also contribute to this interspecific differentiation, along with β -carotene hydroxylase (HY b) and zeaxanthin epoxydase (ZEP), which are involved in the formation of β -cryptoxanthin and *cis*-violaxanthin from β -carotene.

A phylogenetic origin of alleles in cultivated species has been proposed for four out of seven analysed genes. The allelic variability in two genes, ie *Lcy-b* and *Lcy-e*, which code for the two lycopene cyclases involved in the formation of α - and β -carotene from lycopene could be linked to the phenotypic diversity. Variability in the other key steps is likely to be associated with the different expression levels of the corresponding genes. Underexpression of the *DXS* and *PSY* genes that encode DOXP synthase and phytoene synthase, which are located in the upper part of the biosynthesis chain, is associated with the overall low carotenoid contents in grapefruit and lemon. Moreover, the absence of

β -cryptoxanthin and corresponding molecules in the pummelo group would be linked with underexpression of the *HY-b* gene.

Expression variations according to the environment

Environmental conditions also have a role in determining carotenoid contents. In the mandarin and orange group, Mediterranean cropping conditions boost interspecific differentiation by reinforcing β -carotene and β -cryptoxanthin contents in mandarins, as well as lutein, zeaxanthin and violaxanthin contents in sweet oranges. Conversely, lycopene accumulation is greater in Star Ruby pummelos under tropical environmental conditions.

The nutritional quality of citrus fruits and juice will be a major issue for citrus growing in the future, and should thus be taken into account in breeding programmes geared towards developing innovative new varieties. Findings on factors that determine its variability will pave the way for genetic improvements that are targeted to different citrus-growing regions.

Contact > Patrick Ollitrault, Genetic Improvement of Vegetatively Propagated Crops (UPR), Claudie Dhuique-Mayer, Integrated Food Quality System (UMR QUALISUD), patrick.ollitrault@cirad.fr

For further information

Dhuique-Mayer C., 2007. Evaluation de la qualité nutritionnelle des jus d'agrumes : estimation in vitro de la biodisponibilité des caroténoïdes. PhD thesis, University of Montpellier II, 114 pp.

Dhuique-Mayer C., Borel P., Reboul E., Caporiccio B., Besançon P., Amiot M.J., 2007. Beta-cryptoxanthin from Citrus juices: assessment of bioaccessibility using an in vitro digestion/Caco-2 cell culture model. *British Journal of Nutrition*, 97: 883-890.

Fanciullino A.L., 2007. Etude des déterminants génétiques et moléculaires de la variabilité des compositions en caroténoïdes au sein du genre *Citrus*. PhD thesis, University of Corsica, 188 pp.

Fanciullino A.L., Dhuique-Mayer C., Luro F., Morillon R., Ollitrault P., 2007. Carotenoid biosynthetic pathway in the *Citrus* genus: number of copies and phylogenetic diversity of seven genes. *Journal of Agricultural and Food Chemistry*, 55: 7405-7417.

The variations in citrus fruit colour are primarily due to their carotenoid content
© A.L. Fanciullino/CIRAD





Genetic resources of coffee in Ethiopia



Coffee trees in Harerge, Ethiopia
© J.-P. Labouisse/CIRAD

Partners

Centro Agronómico Tropical de Investigación y Enseñanza (CATIE, Costa Rica), Ethiopian Institute of Agricultural Research (EIAR, Ethiopia), Institut de recherche pour le développement (IRD), Jimma Agricultural Research Center (JARC, Ethiopia), University of Montpellier II.

The centre of diversity of *Coffea arabica* is located in the natural rainforests that stretch across the high plateaus of southwestern Ethiopia. Coffee is currently harvested from trees in their natural habitat, but also more intensively in traditional gardens and modern plantations. The diversity of ecological conditions, plant material, cropping methods and farmers' practices has given rise

to a range of different coffees with sensorial traits that are specific to each growing region. Ethiopian coffee trees represent the main source of *Coffea arabica* diversity. They have been the focus of several collection surveys conducted to build up international germplasm collections that can be tapped by coffee breeders. These accessions are used as parent material to propagate—via crosses with commercial varieties—F1 hybrids that are resistant to pathogens (nematodes, diseases) and produce coffees with excellent taste quality.

CIRAD has been conducting research for several years on coffee origins and genetic diversity using

molecular markers and biochemical phenotyping by near-infrared spectrometry. As part of a coffee improvement project in collaboration with EIAR, CIRAD has developed a database to manage the passport data of over 5 000 coffee accessions preserved in research stations throughout Ethiopia. Through this ongoing collaboration, studies are under way on coffees collected in various coffee-growing regions of Ethiopia.

Contact > Jean-Pierre Labouisse, Plant Resistance to Parasites (UMR RPB), jean-pierre.labouisse@cirad.fr

Bertrand B., Vaast P., Alpizar E., Etienne H., Davrieux F., Charmetant P., 2006. Comparison of bean biochemical composition and beverage quality of Arabica hybrids of Sudanese-Ethiopian origins with traditional varieties at various elevations in Central America. *Tree Physiology*, 26: 1239-1248.

Labouisse J.P., 2007. Les systèmes de culture et les ressources génétiques du caféier *Coffea arabica* L. Montpellier, CIRAD (CD-ROM).

Labouisse J.P., Bellachew B., Hamelin C., Kotecha S., Bertrand B., 2007. Collection and ex situ conservation of coffee landraces in Ethiopia: the example of Harerge. *In: XXIst International Conference on Coffee Science*, Montpellier, 11-15 September 2006. Montpellier, ASIC, p. 926-930.



Network for plant genetic resource management in the West Indies



A bunch of wild *Musa acuminata* bananas
© C. Jenny/CIRAD

CAPGERNET* is a network that was recently set up in the West Indies following a workshop funded by Bioversity International and the Caribbean Agricultural Research and Development Institute (CARDI), which was held within the framework of a Global Crop Diversity Trust (GCDDT) initiative in Trinidad and Tobago. The aim is to promote management and long-term conservation of plant genetic resources in the Caribbean region. CIRAD is an active participant in this network and was asked to manage collections of two species on the FAO list of Plant Genetic Resources for Food and Agriculture (PGRFA), ie bananas and yams (in collaboration with INRA for this latter crop). In this workshop, it was also recommended that CIRAD's pineapple germplasm collection be safeguarded and that this

species be added to the FAO list. This is an acknowledgement of the quality of CIRAD's genetic resource management work in the French West Indies. It also confirms the importance of the Centre de ressources biologiques sur les plantes tropicales, which was founded by CIRAD and INRA in Guadeloupe and Martinique to promote the conservation and dissemination of genetic resources.

* CAPGERNET: Caribbean Plant Genetic Resources Network.

Contact > Christophe Jenny, Genetic Improvement of Vegetatively Propagated Crops (UPR), christophe.jenny@cirad.fr

<http://collections.antilles.inra.fr/BRCPortal/>



A method to improve plant selection accuracy

In arid regions, rainfall varies markedly between years, so it is especially hard to decide on the best varieties. The choice of the best varieties is generally based on multilocation trials lasting three years on average, which is too short to obtain varieties that would be well adapted to such unstable environments. A new method has been developed at CIRAD to improve selection efficiency and draw up recommendations tailored to each specific situation. This method can predict genotype x environment interactions on the basis of historical or simulated rainfall data in locations where the new varieties have not been tested.

●●●●● **The high interannual rainfall variability** that prevails in arid and semiarid regions like the Sahel is a serious constraint when trying to choose the best varieties. Farmers require varieties that will generate a steady income, thus that are not very sensitive to climatic variations. To make the best possible choice, plant breeders test the progenies of their crosses in multilocation trials lasting several years. They usually note a substantial interaction between the genotype and the environment, ie the progenies may be ranked differently depending on the year or the trial

Estimating
the surface temperature
of a groundnut crop
© S. Braconnier/CIRAD



site. Theoretically, when breeding varieties for a target locality, selection should be carried out on a sample of years representing the interannual rainfall variability. In the Sahel, however, where this variability is high, 20 years of testing would be required to be able to compare varieties with sufficient precision. In practice, each variety is monitored for only two-three years, and breeders use the multilocation data to predict the potential behaviour of the variety over several years. This informal geographical-to-temporal deduction step is mainly dependent on the breeder's expertise, but no satisfactory tool has been available to date that could validate the breeder's conclusions.

From simulation of a variety's growth to prediction of its behaviour

Historical meteorological data that account for the interannual climatic variability are nevertheless available for all cropping areas. Plant growth simulation models such as SarraH, which was designed by CIRAD and CERAAS, can predict genotype x environment interactions from these meteorological data. This model simulates a plant cover in its environment, ie growth patterns of a plant and its reaction to water stress, while also simulating the crop water balance. The parameters that control these phenomena are specific to each variety. The SarraH model

Partners

Centre d'étude régional pour l'amélioration de l'adaptation à la sécheresse (CERAAS, Senegal), Institut national de la recherche agronomique (INRA, France), Universities of Montpellier I and Montpellier II (France).

can thus account for an environmental effect that may differ between varieties, ie a variety x environment interaction. However, the parameters of such a model are only available for a few varieties. Specific trials and many observations are required to be able to estimate them for new varieties (model parameterization)—this would be much too expensive to carry out for all varieties during their selection process, some of which will inevitably be discarded.

The APLAT (approximation via linearization in the neighbourhood of a control) method was developed at CIRAD within the framework of the PhD thesis research of a CERAAS scientist. APLAT overcomes this costly parameterization problem as only standard multilocation or multiyear experiments are required. However, in each trial, a control variety with known parameters must be present, and input data for the growth simulations must be recorded. For the SarraH model, a rain gauge should be used in these trials and they should be conducted in the vicinity of a more comprehensive meteorological station. APLAT is based on linearization of the crop's response to variations in SarraH varietal parameters.



Comparing groundnut varieties under different degrees of water stress
© S. Braconnier/CIRAD

The APLAT method can generally be used to predict the behaviour of new varieties in environments where they have not been studied. This generic method permits genotype x environment interaction predictions via any crop simulation model, while avoiding expensive parameterization of the model for these new varieties. It improves the breeding accuracy by offering the operator the possibility of simulating a range of environments representative of soil-climate situations targeted by the breeding programme. It thus enhances plant breeding methods by reducing the impact of climatic

variability on the accuracy of between-variety comparisons.

Conclusive tests in groundnut

APLAT was tested on groundnut varieties using the SarraH model. The data used to validate the method included historical data from selection trials carried out on groundnut over several years at the Bambey research station in Senegal, where climatic data are regularly recorded, as well as data from a multilocation trial carried out at eleven sites in Senegal during the 2005 rainy season. APLAT reduced the confidence intervals for between-variety differences by half for the multilocation trial.

Advances in plant breeding methods have had unexpected spinoffs for chemical analysis. The partial least squares (PLS) regression method had to be extended to trials with several sources of variability (plot, site, year) when implementing APLAT. This mixed PLS extension can also be directly used for a chemical analysis application, ie for calibration of near-infrared reflectance spectrometry (NIRS) absorption measurement methods from collected field data with several sources of variability, such as split plots.

Contacts > Eric Gozé, Annual Cropping Systems (UPR), Ibnou Dieng, AGRHYMET, eric.goze@cirad.fr

For further information

Dieng I., 2006. Mixed PLS models to predict genotype x environment interaction. *In*: XXIIIrd International Biometric Conference, International Biometric Society, 16-21 July 2006, Montreal, Canada.

Dieng I., 2007. Prédiction de l'interaction génotype-environnement par linéarisation et régression PLS-mixte. PhD thesis, University of Montpellier II, 133 pp.

Dieng I., Gozé E., Sabatier R., 2006. Linéarisation autour d'un témoin pour prédire la réponse des cultures. *Comptes rendus de l'Académie des sciences, Biologie*, 329: 148-155.

Dieng I., Gozé E., Sabatier R., 2006. Prédiction de l'interaction génotype-environnement par linéarisation autour d'un témoin : nouveaux résultats pour la méthode Aplat. *In*: 38^e Journées de statistiques, 29 May - 2 June 2006, Clamart, France. Société française de statistique, EDF recherche et développement.



Timber production in French Guiana: what is the impact on the evolution of forest tree species?

In the tropical rainforests of French Guiana, large trees of major commercial timber species, which are often the most reproductive, are cyclically eliminated in selective logging operations. In the long run, this can modify the demography and genetic diversity of populations of these species. CIRAD and partners have developed a forest dynamics model that integrates gene flows to study and predict such phenomena. This model, which can simulate different logging scenarios over periods of hundreds of years, should help to draw up decision-making guidelines to ensure sustainable timber production.

●●●●● **Selective logging** can have various impacts on the demography and genetic diversity of commercial timber species populations. These operations have major consequences by eliminating large reproductive trees, ie reducing the pollen and seed production potential, and increasing the mean distance between reproductive trees. Demography and gene flows may be negatively affected and genetic diversity within the concerned populations can be altered. In contrast, logging also opens the canopy, thus increasing the light

availability for all forest strata, which can stimulate the survival and growth of young trees, and in turn offset the loss of the largest trees.

Sustainable timber production therefore depends on the balance between the two phenomena, and forest managers require decision-making guidelines to enable them to preserve timber species populations and their genetic diversity in the long term. CIRAD and partners have developed prediction models to simulate forest dynamics and gene flows for several biological model species to be used as tools for studying and quantifying the effects of logging in French Guiana and for drawing up decision-making guidelines.

Model for basralocus

The most comprehensive model currently available was designed for basralocus (*Dicorynia guianensis*), a major commercial species. It was designed on the basis of data concerning the life cycle of the species, from seed production to adult mortality, and gene flows, derived from genotyping most of the reproductive and juvenile trees in a plot at the Paracou field station. In the model, the spatiotemporal dynamics of a basralocus population interacts with the dynamics of populations of all other forest tree species, whose life cycle descriptions are not as detailed. All of these models were inte-

Basralocus seedling at the Paracou silvicultural test facility, in French Guiana
© H. Wernsdörfer/CIRAD



Partners

AgroParisTech (France),
Bureau des ressources
génétiques (BRG, France),
Groupement d'intérêt
public Ecosystèmes
forestiers (GIP ECOFOR,
France), Institut national de
la recherche agronomique
(INRA, France), Muséum
national d'histoire
naturelle (France)

grated under the name Selva in the CAPSIS* tree growth and forest dynamics simulation software platform.

Selva can simulate different logging scenarios, eg by adjusting the minimum diameter cutting limit or the length of the logging cycle, and assess changes in demographic and genetic characteristics of the basalocus population relative to its natural undisturbed evolution.

Enhancing prediction

These studies generated essential data on the basalocus life cycle, but all aspects have not yet been covered sufficiently, eg data to accurately describe the mortality at different development stages are still lacking. These imperfections could lead to model prediction uncertainties. A sensitivity analysis revealed that mortality in the juvenile phase is the process that has the greatest effect on the predictions. Recalibration of

this component from a broader database could enhance the prediction reliability, which should be a priority for the coming years. The model could also be improved by explicitly describing the stimulation of basalocus juvenile survival and growth after opening of the canopy by logging or natural tree falls.

Forest dynamics, gene flows and logging

In the model, gene flows are associated with several forest dynamics processes: seed production, which increases with the size of the reproductive tree; spatial seed dispersal patterns; and the survival and growth of trees at different stages. Selective logging affects these relationships by eliminating the largest reproductive trees. Simulations performed to date indicate that logging leads especially to reductions in population sizes, whereas the impact on genetic diversity does not seem to be as serious. Decision-making guidelines that are poorly adapted to the basalocus demography features could thus affect the future of this species—more by reducing its regeneration potential than by depleting its genetic base.

* CAPSIS: Computer-Aided Projection of Strategies in Silviculture

Contacts > Holger Wernsdörfer,
Sylvie Gourlet-Fleury,
Dynamics of Natural Forests (UPR),
holger.wernsdoerfer@cirad.fr

For further information

Dreyfus P. *et al.*, 2005. Couplage de modèles de flux de gènes et de modèles de dynamique forestière. Les Actes du BRG, 5: 231-250.

Gourlet-Fleury S. *et al.*, 2005. Using models to predict recovery and assess tree species vulnerability in logged tropical forests: a case study from French Guiana. *Forest Ecology and Management*, 209 : 69-86.

Gourlet-Fleury S. *et al.* (ed.), 2004. *Ecology and management of a neotropical rainforest*. Paris, Elsevier, 311 pp.

Wernsdörfer H. *et al.*, 2008. Sensitivity of a complex forest dynamics model. *Ecological Modelling* (*submitted*).

Adult, reproductive
basalocus tree
© H. Wernsdörfer/CIRAD



● ● ● ● ● International group of scientific expertise on biodiversity



Participants in the Asian regional consultation meeting in Beijing, in September 2007
© IFB-IMOSEB

An international group of scientific expertise on biodiversity—at the science-policy interface—should soon be formed. This is the conclusion of the International Steering Committee of the consultation process towards an International Mechanism of Scientific Expertise on Biodiversity (IMoSEB) at the second meeting that was held in Montpellier (France) in November 2007, following two years of international consultations. Since 2005, the Executive Secretariat of the Consultative process, which was entrusted to the Institut français de la biodiversité (IFB), is hosted at CIRAD.

This initiative is focused on creating an international group of expertise with a status and audience com-

parable to that of the International Panel on Climate Change (IPCC). The aim of this new group will be to disseminate scientific expertise on biodiversity, with the backing of an international network of scientists and experts, to all types of private and public decision-makers. It will also have the capacity to quickly provide scientific expertise on specific questions, especially in ecological crisis situations, eg emerging diseases, biological invasions, severe pollution, etc. The group will have a hybrid structure, with a strong intergovernmental component, while integrating other biodiversity stakeholders, such as international organizations, conventions and major NGOs.

The next step towards the founding of this group will be an intergovernmental meeting to be held under the auspices of the United Nations Environment Programme (UNEP) to discuss governance, operational and funding modalities. The mechanism will be presented during the Conference of the Parties to the Convention on Biological Diversity to be held in May 2008 in Bonn, Germany. IMoSEB should take effect by late 2008.

Contact > Didier Babin,
Forest Resources and Public Policies (UPR),
didier.babin@cirad.fr

Loreau M. *et al.*, 2006. Diversity without representation. *Nature*, 442: 245-246.

www.imoseb.net

Preventing and managing health risks



Geomatics and epidemiology: animal diseases from above

Geomatics, a discipline that deals with spatially referenced data, has been used in epidemiology for several years now, to observe the spatiotemporal distribution of diseases and identify environmental risk factors. It is used in numerous CIRAD projects, particularly studies of vector-borne diseases. The aim is to determine high-risk zones and periods so as to improve the surveillance and control of such diseases.

●●●●● For several years now, geomatics tools, particularly satellite image processing and geographical information systems, have been used in epidemiology to gain a better understanding of the spatiotemporal distribution of diseases and identify environmental risk factors. Remote sensing, in particular, is often used in studies of vector-borne diseases, since insects, and thus the diseases they carry, are closely linked to the environment. The aim of such studies is to characterize high-risk zones and periods so as to improve animal and zoonotic disease surveillance and control.

Defining environmental indicators

Remote sensors measure the electromagnetic radiation emitted or reflected by objects on the Earth's surface and structure that information in the form of images: each pixel of an image, which corresponds to a given area, takes on the value of the radiation measured within that area. Various processing methods are used to link that measurement to a relevant environmental characteristic, in order to describe how the disease and its vector are distributed. Each stage relies on geomaticians, entomologists and epidemiologists working together to define the environmental indicators that are of ecological significance in the epidemiological cycle of the disease: depending on the target indicator, different images may be used.

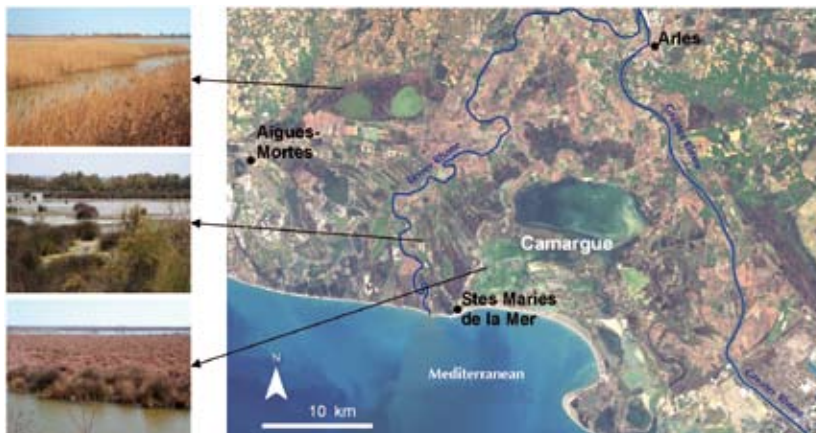
For instance, in studies of mosquito-borne diseases, high spatial resolution data have been

used to detect the humid zones propitious to mosquito reproduction. In the case of West Nile virus, the humid environments of the Camargue, the Danube delta and the Senegal River valley include key habitats for both the mosquito vector and the birds responsible for transmitting the disease. In the case of Rift Valley fever, the vectors breed in temporary pools in the Sahelian zone of Senegal.

Vegetation maps based on these images can also be used to extract landscape indicators, which reflect the spatial structure and composition of the mosaic of vegetation patches. Indeed, some insects are more sensitive to landscape composition—fragmentation, alternation of open and closed environments, etc—than to

In studies of mosquito-borne diseases, high spatial resolution data have been used to detect humid zones propitious to mosquito reproduction. In the case of West Nile virus, the humid environments of the Senegal River valley. Landsat ETM+ image, 4 November 1999
© NASA Landsat Programme





The humid environments of the Camargue act as contact zones between the birds and mosquitos that may be involved in transmitting West Nile virus: reed marshes, bulrush and rush marshes, "sansouire"
 © A. Tran/CIRAD, Landsat ETM+ image, 25 October 2001
 © Eurimage

the type of vegetation alone. This approach has been taken with the *Culicoides imicola* midge, which transmits bluetongue in the western Mediterranean and which does not seem to be specific to any particular type of vegetation. It has also been carried out with tsetse flies, which carry animal trypanosomosis in Burkina Faso and which are sensitive to human activity in their environment.

Identifying high-risk landscapes

Statistical analyses are required to establish possible links between the presence of a vector and the environmental indicators calculated previously. These analyses reveal the determining parameters, quantify the link and assess its relevance. Geographical information systems can be used at this stage to cross several sources of information and study different types of spatial relations. Finally, the accuracy of the statistical model is assessed to judge its validity.

For instance, a link between the spatial distribution of the midges that carry bluetongue and the environment has been established in a study in southern Corsica. *Culicoides imicola* midges were trapped at 75 sites located by GPS. Within a 500-metre radius of each site, the landscape was described: topography, hydrography, land use and landscape structure. The results showed that two landscape characteristics—the vegetation index and patch richness density—accounted for the presence or absence of midges. The statistical model was validated at 28 sites in the Var département (France), where midge presence and absence data were

compared with the forecasts provided by the model. The results demonstrated that the model discriminated effectively between the traps in which the vector was present and those in which it was not.

Similar analyses for other vectors such as tsetse flies or various species of mosquito (*Culex*, *Anopheles*) revealed strong links between the presence or abundance of these insects and the landscape characterized by remote sensing, hence the possibility of compiling maps of zones that are potentially propitious to those vectors. Such studies provide information on vector bioecology by identifying the environmental conditions that favour their development. Provided the link between the vector and the environment is significant, it is possible to use remote sensing data to extrapolate the results of one-off insect trapping operations to large zones. The vector distribution maps obtained serve to target insect surveillance or vector control operations more effectively. For instance, the most dangerous landscapes identified in the case of animal trypanosomosis in the Mouhoun basin in Burkina Faso account for just 21% of the 700 kilometres of river. Lastly, characterizing vector habitats is the first step towards disease risk modelling, which combines the presence and characteristics of the vectors with those of the hosts.

Contact > Annelise Tran,
 Integrated Wildlife Management (UPR),
 annelise.tran@cirad.fr

For further information

Guerrini L., Bouyer J., 2007. Mapping African animal trypanosomosis risk: the landscape approach. *Veterinaria Italiana*, 43: 643-654.

Guis H. *et al.*, 2007. Use of high spatial resolution satellite imagery to characterize landscapes at risk for bluetongue. *Veterinary Research*, 38: 669-683.

Soti V. *et al.*, 2007. Landscape characterization of Rift Valley Fever risk areas using very high spatial resolution imagery: case study in the Ferlo area, Senegal. *In: GISVet conference*, 20-24 August 2007, Copenhagen, Denmark.

Tran A. *et al.*, 2007. The use of remote sensing for the ecological description of multi-host disease systems: a case study on West Nile virus in southern France. *Veterinaria Italiana*, 43: 687-697.

Partners

Centre international de recherche-développement sur l'élevage en zone subhumide (CIRDES, Burkina Faso), Danube Delta Institute (DDI, Romania), Entente inter-départementale pour la démontstration du littoral méditerranéen (EID-Méditerranée, France), Institut de recherche pour le développement (IRD, France), Institut Pasteur (France, Senegal), Institut sénégalais de recherches agronomiques (ISRA, Senegal), Louis Pasteur University (France), University of Franche-Comté (France), University of Liverpool (United Kingdom), University of Louvain-la-Neuve (Belgium).



Understanding and preventing the emergence of bird flu in developing countries



Various techniques are used to capture wildfowl: capturing blue-winged teals using a Japanese net in the inner delta of the Niger River, in Mali
© P. Poilecot/CIRAD

Bird flu is a highly contagious cosmopolitan viral disease. In 1997, a highly pathogenic H5N1-type virus became established in Southeast Asia, spreading to Europe in 2005 and Africa in 2006. There are still many questions surrounding how it spreads and survives in the environment, and its epidemiological cycle. In the hope of finding answers, CIRAD launched right at the start of the crisis a set of research projects aimed at understanding the virus better and at anticipating its spread.

Bird flu, or more precisely avian influenza, is a highly contagious cosmopolitan viral disease that causes high mortality among birds. In 1997, a highly pathogenic H5N1-type virus (HPAI) became established in Southeast Asia, spreading to Europe in 2005 and Africa in 2006. Since the start of the crisis, CIRAD has been coordinating research projects on the virus and the disease, and has been involved in risk analysis and wild and domestic fowl surveillance missions. It has also been assessing surveillance systems and control methods, two crucial weapons in the fight against the virus.

Virus ecology and wildfowl surveillance

Migratory water birds, particularly ducks and waders, are natural reservoirs of the avian influenza virus and consequently may carry the H5N1 strain. However, their true role in the spread of the virus is still controversial. In 2005, FAO, in partnership with CIRAD, launched five regional surveillance projects within the framework of technical aid programmes in Eastern Europe, the Middle East and Africa. More than 16 000 samples, taken from 11 000 wild birds in 19 countries in those regions in 2006 and 2007, have been analysed using the high-speed molecular diagnosis plat-

form in CIRAD's sealed laboratory. Following virus detection using PCR (polymerase chain reaction), genetic analyses were conducted to monitor the spread and evolution of the viruses. Overall, 2% of the birds tested were positive for avian influenza virus, with a prevalence of up to 14% in some species, but the H5N1 virus was not detected. Fourteen strains of the low-pathogenic virus were isolated in European migratory bird species, but also in tropical species confined to Africa. There seem to be conditions within tropical and subtropical ecosystems that favour avian influenza virus transmission, which may play a role in the ecology of these viruses within the Afro-Eurasian system.

Analysing the risks and assessing control measures

In addition to such analyses, it is possible to determine which control measure to apply by estimating the risks of virus introduction and spread: introduction via wild birds, import, spread via infected birds and virus survival in the environment. For instance, analysis tools developed by CIRAD have been used to demonstrate that in Ethiopia, there is little, if any, risk of the virus being introduced via local cross-border trade and migratory bird movements.

Partners

Agence française de sécurité sanitaire des aliments (AFSSA, France), Central veterinary laboratory (Mali), Centre international de recherche-développement sur l'élevage en zone subhumide (CIRDES, Burkina Faso), Centre national d'élevage et de recherches vétérinaires (CNERV, Mauritanie), Centre national de la recherche appliquée au développement rural (FOFIFA, Madagascar), Ecole inter-Etats des sciences et médecine vétérinaires (EISMV, Senegal)...

... Food and Agriculture Organization of the United Nations (FAO, Italy), Hanoi Agricultural University (HAU, Vietnam), Institut national de la recherche agronomique (INRA, France), Institute of Policy and Strategy for Agriculture and Rural Development (IPSARD, Vietnam), Istituto zooprofilattico sperimentale delle Venezie (IZS, Italy), National Animal Health Diagnostic and Investigation Center (NAHDIC, Ethiopia), National Institute for Animal Husbandry (NIAH, Vietnam), National Institute for Veterinary Research (NIVR, Vietnam), Office national de la chasse et de la faune sauvage (ONCFS, France), Onderstepoort Veterinary Institute (OVI, South Africa), Royal Veterinary College (RVC, United Kingdom), veterinary services (Zimbabwe, Ethiopia), Wetlands International (Netherlands), World Organization for Animal Health (OIE, France).



Avian influenza viruses concentrate in the trachea and cloaca of birds, from which samples are taken to measure virus circulation: taking a cloacal swab from a wild bird in Mali
© A. Caron/CIRAD

Finally, the last component of CIRAD's operations in this field, assessment of control methods, makes it possible to adjust the resources devoted to control to the actual risk. In Vietnam, where more than 50 million poultry birds have been slaughtered since the start of the epizootic and 93 human cases have been reported, the

government launched a mass vaccination campaign in 2005, which significantly reduced the number of outbreaks but did not stop the virus from circulating. CIRAD has launched studies to assess surveillance systems and control measures in place in the country and to assess their socioeconomic impact. In collaboration with FAO, commercial and village farm surveillance systems have been reinforced, to improve early detection and declaration of outbreaks. The number of notifications increased significantly in 2007 in the provinces where the system existed. A socioeconomic study of smallholdings revealed a direct link between the benefits of vaccination and farmers' attitudes in the event of an epizootic. Indeed, it showed that farmers sometimes prefer to sell dead or slaughtered birds at a lower price, to limit their financial losses, and that this type of behaviour has a significant impact on the efficacy of control measures and plays a major role in maintaining the disease. Other factors

Training and communication

Since 2004, CIRAD has been designing computer learning tools in the field of epidemiology, and organizing training sessions in virological and molecular diagnosis, quality assurance in laboratories in the South, wildfowl capture and sampling. In 2007, it organized workshops on risk analysis and surveillance of avian influenza and other cross-border diseases, under OIE regional projects. These training operations are based on a multidisciplinary approach, and include practical applications with CIRAD computer learning tools, such as RANEMA* and a specific module for avian influenza, RANEMA-Flu, developed with FAO.

* RANEMA: Remise à niveau en épidémiologie des maladies animales (refresher course in animal disease epidemiology)

also have a direct effect on the efficacy of campaigns at national level, such as the differences in how national policy is applied by the various provinces. A model is being developed to assess vaccination strategies, in order to assess the financial impact and potential efficacy of more targeted control strategies. Similar work is planned in Mali, Ethiopia and Madagascar, under the Gripavi* project.

* Gripavi: a French Ministry of Foreign and European Affairs project on the ecology and epidemiology of avian influenza in developing countries.

Live research

A bilingual web platform, FluTrop (<http://avian-influenza.cirad.fr/>), has been developed by CIRAD in partnership with the Ministry of Foreign and European Affairs and FAO. It presents the activities and research on avian influenza being conducted by CIRAD and its partners: work progress, research projects and current and future surveillance missions. Databases on worldwide poultry production, trade and avian influenza viral strains are due to be compiled shortly.

Contact > Marie-Isabelle Peyre, Animal and Integrated Risk Management (UPR), marisa.peyre@cirad.fr

For further information

Desvaux S. *et al.*, 2007. Field surveillance model for HPAI in Vietnam in a vaccination context. *In: XIIIth International Conference of the Association of Institutions for Tropical Veterinary Medicine*, 20-22 August 2007, Montpellier, France.

Gaidet N. *et al.*, 2007. Avian influenza viruses in water birds, Africa. *Emerging Infectious Diseases*, 13: 626-629.

Goutard F. *et al.*, 2007. Conceptual framework for avian influenza risk assessment in Africa: the case of Ethiopia. *Avian Diseases*, 51: 504-506.

Phan Dang T., Desvaux S., Renard J.F., Vu Dinh T., Roger F., Peyre M., 2007. Cost-benefit analysis of mass vaccination campaign against H5N1 in small scale production systems in Vietnam. *In: XIIth International Conference of the Association of Institutions for Tropical Veterinary Medicine*, 20-22 August 2007, Montpellier, France.



Preserving fruits without using fungicides



© J.-C. Maillard/CIRAD

In general, to preserve tropical fruit and vegetables during transport and storage, exporters use chemical fungicides, which prevent the development of fungi that adversely affect product quality. However, certain natural molecular complexes, such as the lactoperoxidase system (LPS), which is found naturally in milk, could have the same effect.

CIRAD researchers have tested the antifungal efficacy of the LPS, using the enzyme in either free form—in direct contact with the fruit to be treated—or fixed form—ie using only the specific ions generated by the active enzyme system. Its efficacy differs depending on whether the enzyme is free or not, and on the stability of the ions produced, which itself varies depending on environmental conditions. To improve the performance of the LPS, stabilize the ions produced and improve the reproducibility of the effects, researchers are also testing other active natural molecules of plant origin, which could work in synergy with the LPS.

This research, which should eventually serve to reduce the use of synthetic fungicides during fruit

and vegetable postharvest processing operations, is of value to fruit production chains in developing countries while also preserving the environment and consumer and producer health.

Contact > Marie-Noëlle Ducamp, Integrated Food Quality System (UMR QUALISUD), marie-noelle.ducamp-collin@cirad.fr

Le Nguyen D.D., Ducamp M.N., Dornier M., Montet D., Loiseau G., 2006. Effect of the lactoperoxidase system against three major causal agents of diseases in mangoes. *Journal of Food Protection*, 68: 1497-1500.

Le Nguyen D.D., Ducamp-Collin M.N., Dornier M., Montet D., Reynes M., Loiseau G., 2006. Evaluation of lactoperoxidase system treatment to reduce anthracnose, stem-end rot and bacterial black spot development during storage of mangoes. *Journal of Food Protection*, 68: 1671-1675.

Sagoua W., Ducamp-Collin M.N., Loiseau G., De Lapeyre de Bellaire L., 2007. Effect of the lactoperoxidase system on bananas *Colletotrichum*. *Journal of Food Protection (submitted)*.

Partners

Bioserae firm, Tshwane University of Technology (South Africa), United States Department of Agriculture (USDA).



An entomotoxic albumin from peas in transgenic rice

Rice weevils are the main pest affecting grain stocks in developing countries. They are primarily eradicated by chemical treatments, which are now banned or to which the insect has already developed resistance. In the absence of any effective biological treatments or known natural resistance in rice, CIRAD is looking into the possibilities offered by an entomotoxin found in peas, whose expression was recently achieved in transgenic rice.

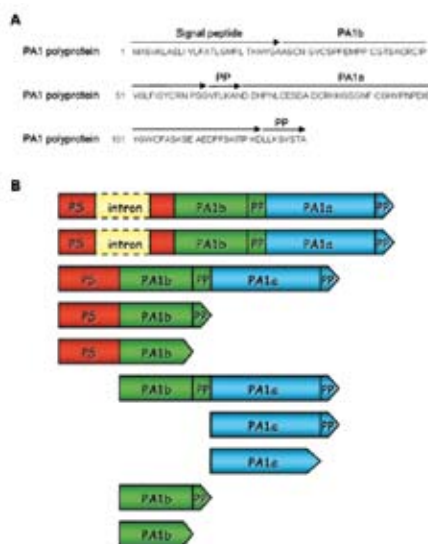
●●●●● The rice weevil, *Sitophilus oryzae*, affects grain stocks in developing countries. The coleopteran is primarily controlled by chemical treatments, which were banned in the Montreal Protocol or to which it has already developed resistance. The remanence of the available biological treatments is poor and their efficacy limited, as they cannot reach the larvae inside rice grains. Lastly, the lack of any known varietal resistance in rice means that varietal improvement is pointless.

An entomotoxin that works against weevils

A new entomotoxin, PA1b (*pea albumin 1 subunit b*), effective against insects of various orders, notably cereal weevils and flour moths, has been identified in peas. In addition to being highly toxic to these insects, this protein of the albumin family contains 16% cysteines and is the main reserve of sulphur amino acids in peas. It is found in large quantities in garden peas and its heat stability means that it remains intact after cooking, even in canned peas.

PA1b is synthesized from a polyprotein, PA1, comprising a signal peptide, proteins PA1b (4 kDa) and PA1a (6 kDa), and their respective propeptides, whose complex maturation also leads to the synthesis of another peptide, PA1a. The conservation of the structure and biological activity of PA1b in Fabaceae makes its isoforms a new family of plant entomotoxins.

To investigate the mechanisms by which an active PA1b toxin is synthesized, CIRAD and its partners decided to study the structure and function of the polyprotein coded by pea gene *pa1* in a large population of transgenic rice plants, into which ten genetic constructs were introduced. The transformants were characterized on a molecular level, to describe the integration and transcription of the transferred sequences. PA1b and PA1a peptide accumulation in the grains was detected by in situ immunological reaction, then by infrared spectroscopy, and



A) In pea, synthesis of the PA1 polyprotein led to the formation of proteins PA1b (37 aa) and PA1a (53 aa) after eliminating the signal peptide (SP) and two propeptides (PP) by proteolytic cleavage

B) Diagram of the various genetic constructs introduced into and studied in rice

Partners

Institut national de la recherche agronomique (INRA, France), Institut national des sciences appliquées (INSA, France), International Rice Research Institute (IRRI, Indonesia), University of the Rio dos Sinos Valley (Unisinos, Brazil).

Patent application registered on 29 October 2007, no. PCT/FR2007/001785, entitled "Utilisation d'une albumine PA1a de légumineuse comme insecticide" (Use of a legume albumin, PA1a, as an insecticide)

elite lines with high peptide PA1b accumulation in the aleurone layer of the grain were selected over several generations of grains. Lastly, studies conducted using Maldi-Tof mass spectrometry demonstrated beyond any shadow of a doubt that the PA1b toxin accumulated in the grains showed post-transductional modifications similar to those seen in peas.

Effective, total protection

Trials conducted with *Sitophilus* larvae and adults and second- and third-generation grains showed that the stable accumulation of the PA1b entomotoxin protected rice grains in a similarly effective way as it does peas. Quite unexpectedly, all the grains, even those that only expressed peptide PA1a, were toxic to the weevil: PA1a, which differs from PA1b and whose toxicity had not previously been demonstrated, may thus act in synergy with PA1b and could also, on its own, be a new source of entomotoxic peptides. This discovery led to the joint registration of a patent by CIRAD and INRA in 2007.

Functional analyses of the *pa1* gene in rice have provided a clearer understanding of the role of each domain of the PA1 polypeptide in terms of expression, regulation and entomotoxic activity. The work has also shown that it is possible to give rice grain stocks total protection against

Sitophilus using the *pa1* gene. Under the Génoplatte and Emergence projects funded by the Agence nationale de la recherche, trials are now due to look at other cereal weevils and moths, and also at other organs of the plant, to determine whether PA1 peptides accumulate in those organs and whether they play a protective role against insects in the field. This class of toxins could become a major source of protection against pests.

Contact > Emmanuel Guiderdoni, Plant Development and Genetic Improvement (UMR DAP), emmanuel.guiderdoni@cirad.fr

For further information

Delobel B., Grenier A.M., Gueguen J., Ferrasson E., Mbailao M., 1998. Utilisation d'un polypeptide dérivé d'une albumine PA1b de légumineuse comme insecticide. Patent no. 98-05877, registered in France on 11 May 1998, INRA and INSA, 31 pp.

Petit J., 2006. Etude structure/fonction d'une albumine entomotoxique de type PA1b du pois chez le riz : application à la protection contre le ravageur des stocks *Sitophilus oryzae*. Doctoral thesis, University of Montpellier II, 182 pp.

Petit J., Duport G., Gressent F., Rahbé Y., Guiderdoni E., Breitler J.C., 2007. Utilisation d'une albumine PA1a de légumineuse comme insecticide. Patent application registered on 29 October 2007, no. PCT/FR2007/001785, France, Inra and Cirad, 42 pp.

Transgenic rice in a greenhouse
© E. Guiderdoni/CIRAD





Cassiicolin, a toxin produced by a pathogenic fungus of rubber trees

Corynespora cassiicola, a fungus of the family Ascomycetes, causes a serious leaf disease in rubber trees. The disease appeared in India and Malaysia in the early 1960s and has since gradually spread to the whole of Asia and recently to Africa, causing major yield losses. Molecular analyses of the toxin responsible for the fungus' pathogenicity have revealed an entirely new type of virulence mechanism, offering new prospects for diagnosis and control.

●●●●● *Corynespora cassiicola* is a fungus of the family Ascomycetes that primarily affects tropical zones, where it attacks a very wide range of plant species, including economically important plants such as rubber, soybean, cotton, tomato and cucumber, among others. However, it is selective inasmuch as each strain has its own host range. In susceptible hosts, the fungus causes necrotic lesions on most organs, which affect both growth and yields.

In rubber, *C. cassiicola* causes a leaf disease known as CLFD (*Corynespora* leaf fall disease), which is one of the most serious diseases affecting the crop. The disease was first seen in India and Malaysia in the early 1960s and has since gradually spread to all the Asian producing countries, which account for 94% of global rubber production, and more recently to Africa.

It occurs in sporadic severe epidemics, which sometimes necessitate grubbing up the most susceptible varieties. In view of the cost of chemical treatments and their environmental impact, it is crucial that we look at other control strategies, particularly the creation of tolerant varieties, and we thus need to investigate how the fungus operates.

Cassiicolin: a hitherto unknown toxic molecule

Work began on cassiicolin, the toxin responsible for *Corynespora cassiicola* pathogenicity, under a partnership between CIRAD and the University of Montpellier II, from 1994 to 2000, and was resumed by CIRAD in 2002. The development of an improved purification process, in conjunction with INRA, eventually led to the full molecular characterization of the toxin. Cassiicolin is a small protein with just 27 amino acids, folded in an unusual structure stabilized by three disulphur bridges, with a sugar group on the second amino acid. It is derived from a larger protein, procassiicolin, whose gene was isolated during the work. No sequence homology with other proteins or genes was detected, but its three-dimensional structure bears similarities with other molecules, albeit without any established functional links.

Leaf symptoms of the disease caused by the fungus *Corynespora cassiicola* on a young rubber seedling
© L. Vaysse/CIRAD



Symptoms of *Corynespora cassiicola* on a rubber tree leaf © L. Vaysse/CIRAD



Partners

Centre d'études atomiques (CEA, France), Centre de biochimie structurale (CBS, France), Centre national de la recherche scientifique (CNRS, France), Institut de génétique fonctionnelle (IGF, France), Institut national de la recherche agronomique (INRA, France), Malaysian Rubber Board (MRB, Malaysia), State University of Maringá (Brazil).

This is both disappointing and exciting. Disappointing, because this new structure does not immediately explain how the toxin works; and exciting, because cassiicolin is a new, original model in the field of host-pathogen interactions, and more particularly of "host-selective" toxins (HSTs). In effect, most of the host-selective toxins described to date are not proteins but very small molecules generated by a complex assembly process. Only two protein HSTs, produced by conventional ribosome synthesis, had previously been described (toxins produced by the wheat pathogens *Pyrenophora triticii-repentis* and *Stagonospora nodurum*). However, they do not have any homology with cassiicolin either. We are indeed looking at a new virulence mechanism.

Three-dimensional structure of cassiicolin, the toxin responsible for *Corynespora cassiicola* pathogenicity
© CIRAD



Promising prospects for diagnosis and control

This work paves the way for several applications and new lines of research. As regards its applications, a DNA test based on detecting the cassiicolin gene in leaf samples could be developed, to diagnose the existence in plantations of potentially virulent *C. cassiicola* strains. A simple susceptibility test could also be developed: by applying the purified toxin to detached leaves, it would be possible to assess the susceptibility of a given rubber variety to the disease. In effect, susceptibility to purified cassiicolin fully reflects susceptibility to the fungus strain from which it came. However, it is important to remain vigilant, as the existence of distinct *C. cassiicola* races, possibly involving different toxins, cannot be ruled out. This hypothesis could be checked by analysing the range of toxins within a large collection of strains.

In terms of research, it may now be possible to pinpoint the specific susceptibility factor

carried by the plant by using cassiicolin to trap its molecular target. In effect, in the case of plant-pathogen interactions involving host-selective toxins, a specific susceptibility factor carried by the plant generally corresponds to each virulence factor carried by a fungus, in this case cassiicolin. The eventual aim of such a study would be to select individuals devoid of the susceptibility factor. Furthermore, the work revealed the presence in cassiicolin of a sugar group. What role does it play in toxicity? We know that some of the microorganisms already used successfully for biological control are capable of inactivating fungal toxins by deglycosylation, ie by breaking down the sugar residues attached to proteins. The answer to this question should shed light on research aimed at developing new control strategies.

This work, which combines biochemistry, molecular biology and plant pathology, demonstrates the merits of a multidisciplinary approach. The fact that we now have a purified toxin and the corresponding gene offers new, interesting prospects for the development of diagnostic and breeding tools and for the drafting of new control strategies against the fungus.

Contact > Valérie Pujade-Renaud,
Plant Development and Genetic Improvement (UMR DAP),
valerie.pujade-renaud@cirad.fr

For further information

Barthe P. *et al.*, 2007. Structural analysis of cassiicolin, a host-selective protein toxin from *Corynespora cassiicola*. *Journal of Molecular Biology*, 367: 89-101.

Barthe P., Pujade-Renaud V., Duviau M.P., De Lamotte F., Roumestand C., 2007. Détermination structurale de la cassiicoline, la toxine glycosylée de *Corynespora cassiicola*. *In: XX^e Congrès du GERM, Alénça, France.*

De Lamotte F. *et al.*, 2007. Purification and characterization of cassiicolin, the toxin produced by *Corynespora cassiicola*, causal agent of the leaf fall disease of rubber tree. *Journal of Chromatography B, Analytical Technologies in the Biomedical and Life Sciences*, 849: 357-362.

Pujade-Renaud V., De Lamotte F., Barthe P., Roumestand C., 2007. Fungal phytotoxins: story-case of cassiicolin, a new proteinaceous host-selective toxin from *Corynespora cassiicola*. *In: 40th Brazilian Phytopathological Society Meeting, Maringá, Brazil.*



Fruit flies, a pest to be reckoned with in the mango orchards of West Africa

Mangoes play a major role in the West African economy. During the period between crop harvests, mangoes are a vital part of the diet of rural populations. However, mangoes are also an export crop very popular with European consumers. These assets are under threat from fruit flies, which are a pest to be reckoned with and can severely damage orchards. They are found throughout the mango growing zone and are currently the object of research projects that should give rise to regional-scale control programmes.

●●●●● In the **Sudano-Sahelian countries of West Africa**, mangoes are grown for the local and regional markets, and also for export to Europe. However, producers are faced with outbreaks of fruit flies (Diptera: Tephritidae), which are found throughout West Africa and cause considerable damage in orchards. This explains why control programmes are now drawn up on a regional scale. CIRAD is working on every aspect of the control of these pests, using the experience acquired in

Development of fruit fly damage on a Smith mango
© J.F. Vayssières/CIRAD



Réunion and through its partnerships with IITA in West Africa and COLEACP in Europe.

Considerable harvest losses

In northern Benin (Borgou), in 2006 and 2007, fruit fly damage was estimated in some ten orchards, on the eight most common cultivars, which account for 95% of the areas planted: Gouverneur, Eldon, Dabsha, Kent, Smith, Keitt, Alphonso and Brooks. Some 15% of fruits on average were damaged in April, and up to 80% in mid-June, towards the end of the season. The early cultivar Gouverneur was the least affected, while the late cultivar Brooks suffered the most damage. For Kent and Keitt, which are grown for export, harvest losses were between 60 and 70%. In other West African countries, the damage level apparently runs at well over 50% on average towards the end of the season.

A new Tephritidae species has been detected in West Africa

Six mango fruit fly species of economic significance are found in West Africa. They include *Bactrocera invadens*, a species of Asian origin, which was only discovered in 2004 but has



Female *Bactrocera invadens* on a mango © J.F. Vayssières/CIRAD

since spread rapidly throughout the region. In just a few years, it has considerably exacerbated the damage caused by native species. This invasive species is a formidable pest that attacks around thirty fruit species, including mango, citrus fruit and guava, and several wild species such as crab apple, tropical almond and shea nut. Steps are already being taken in Benin to prevent attacks and control insect levels in the field.

The arrival of this new exotic species in West Africa and the destruction in Europe of numerous containerloads of mangoes because of fruit fly infestation have opened the eyes of international bodies to the problem. The West African Economic and Monetary Union, the World Bank Institute and the European Union are due to intervene in the supply chain shortly, and to support a regional control programme. The European Union also launched a study of the supply chain in 2007, through several consultation operations. The joint intervention of these various bodies should enable the launch

of a research programme covering the whole of the mango supply chain in West Africa

Contact > Jean-François Vayssières,
Integrated Fruit Production (UPR),
jean-francois.vayssieres@cirad.fr

For further information

Ducamp-Colin M.N., Arnaud C., Kagy V., Didier C., 2007. Fruit flies: disinfection, techniques used, possible application to mango. *Fruits*, 62: 223-236.

Vayssières J.F., 2007. L'IITA dans la lutte contre les mouches des fruits du manguier. La lutte régionale contre les mouches des fruits et légumes en Afrique de l'Ouest, 1: 3.

Vayssières J.F., Goergen G., Lokossou O., Dossa P., Akponon C., 2005. A new *Bactrocera* species detected in Benin among mango fruit flies (Diptera: Tephritidae) species. *Fruits*, 60: 1-9.

Vayssières J.F., Sanogo F., Noussourou M., 2007. Inventory of the fruit fly species (Diptera: Tephritidae) linked to the mango tree in Mali and tests of integrated control. *Fruits*, 62: 329-341.

Partners

Europe-Africa-Caribbean-Pacific Liaison Committee (COLEACP, France), European Union, International Institute of Tropical Agriculture (IITA), West African Economic and Monetary Union (UEMOA), World Bank Institute.



The cotton aphid: an identity survey

The cotton aphid, a polyphagous, cosmopolitan insect, is one of the main cotton pests in the savannahs of Africa. How does it survive in this hostile environment, despite insecticide treatments? A study in northern Cameroon has shown that depending on the season, it has various host plants, and that it is resistant to many insecticides. These results could give rise to new control strategies.

●●●●● The aphid *Aphis gossypii* is a widespread pest in tropical, subtropical and temperate regions. Its winged forms, its exceptional fertility and the fact that it reproduces parthenogenetically enable it to spread widely throughout the range of different cultivated ecosystems. In the savannahs of Africa, this aphid is one of the main pests found on cotton: it draws and feeds on the sap of young plants, directly affecting their vigour, and has an adverse effect on the quality of the cotton fibres produced

by mature plants by depositing honeydew on the bolls. In these regions, where a short rainy season alternates with a long dry season, aphid populations can survive in a diversified yet stable habitat in which some crops are protected using insecticides.

Specialist populations depending on the host plants

This very particular environment prompted CIRAD to embark upon a study of the genetic diversity of populations of this aphid in northern Cameroon, where cotton is widely grown. Over a two-year period, more than 1600 aphids were collected from two cotton plots 250 kilometres apart, in Garoua and Maroua, and from cultivated or wild host plants of the families Malvaceae, Cucurbitaceae and Solanaceae. The genotype of each individual collected was analysed in the laboratory using microsatellite markers. Toxicological tests of susceptibility to insecticides and analyses to detect resistance alleles were conducted in parallel.

The study showed that aphid populations differed genetically depending on the host plants from which they were collected. During the rainy season, more than 90% of the aphids collected in cotton plots were dominated by a single multilocus genotype called "Burk1". During the dry season, aphids of the Burk1 genotype were found on cultivated plants in irrigated areas, such as okra (*Abelmoschus*

Underside of a roselle leaf infested with *Aphis gossypii*
© T. Brévault/CIRAD



Partners

Institut de recherche agricole pour le développement (IRAD, Cameroon), Institut national de la recherche agronomique (INRA, France), University of Nice-Sophia Antipolis (France).

This study received funding from the Pôle régional de recherche appliquée au développement des savanes d'Afrique centrale (PRASAC) and the Société de développement du coton au Cameroun (SODECOTON).

esculentus) or roselle (*Hibiscus sabdariffa*), which are both Malvaceae, like cotton. Market garden plants of the families Cucurbitaceae and Solanaceae, on the other hand, played host to very different genotypes. Moreover, the study also showed that not all populations were equally susceptible to insecticides. In fact, genotype *Burk1* had several alleles that made it resistant to the many insecticides used on cotton crops. This would account for its preponderance over aphids of the genotype "Ivo", which are also found on cotton plants but are considerably more susceptible to insecticides.

A super-genotype specific to cotton

Thus the species *Aphis gossypii*, which is reputed to be highly polyphagous as it is found on more than 300 plant species in northern Cameroon, is in fact split into various genotypes that are specific to different host plants. Genotype *Burk1*, for instance, is a super-genotype specific to cotton: it can adapt to an apparently hostile environment since depending on the season, it has different host plants, and it is resistant to several insecticide families.

These results shed new light on the identity of cotton aphids and should give rise to different control strategies tailored to the different genetic types found in crops.

Contact > Thierry Brévault,
Annual Cropping Systems (UPR),
thierry.brevault@cirad.fr

For further information

Brévault T., Carletto J., Linderme D., Vanlerberghe-Masutti F., 2007. Genetic diversity of the cotton aphid, *Aphis gossypii*, in the unstable environment of a cotton growing area. *Agricultural and Forest Entomology (in press)*.

Brévault T., Carletto J., Vanlerberghe-Masutti F., 2007. Host specificity and insecticide resistance in the cotton aphid, *Aphis gossypii*. *In: WCRC*, 10-14 September 2007, Lubbock, United States.

Brévault T., Tribot J., Carletto J., Vanlerberghe-Masutti F., 2007. Is insecticide resistance responsible for low genetic diversity of *Aphis gossypii* in cotton? *In: Resistance 2007*, 16-18 April 2007, Rothamsted Research, Harpenden, United Kingdom.

Carletto J., Lombaert E., Chavigny P., Brévault T., Lapchin L., Vanlerberghe-Masutti F. Specialization of the aphid *Aphis gossypii* Glover on cultivated host plants. *Molecular Ecology (submitted)*.

Collecting aphids in a cotton plot at the end of the rainy season © T. Brévault/CIRAD





Coconut palm, tropical forests, productivity and carbon flux

Terrestrial ecosystems are constantly exchanging matter and energy with the environment. How do plantations in tropical areas function in this respect? CIRAD researchers compared carbon flows in a coconut plantation in Vanuatu with flows in tropical rainforests and came up with surprising results—productivity in the coconut plantation was close to that of a natural tropical rainforest. This plantation ecosystem would thus now warrant further in-depth studies to overcome the lack of current data.

●●●●● **There is a perpetual exchange of matter** (carbon, water) and energy between terrestrial ecosystems and their environments. The type of cover and its microclimate influence these flows, which in turn impact the global climate. These flows can be measured and modelled and the resulting data have many applications in the fields of agronomy, ecology and climatology. Different flows—light absorption, photosynthesis and evapotranspiration—have been recorded and modelled for a wide variety of vegetation covers through the FLUXNET global network for more than ten years at its 250 measurement sites. Spatial or temporal extrapolations can then be performed to, for instance, assess the effects of different climatic scenarios. After standardization, the results are allocated to different databases. They are ultimately used in meta-analyses—the entire network thus has a global scope, which is essential to be able to deal with environmental issues that arise.

CIRAD actively contributes to FLUXNET concerning flows in tropical tree plantations (coconut, eucalyptus, natural rubber, coffee, oil palm) and some associated natural ecosystems (savannahs). In particular, over a three-year period, CIRAD measured carbon, water and energy flows between a 25 ha coconut plot and the atmosphere under almost optimal growing conditions in Vanuatu—fertile soil with a humid tropical climate throughout the year. Measurements were continuously recorded 10 times/s and then integrated on a 0.5 h time

step. All flow variations could then be studied on different scales: instantaneous, such as the movement of a cloud; seasonal, such as dry or rainy periods; or interannual.

The results of these carbon flow analyses were compared to records obtained by CIRAD's partners in tropical rainforests. The results were surprising—the productivity of a coconut plantation under almost optimal growing conditions was close to that of a natural tropical evergreen rainforest. This “productivity” concept encompasses three general ideas: the gross primary production of plants (photosynthesis of the cover), the net primary production (sum of the visible annual plant growth and the litter production), and the net primary production of the ecosystem (difference between carbon uptake in the ecosystem by photosynthesis and its loss by respiration), which represents the ecosystem's carbon balance, ie the key factor

Flux towers in a coconut planting in Vanuatu
© E. Malézieux/CIRAD



Partners

Centre d'écologie fonctionnelle et évolutive (CEFE, France), Institut national de la recherche agronomique (INRA, France), Languedoc-Roussillon Regional Council (France), Henri Poincaré University (France), Vanuatu Agricultural Research and Training Center (VARTC, Vanuatu).

in carbon sequestration. Coconut plantations fix high quantities of carbon (39 t/ha a year), which is close to that of tropical rainforests (35 t). These plantations are also excellent biomass and litter producers (around 16 t/ha a year of carbon). Moreover, their carbon balance is high, ie 7 t/ha a year of carbon fixed (after deducting copra harvest yield), which is higher than but comparable to the mean carbon balance of tropical evergreen rainforests (4 t).

These meta-analyses also indicated how the natural or artificial carbon production of an ecosystem varies according to the leaf surface of the prevailing plants, duration of the vegetative growth period, climate and soil fertility. The highest production was noted in tropical evergreen rainforests, and the results were comparable to those obtained for the studied coconut plantation.

Few studies have been carried out to date on tropical tree plantations, despite their economic and ecological importance—a broad range of strategies may be implemented for the management of these plantations, from high input commercial approaches to agroforestry and organic farming approaches. It is thus essential to conduct further research to describe and model

these new systems, including their sustainability and versatility with respect to climate change, and to compare the resulting information in terms of two key criteria, ie human development and biodiversity conservation.

Contacts > Olivier Roupsard, Christophe Jourdan, Functioning and Management of Tree-based Planted Ecosystems (UPR), olivier.roupsard@cirad.fr

For further information

Luysaert S. *et al.*, 2007. The CO₂-balance of boreal, temperate and tropical forests derived from a global database. *Global Change Biology*, 13: 2509-2537.

Roupsard O. *et al.*, 2006. Partitioning energy and evapotranspiration above and below a tropical palm canopy. *Agricultural and Forest Meteorology*, 139: 252-268.

Roupsard O. *et al.*, 2008. Cross-validating sun-shade and 3D models of light absorption by a tree-crop canopy. *Agricultural and Forest Meteorology*, 148 (4): 549-564.

Roupsard O., Bonnefond J.M., Luysaert S., 2007. Productivity of a tropical plantation of coconut tree (*Cocos nucifera* L.), compared with tropical evergreen humid forests. *Asiaflux Newsletter*, 23: 4-9.

Over a three-year period, CIRAD measured carbon, water and energy flows between a 25-ha coconut plot and the atmosphere in Vanuatu

© O. Roupsard/CIRAD





Oscar and Oswald, computer-assisted weed identification tools

Accurate plant identifications are generally difficult for non-botanists—standard flora manuals are often hard to follow and identification keys are ill adapted to agricultural constraints. CIRAD has tried to overcome these drawbacks by developing software tools to facilitate plant identification graphically through composite drawings. Two applications have just been implemented to facilitate Asian weed identification.

The Oscar project was awarded, in September 2007, a prize by the Manthan Foundation, under the auspices of the World Summit Award, in the category “India’s best e-content for development”.

The number of flora specialists is drastically declining. This is unfortunate since they have never been in such high demand, especially for studies on biodiversity and agriculture, where it is essential to have a clear picture of the plants to be controlled. Moreover, non-specialists are hampered by many problems when attempting to identify weeds according to conventional flora manuals: identifications that are primarily based on the flowers, whereas weeding should be done before flowering; a dichotomous key

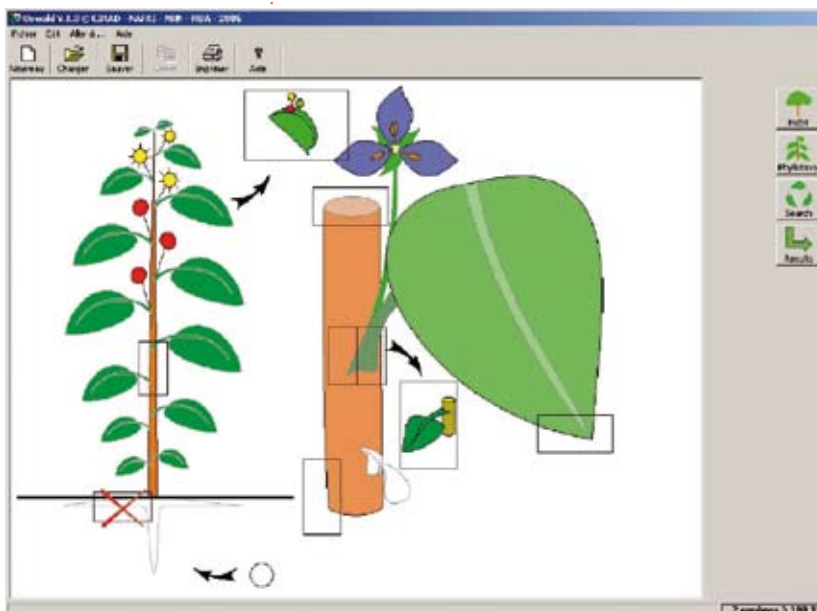
system that does not allow errors and has a compulsory question choice and order; and an abstruse terminology.

Software tools that enable users to identify a plant graphically through composite drawings have been developed to overcome these drawbacks. These tools have several advantages. They are based only on drawings, without any technical terminology, and the user is given a choice concerning the characters to describe. Incomplete specimens may be identified and observation errors are tolerated. At each identification step, a likelihood probability is calculated for each target species, which are sorted in decreasing order of likelihood. The user has constant access to photographs, descriptive texts and botanical drawings of the species, and the texts also provide links to illustrated definitions of technical terms. Finally, these software tools indicate the most relevant characters, so as to be able to quickly differentiate species, and highlight character misinterpretations when a species has been identified with a probability of under 100%.

These software programs can be used without any special computer skills or botanical knowledge. Buttons on the screen provide ready access to the different choices by a simple click. All of the technical terms can be replaced by drawings and information displayed on the screen may be printed.

The species identification software IDAO (Identification assistée par ordinateur) was designed

A page of the Oswald software
© CIRAD



Partners

Institut français de Pondichéry (IFP, India), National Agriculture and Forest Research Institute (NAFRI, Laos), Leiden University (Netherlands), Rice-Wheat Consortium for Indo-Gangetic Plains (RWC, South Asia), Royal University of Agriculture (Cambodia), Wageningen University (Netherlands). Oscar and Oswald benefited from European Commission funding (Asia IT&C programme).

by CIRAD to fulfil this need. Two downloadable versions are available, one that was developed with open source software and the other in SVG format. Two other software packages have been developed for the identification of Asian weed species: Open Source Simple Computer for Agriculture in Rural Areas (OSCAR) for the identification of weeds on the Indo-Gangetic Plain; and Open Source for Weed Assessment in Lowland Paddy Fields (OSWALD) for weeds in Cambodian and Laotian rice fields.

OSCAR assists users in identifying and controlling weeds on plains in Pakistan, Nepal, India and Bangladesh. This software can be used on a Simputer, PC or online. It is highly intuitive and fast reference cards can be displayed for each weed species, while also describing the most ef-

icient control methods, in English, Hindi, Bengali and Urdu. OSWALD is a similar software tool that was developed for the identification of weeds in Cambodian and Laotian rice fields. The reference cards are in Khmer and Laotian, as well as English and French. It enables users to identify 113 major weeds. An extension is being prepared for Vietnam.

Contact > Pierre Gard,
Botany and Computational Plant Architecture (UMR AMAP),
pierre.gard@cirad.fr

Websites

<http://www.oscarasia.org>
<http://www.oswaldasia.org>



LIAMA celebrates its 10th anniversary

Partners

Beijing Forestry University (China), Bureau de recherches géologiques et minières (BRGM, France), Centre national de la recherche scientifique (CNRS, France), Chinese Academy of Forestry (China), Chinese Academy of Sciences (China), Chinese Academy of Sciences Institute of Automation (CASIA, China), Chinese Agricultural University (China), Ecole centrale de Paris (ECP, France), Institut national de la recherche agronomique (INRA, France), Institut national de recherche en informatique et en automatique (INRIA, France).

Philippe de Reffye was granted the 2006 Friendship Award by the Chinese Ministry of Foreign Affairs for his LIAMA activities.

In January 2007, the Sino-French Laboratory for Computer Science, Automation and Computer Mathematics (LIAMA), which was created by the Chinese Academy of Science and INRIA, celebrated its 10th anniversary. This laboratory, which is hosted by the Institute of Automation of the Chinese Academy of Science (CASIA), was founded through a partnership between CASIA, the Academy and a French consortium involving INRIA CNRS, CIRAD, INRA and BRGM. CIRAD actively participated in setting up this laboratory and posted scientists to the laboratory as early as 1998—five CIRAD scientists worked in the laboratory between 1998 and 2007, with two of them responsible for the French management. The research has been focused on modelling plant growth (GreenLab project) and its applications, especially for modelling and predicting plant architecture and production, functional landscape display, and slope stability ecoengineering. CIRAD has productive collaborations with many Chinese agricultural research and educational organizations through this partnership. Over 30 Chinese PhD students have been supervised by CIRAD since 2000. These collaborations have also led to the organization of two international conferences on plant modelling and growth, as well as an ecoengineering seminar to be

held in 2008. Many articles in international journals, books and a special issue in the *Annals of Botany* on plant modelling and growth have been published on research associated with this laboratory.

Contacts > Thierry Fourcaud, Marc Jaeger, Philippe de Reffye, Botany and Computational Plant Architecture (UMR AMAP),
thierry.fourcaud@cirad.fr

Fourcaud T., Zhang X.P., 2008. Plant growth modeling and applications - Proceedings of PMA06. IEEE Computer Society, Los Alamitos, California, 336 pp.

Fourcaud T., Zhang X.P., Stokes A., Lambers H., Koerner C., 2008. Plant growth modelling and applications: the increasing importance of plant architecture in growth models. *Annals of Botany* 101: 1053-1063.

Le Chevalier V., Jaeger M., Mei X., Cournède P.H., 2007. Simulation and visualisation of functional landscape: effects of the water resource competition between plants. *Journal of Computer Science and Technology*, 22: 835-845.

Ma Y., Li B., Zhan Z., Guo Y., Luquet D., de Reffye P., Dingkuhn M., 2007. Parameter stability of the functional-structural plant model GreenLab as affected by variation within populations, among seasons and among growth stages. *Annals of Botany*, 99 : 61-73.

<http://liama.ia.ac.cn>

A virtual landscape
© M. Jaeger/CIRAD





Borates and vegetable oils— promising wood preservatives

Borates have wood preservative properties and a low environmental impact. These active substances are, however, rapidly leached out when used alone to treat outdoor wood, therefore reducing their efficacy. CIRAD and partners have combined boron with vegetable oils with the aim of enhancing the fixation of this substance within treated timber. The results of this research could give rise to environment-friendly wood preservatives that effectively control termites and fungi.

Partners

Agence de l'environnement et de la maîtrise de l'énergie (ADEME, France), Kyoto University (Japan), Oléobois (France), Languedoc-Roussillon Regional Council (France), University of Montpellier II (France), University of Nancy (France).

●●●●● Borates are efficient environment-friendly wood preservatives.

Unfortunately they may be rapidly leached away when used to treat outdoor wood. CIRAD thus investigated different combinations of these borates with vegetable oils to improve boron fixation in the treated wood, including: borate-vegetable oil double treatments, synthesis of an ammonium borate-oleate salt, borate-oil emulsions and grafting of an oil on borate-impregnated wood. These different combinations were tested for their boron fixation capacity and also for their protective effect against termites and wood-rotting fungi (basidiomycetes). The results of this research could ultimately give rise to efficient environment-friendly wood preservatives that comply with the requirements of the EU biocide products directive (98/8/EC).

These different combinations were tested for their boron fixation capacity and also for their protective effect against termites and wood-rotting fungi (basidiomycetes). The results of this research could ultimately give rise to efficient environment-friendly wood preservatives that comply with the requirements of the EU biocide products directive (98/8/EC).

Improving boron fixation

In the double treatments, the high drying capacity of vegetable oils increased boron retention, ie 30-40% of the

initial boron was retained. Linseed oil was more efficient than rapeseed or soybean oil. Ammonium salt synthesized from boric acid and oleic acid retained 50% of the initial boron. Emulsion combinations were found to have exceptional boron retention properties (up to 90% retention). However, these emulsions are highly viscous, which reduces their retention potential—they do not penetrate deep enough into the wood and are thus surface leached. Finally, grafting of an oil on wood did not give interesting results under any of the tested reaction conditions.

Efficient rot and termite protection

Following the boron fixation tests, the efficacy in providing protection against wood-rotting fungi and termites was confirmed for double boron-oil treatments and for the ammonium borate-oleate salt. This efficacy was linked especially with the quantity of boron remaining in the wood after the leaching trial.

In the double treatments, the treatment efficacy depended mainly on the extent of oil unsaturation, ie the number of carbon-carbon double bonds in the fatty acids. The oil acted as a temporarily effective barrier against rot and boron was highly effective in controlling termites. However, these treatments were inefficient against mould fungus (*Aspergillus niger*), which aesthetically depreciated the oil-treated wood. The ammonium borate-oleate salt was found to be non-toxic to daphnia (small



Measuring the resistance of treated wood to wood-rotting fungi
© F. Lyon

Florent Lyon was awarded, within the framework of his PhD thesis *Amélioration de la durée de vie d'essences peu durables à l'aide d'un traitement combiné à base de borates et d'huiles*, the Ron Cockroft Award from the International Research Group on Wood Protection in 2007, the Gareth Williams Scholarship Award (funded by Arch Chemical Inc.) granted by a panel of scientists and commercial stakeholders, members of the International Research Group on Wood Protection in 2007, and the Prix Doctiss 2007 for his oral presentation within the framework of the Ecole doctorale I2S, University of Montpellier II.

susceptible crustaceans used in the toxicity tests). This wood preservative product thus has highly promising applications.

There are still many yet unanswered questions. The addition of boron to the oil treatments does not reduce the wood flammability. The fire-hazard aspect of oiled wood hampers the development of these treatments. The possibility of adding fire retardants has been considered. Further studies are under way on the double borate-oil treatments and on the

borate-oleate salts, with the aim of improving their performances against degradation agents while also boosting the fire resistance of treated woods.

Contact > Marie-France Thévenon,
Production and Processing of Tropical Woods (UPR),
marie-france.thevenon@cirad.fr

For further information

Lyon F., Pizzi A., Imamura Y., Thévenon M.F., Gril J., 2007. Synthesis of boric acid ammonium oleate salt for wood preservation: leachability and termite resistance test. *In: International Research Group on Wood Protection, 20-24 May 2007, Jackson Hole, USA, Doc IRG-WP-07-30435, 14 pp.*

Lyon F., Pizzi A., Imamura Y., Thévenon M.F., Kartal S., Gril J., 2007. Leachability and termite resistance of wood treated with a new preservative: ammonium borate oleate. *Holz als Roh- und Werkstoff, 65: 359-366.*

Lyon F., Thévenon M.F., Hwang W.J., Imamura Y., Gril J., Pizzi A., 2007. Effect of an oil heat treatment on the leachability and biological resistance of boric acid impregnated wood. *Annals of Forest Science, 64: 673-678.*

Lyon F., Thévenon M.F., Imamura Y., Gril J., Pizzi A., 2007. Development of boron/linseed oil combined treatment as a low-toxic wood protection. Evaluation of boron fixation and resistance to termites according to Japanese and European standards. *In: IUFRO Conference, Forest products and environment: a productive symbiosis, 29 October-2 November 2007, Taipei, Taiwan, Doc IRG-WP-07-30448, 13 pp.*



A new phytosanitary waste treatment technique



The BIOBED system
© F. Le Bellec/CIRAD

The chemical quality of almost half of all fresh water available in Guadeloupe is poor. Pesticides used to treat crop fields are the main cause of this pollution, with the active substances being glyphosate, malathion, diazinon and cadusafos. This pollution is often the result of cleaning of spraying equipment and containers and dumping of leftover spraying solution. How could this pollution be avoided and what could be done with this phytosanitary waste on farms?

CIRAD adapted a new phytosanitary waste treatment system called BIOBED to solve this problem. This system consists of a trench filled with an organic substrate in which phytosanitary waste is poured. Sugarcane bagasse mixed with soil serves as this substrate in Guadeloupe. This mixture confines the active substances and ensures their decomposition via the enzymatic activity of the microorganisms it contains. The BIOBED tested in Guadeloupe is a closed, covered and impervious system. The efficiency of this system is currently being assessed in tropical environments, but it has already proven effective in neutralizing five active substances used

in citrus growing: glyphosate (herbicide), mancozebe (fungicide), abamectin (acaricide), malathion and lambda-cyhalothrin (insecticides). After six months of BIOBED treatment, over 90% of these active substances are degraded. Ecotoxicity tests performed on the final substrate to check its safety according to ISO standards 11268-1 and 11269-2 revealed no toxicity. This final substrate could thus be freely disposed of without danger. Some improvements to BIOBED are planned to further enhance its efficiency, but the system is already easy and inexpensive to use on smallholdings.

Contact > Fabrice Le Bellec, Integrated Fruit Production (UPR), fabrice.le_bellec@cirad.fr

De Roffignac L., Cattan P., Mailloux J., Herzog D., Le Bellec F., 2007. Un Biobed à la bagasse testé en Guadeloupe : expérimentation d'un dispositif de gestion d'effluents phytosanitaires agrumicoles sur l'exploitation. *Phytoma, 606: 4-7.*

De Roffignac L., Cattan P., Mailloux J., Herzog D., Le Bellec F. Degradation of glyphosate, malathion and lambda cyhalothrin in a bagasse-based substrate in a biobed system, under tropical climate. *Pest Management Science (in press).*

Partners

Direction régionale de l'environnement de Guadeloupe (France), European Union, Guadeloupe Regional Council (France).



Cotton pests in Mali—making pesticide management more sustainable

In Mali, 24 000 ha of cotton crops are currently managed under new pest control strategies—growers only spray their fields if pest infestation levels exceed certain preset thresholds. They save over 60% on pesticides by conducting just one or two spray treatments instead of four to six as recommended in conventional farming conditions. This is the result of research conducted by CIRAD and IER aimed at reducing pesticide use in cotton crop fields.

Partners

Agence française de développement (AFD, France), Compagnie malienne pour le développement des textiles (CMDT, Mali), Institut d'économie rurale (IER, Mali).

●●●●● **Malian cotton growers** have been using fewer pesticides since 2001. They only conduct pest control treatments if infestation levels exceed certain preset thresholds, thus enabling them to save over 60% on pesticides in one or two sprays instead of four to six as recommended in conventional farming conditions. The aim is to decrease production costs while also lowering the impact of treatments on human health and the environment. Drawing up guidelines to help farmers decide when to treat their fields was, however, a complicated joint task for CIRAD and IER. This collaboration is ongoing to refine the treatment conditions and promote clean practices for reducing pests and diseases in cotton crop fields.

Defining treatment thresholds

Crop fields should be regularly monitored to count numbers of different types of pest using a special procedure. The results of these

Hairy-leaved cotton varieties reduce infestations of jassids, which are serious pests in Mali, by hampering their egg laying

© A. Renou/
CIRAD



counts are compared to preset thresholds beyond which pesticide treatments should be conducted. These vary for different cropping conditions, eg the treatment threshold will be lower for fields with a low planting density (common in Mali) than for dense crop stands. The crop yield potential in the field should also be considered when determining the treatment threshold.

The treatment thresholds can also be adjusted according to the development stage of the crops, ie pests have a greater impact on the early plant growth and fruiting stages. The threshold will be low at the beginning of the cropping period (only minor infestations are tolerated) whereas it can be higher near the end. This will save the first fruiting organs, which are essential for production.

Simple guidelines investigated

The treatment threshold is still a relatively complicated concept to put into practice—farmers often just focus on whether or not pests are present in their fields rather than on their density. Simple guidelines to facilitate decision-making are thus currently being tested, eg the presence of just one pest is enough to decide on whether or not to conduct a pesticide spray. These new guidelines could lead to an increase in pesticide use when infestation peaks occur at the end of the cropping period, but they simplify field monitoring and could address

the concerns of some farmers who do not want to take any crop pest and disease risks. Tests are also under way on another possible simplification, ie the presence of just one type of pest (bollworms) would seem to be enough to decide on whether or not to conduct a pesticide spray.

A set of practices to reduce infestations

Other practices could reduce insect pest populations. Some hairy-leaved cotton varieties could be planted to reduce infestations of jassids, which are serious pests in Mali, by hampering their egg laying. Cotton plants can also be topped at the peak of the flowering period to reduce infestations of bollworms, which are the main cotton pests in Mali. Moreover, planting at high densities will promote earlier and faster fruiting, thus sidestepping potential attacks of bollworms, which are generally more numerous at the end of the cropping cycle.

These results will be validated on a larger scale in participatory research to be carried out in

2008 within the framework of the PASE* II project, funded by the Agence française pour le développement. In addition to investigating issues concerning agricultural techniques, this project will focus on determining the best decision-making scale (plot, set of plots, cropping area) and on preventive measures to avoid the development of pest resistance to the pesticides used.

* PASE: Programme d'appui aux systèmes d'exploitation

Contact > Alain Renou,
Annual Cropping Systems (UPR),
alain.renou@cirad.fr

For further information

Fok M., Renou A., Vaissayre M., 2007. Challenge of improving cotton competitiveness in a distorted market: analysing the role of crop protection in Francophone Africa. *In: BCPC Conference, 16-18 October 2007, Glasgow, UK.*

Renou A., Bagayoko B., Téréta I., Togola M., 2007. Topping cotton plants: a promising alternative to late insecticide spraying in Mali. *In: Beltwide Cotton Conference, 9-12 January 2007, New Orleans, USA.*

Cotton plants can be topped at the peak of the flowering period to reduce infestations of bollworms
© A. Renou/CIRAD





Climate policies— what are the options?

Climate change will be a major issue for decades to come. The most recent scientific findings indicate that greenhouse gas emissions must be significantly reduced in order to curb climate change. But on what basis will negotiations be possible within the framework of new international bodies and how could decisions resulting from these negotiations be implemented in the field?

Partners

CATIE (Centro Agronómico Tropical de Investigación y Enseñanza, Costa Rica), Center for International Forestry Research (CIFOR, Indonesia).

●●●●● The **CATIE Global Change Group**, in Costa Rica, and CIRAD have undertaken a series of research studies on climate change policy instruments. These studies are jointly focused at the global, ie negotiations on the Convention on Climate Change and the Kyoto Protocol, national and local levels. Scientists can provide policy-makers with basic elements required for effective international negotiations and for implementing the resulting policies in the field. Some decisions made concerning the Kyoto Protocol could, for instance, have impacts on economic stakeholders at the national level, as well as on local communities and ecosystems.

On a global scale, in the framework of Latin American negotiations on the Convention on Climate Change, specific research issues have been outlined concerning the Clean Development Mechanism (CDM) guidelines. These are, for instance, issues on certain technical aspects such as carbon credit accounting methods in forestry projects under this mechanism. Few negotiators would be able to devote enough time for an in-depth analysis of the different options considering the complexity of the methods proposed and the broad range of topics for discussion. Models have therefore been developed to assess the impact of these options on forestry projects. The modelling results are passed on to interested parties prior to negotiations so as to provide them with a solid foundation for discussion on these issues. A similar study was carried out on simplified modalities and procedures for small-scale CDM forestry projects.

This research has real measurable spinoffs. Peru, in the name of eleven Latin American countries, referred to one of these studies during global climate negotiations. Moreover, in September 2007, the World Bank Carbon Finance Unit sent the Secretariat of the Convention on Climate Change a proposal to raise the baseline for the eligibility of small-scale CDM forestry projects that could benefit from the simplified modalities and procedures—the research studies of CIRAD and CATIE directly underpinned this World Bank request.

On a national scale, this research can assist authorities in applying the CDM by supplying them with technical data. Developing countries

A forest planting
in Costa Rica
© B. Locatelli/CIRAD



should select relevant parameters for defining forests under CDM projects and activities. This choice will have a major impact on determining what land would be eligible for such projects, as well as the activities that could be carried out under the projects. Studies undertaken with national stakeholders of some Latin American countries such as Costa Rica and Guatemala gave rise to a policy that addresses these countries' CDM expectations.

On a local scale, studies are under way to assess the carbon footprint of projects with respect to local development and biodiversity. The findings should be useful in drawing up the Climate, Communities and Biodiversity (CCB) Standards. Technical assistance was also set up for project designers in Latin America. This will facilitate their task in dealing with the complexity of the CDM process, and useful lessons have already been learnt for further projects.

Contact > Bruno Locatelli,
Forest Resources and Public Policies (UPR),
bruno.locatelli@cirad.fr

For further information

Locatelli B., Pedroni L., 2006. Will simplified modalities and procedures make more small-scale forestry projects viable under the clean development mechanism? Mitigation and Adaptation Strategies for Global Change, 11: 621-643.

Locatelli B., Pedroni L., Salinas Z., 2008. Design issues of forestry projects under the Clean Development Mechanism. *In*: Climate change and forests: emerging policy and market opportunities, Streck C. *et al.* (ed.). Washington: Brookings Institution Press (*in press*).

Martínez C., Imbach P., Locatelli B., 2008. ¿Cómo seleccionar una definición de bosque en un país para el Mecanismo de Desarrollo Limpio? Recursos Naturales y Ambiente (*in press*).



Woody species indigenous to Réunion— from propagation to planting



CIRAD is providing training in nursery management
© J.M. Sarrailh/CIRAD

Relatively undisturbed natural forests that still contain an incredible level of biodiversity cover 35% of the island of Réunion. These forests are unfortunately threatened by species that have been introduced via home gardens and ornamental plantations along roadsides. It is now crucial to gradually plant indigenous species to replace these invasive foreign species. In preparation for this reintroduction initiative, CIRAD has been conducting research for several years on the ecology of germination of indigenous species in Réunion and their propagation, from fruit production to seedling emergence and survival.

Plant management methods for nursery gardeners have been developed on the basis of these studies. Detailed factsheets and a CD-ROM describing these species and explaining efficient propagation methods were thus published in 2007. A website is to be launched in February 2008. CIRAD, in collaboration with the Office national des forêts de la Réunion, has also been providing support for a project to plant trees and shrubs along the Route des Tamarins, with the aim of sowing 500 000 plants of indigenous species to adorn the sides of this road. In this Réunion

Regional Council and EC funded project, CIRAD is providing training for nursery gardeners in propagation techniques and nursery management, from seed harvesting to plant production. The results obtained in this project should shed light on the yet relatively unknown ecological requirements of these indigenous plants.

Contact > Jean-Michel Sarrailh,
Dynamics of Natural Forests (UPR),
jean-michel.sarrailh@cirad.fr

Derroire G., Schmitt L., Rivière J.N., Sarrailh J.M., Tassin J., 2007. The essential role of tree-fern trunks in the regeneration of *Weinmania tinctoria* in rain-forest on Réunion, Mascarene Archipelago. *Journal of Tropical Ecology*, 23: 487-492.

Sarrailh J.M., Baret S., Rivière E., Le Bourgeois T., 2007. Arbo Run V1: arbres et arbustes indigènes de la Réunion. Saint-Denis, CIRAD (CD-ROM).

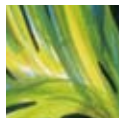
Tassin J., Sarrailh J.M., Rivière J.N., 2007. Essences forestières et invasions: des systèmes de prédiction toujours plus fiables. *Bois et forêts des tropiques*, 292: 71-79.

<http://arbres-reunion.cirad.fr/>

Partners

Conservatoire botanique de Mascarin (CBNM, Réunion),
Etablissements horticoles Yves Payet, LaMare espaces verts SA, Office national des forêts (ONF, Réunion),
Pépinière Vocatour, Réunion General Council, Réunion Regional Council, Scetauroute (Réunion).

Inventing the farming systems of the future



Can the agroforests of Forest Guinea be exploited sustainably?

Forest Guinea is a landlocked region that is home to the last remaining natural forests in West Africa. It is also highly suitable for agriculture: annual and perennial crops are intercropped in various types of system, based on the complex exploitation of the available resources. However, these systems are built on fragile biological and economic balances that current socioeconomic changes are likely to upset. CIRAD is working with the Institut de recherche agronomique de Guinée (IRAG) on the dynamics of such farming systems, their performance and how they can be made sustainable.

●●●●● **Forest Guinea is home** to both classified forest reserves and agricultural zones. Annual and perennial crops are intercropped in various types of system, based on the complex exploitation of the available resources, generally without any external inputs. However, the sustainability of these farming systems is under threat from increased population pressure. In effect, these systems are built on fragile biological and economic balances that it is essential to study in more detail in order to help farmers adapt to local, regional and international socioeconomic changes. Under projects funded by the French Ministry of Foreign Affairs, CIRAD is working with IRAG to study the dynamics of these complex farming systems and assess their performance and how they can be made sustainable.

Trees, a vital part of farming systems

The main three farming systems practised all include trees. Upland rice growing on slopes begins with slash-and-burn, keeping large trees and subspontaneous oil palms (*Elaeis guineensis*) and combining numerous food intercrops (maize, okra, aubergines, cassava and groundnut). These rice fields, which are thus also natural palm groves, serve to produce rice, condiments and red palm oil. Bottomland rice farmers keep raffia palms to make palm wine, which is playing a growing socioeconomic role. Lastly, agroforests form rings around the vil-

lages: they include Robusta coffee trees (*Coffea canephora*), intercropped with many forest tree species. The structure of these agroforests is similar to that of natural forests.

For some 25 years now, coffee-based agroforests have expanded considerably, at the expense of natural forests and rainfed rice fields on slopes. Despite their economic importance and potential role in conserving biodiversity, little is known about these agroforests. Initial studies have shown their considerable floristic wealth—313 recorded plant species, including 232 woody species—and complex structure. They generally comprise three storeys of veg-

Harvesting subspontaneous oil palms in an agroforest in Guinea
© E. Malézieux/CIRAD



Partners

Institut de recherche agronomique de Guinée (IRAG, Guinée), Institut de recherche pour le développement (IRD, France), Ministry of Foreign Affairs (France).

etation. The coffee trees, which are planted in a very heterogeneous way, occupy the middle storey and are sometimes intercropped with cola (*Cola nitida*), cocoa (*Theobroma cacao*), a few fruit trees (citrus, avocados, etc) and banana. The upper storey shades the coffee trees and includes oil palms (*Elaeis guineensis*) and numerous wild dense forest or savannah trees—*Albizia* spp., iroko (*Melicia excelsa*), black afara (*Terminalia ivorensis*), afara (*Terminalia superba*), kapok (*Ceiba pentandra*) and dabema (*Piptadeniastrum africanum*), among others.

Poor yields but a multitude of vital products

Coffee yields from agroforests—around 600 kilograms of commercial coffee per hectare per year—are much lower than from conventional systems—up to 2.25 tonnes per hectare per year. However, these agroforests provide numerous products that are vitally important in the farmers' daily lives, and thus contribute to the economic and social equilibrium of this isolated region. Of the 232 recorded woody species, 75 have commercial uses, 45 food uses and 64 medicinal uses, while 47 provide timber. Some are also used for firewood, fencing and crafts. A given species often has several uses. These agroforests are also a way of establishing and setting the boundaries of

land ownership: they are also a capital that is passed on from generation to generation.

However, the development of such agroforests at the expense of food crops or forest reserves is jeopardizing the sustainability of local farming practices. In effect, increased use of timber from these agroforests is reducing their structural and floristic complexity, the economic and environmental consequences of which remain to be seen. Moreover, farmers are also setting up almost monospecific oil palm commercial plantations to supplement and diversify their income. This is why the aims of agroforestry research in Forest Guinea are now to assess the agroecological and socioeconomic performance of those agroforests and determine their role in conserving biodiversity and local knowledge. The results should enable the establishment of appropriate technical recommendations to help the agricultural support services in Forest Guinea ensure that farming systems in the region are varied, profitable and viable.

Contacts > Eric Malézieux, Nathalie Lamanda, Tropical and Mediterranean Cropping Systems Functioning and Management (UMR SYSTEM), eric.malezieux@cirad.fr

For further information

Camara A., 2007. Dynamiques régionales et systèmes ruraux en Guinée Forestière. Vers la conception d'un observatoire pour le développement. Geography thesis, University of Avignon and Pays de Vaucluse, 250 pp.

Diabaté M., Lamanda N., Wagler C., Malézieux E., de Foresta H., 2007. Farmers' contribution to the conservation of biodiversity: the coffee based agroforestry systems in Guinée Forestière (Guinea, West Africa). *In: IInd Symposium on Multistrata Agroforestry, CATIE, 17-21 September 2007, Turrialba, Costa Rica.*

Lamanda N., Camara A., Diabaté M., Kolie D., Kalms J., Malézieux E., Cheylan J., 2007. Spatio-temporal extension of agroforestry systems in Guinée Forestière (Guinea, West Africa). *In: IInd Symposium on Multistrata Agroforestry, CATIE, 17-21 September 2007, Turrialba, Costa Rica.*

Madelaine C., Malézieux E., Sibelet N., Manlay R., 2008. Semi-wild palm groves reveal agricultural change in the forest region of Guinea. *Agroforestry Systems*, 73: 89-204.

The agroforest belt around the village of Nienh, in Forest Guinea, has many functions: setting the boundaries of land ownership, protection, and food, wood and medicine production

© N. Lamanda/CIRAD





Building sustainable production systems in partnership in Brazil

In the Brazilian Cerrados, family farms are in the majority. The ones that have benefited from the agrarian reform are now in a precarious position, which is affecting their viability. Under a project being conducted jointly with EMBRAPA and the University of Brasilia, CIRAD is developing innovative cropping systems based on the use of direct seeding and of cover crops, and assessing how to build such innovations in effective partnership with local stakeholders.

Partners

AgroParisTech (France), Empresa Brasileira de Pesquisa Agropecuária (EMBRAPA, Brazil), Institut de recherche pour le développement (IRD, France), Institut national de la recherche agronomique (INRA, France), Unai Agricultural Technical College (Brazil), Unai Agronomy Faculty (Brazil), Unai Rural Workers' Union (Brazil), University of Brasilia (Brazil), Wageningen Plant Production Systems Department (Netherlands)

●●●●● **The Brazilian Middle West**, which is part of the Cerrados, is characterized by highly skewed land distribution. Family farms account for 67% of the total number of farms, albeit only 13% of the total area. Of those farms, the ones that have benefited from the agrarian reform are now feeling the pinch: farmers often have largely unfertile land and the socioeconomic situation is far from ideal. This places them in a precarious position, which affects the viability of their farms. Milk has become the main cash product; for instance, in Unai, a *município* in Minas Gerais State, more than half the milk supplied to the cooperative dairy comes from small-scale farms. In view of the shift to more intensive milk production, maize play an increasingly pivotal role, thanks to its many-faceted contribution: feeding families, small animals and cattle, as silage, or pro-

viding supplementary income. However, maize production faces a range of problems, which could be overcome by adopting innovative cropping systems based on direct seeding and cover crops, provided they are tailored to the local farmers' objectives and constraints.

This is what prompted EMBRAPA and the University of Brasilia to launch a project in 2002, based on a participatory approach, with the aim of helping these family farms. The Unai project set out to develop sociotechnical references on production systems, promote farm integration into markets, build farmers' organizational capacities and train young rural development agents from families involved in the agrarian reform. CIRAD joined the project in 2004, concentrating its operations on natural resource management aspects and on accompanying local players.

Experimental structures were set up in farmers' fields and on-station, to assess no-till cropping systems using cover crops. In addition to direct seeding using animal draught and chemical control of weeds, several cover crops legumes (*Cajanus cajan*, *Crotalaria*) or grasses (*Brachiaria ruziziensis*, sorghum, millet) were introduced as relay crops in maize cropping systems. The initial results showed that these innovative systems were highly productive, despite the low level of chemical input use. Farmers, for their part, are keen on such systems as they do not depend on hiring a tractor and production costs are lower. Using cover crops also produces



Demonstration of a tractor-mounted sprayer to students from Unai Agricultural Technical College.
© B. Triomphe/CIRAD



Intercropping maize with a legume cover crop such as *Cajanus cajan* during the dry season ensures good yields
© B. Triomphe/CIRAD

biomass that can be used to feed dairy animals during the dry season. However, the long-term advantages, such as fertility improvement and weed control, have yet to be appreciated by the farmers involved.

In addition to its work on innovative cropping systems, the project has begun to develop an approach for building innovations in close partnership between research and local stakeholders. Through a cycle of debate and training, multi-stakeholder dialogue and experimentation mechanisms are gradually changing. Experience shows that these processes have their difficulties, but has also revealed what needs to be done to ensure that they run smoothly. An analysis of farmers' groups and how they operate enabled an assessment of the relationship between local organizations and public rural development policies on a municipal and inter-municipal level, in the light of the latest federal territorial development programme..

Contacts > Eric Scopel, Tropical and Mediterranean Cropping System Functioning and Management (UMR SYSTEM); Eric Sabourin, Collective Action, Policies and Markets (UPR); Bernard Triomphe,

Innovation and Development in Agriculture and the Agrifood Sector (UMR INNOVATION), bernard.triomphe@cirad.fr

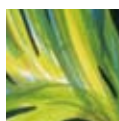
For further information

Maltas A., Corbeels M., Scopel E., Macena F., Oliver R., Douzet J.M., Wery J., 2007. Does soil N supply increase under continuous direct seeding mulch-based cropping systems in the Cerrado region of Brazil? *Plant and Soil*, 298: 161-173.

Métay A., Oliver R., Scopel E., Douzet J.M., Alves Moreira J.A., Maraux F., Feigl B., Feller C., 2007. N₂O and CH₄ emissions from soils under conventional and no-till management practices in Goiânia (Brazil, Cerrados). *Geoderma*, 141: 78-88.

Lenné P., Sabourin E., Triomphe B., Nascimento de Oliveira M., 2007. La coconstruction des connaissances entre chercheurs et agriculteurs dans les processus d'innovation : le cas du semis direct dans les Cerrados brésiliens. *In: 3rd Living Knowledge Conference*, 29 August – 1st September 2007, Paris, France.

Sabourin E., Xavier V.J.H., Oliveira M.N., 2007. Lógica familiar e lógica coletiva nos assentamentos de reforma agrária do Brasil: o caso do município de Unaí (MG). *Estudos Sociedade e Agricultura*, 15: 23-60.



Mafate, modelling and analysing matter flows on a territory scale

CIRAD's work on animal farm effluent management in Réunion has led it to develop a generic approach for modelling and analysing matter flows on a territory scale. The approach sheds light on farmers' practices and helps them draw up strategies for managing such flows.

●●●●● **CIRAD worked with its partners** to develop the "Mafate" approach for modelling and analysing matter flows on a territory scale by looking at animal farm effluent management in Réunion. Using surveys of 200 farms throughout the island, 26 typical farms were

identified based on their natural environment, structural characteristics and management strategies. An action model was then built. It described the structural parameters of farms and the management rules applied, according to five functional modules: production, storage,

Partners

AgroParisTech, Chambers of Agriculture in Brittany, Fédération régionale des coopératives agricoles de la Réunion (FRCA, France), GIE Terre-Eau (France), Institut de recherche en mathématiques, informatique et leurs applications (IREMIA, University of Réunion, France), Institut national de la recherche agronomique (INRA, France).

spreading, treatment, import and export. This preliminary work resulted in three simulation models. The first, Magma, simulates transfers between animal production units and crops within a farm. The second, Biomax, simulates organic matter transfers within a small region, between farms with surpluses and farms with shortages. The third, Approzut, simulates supplies to a collective effluent treatment unit from a number of farms. Calculation tools were also developed, to compare the performance and cost of different effluent treatment processes, and a geographical information system was built to establish fertilizer balances.

These models simulate matter transfers between production units—animal farms, crops, treatment units—represented by stocks connected by flows. They provide answers to the usual questions relating to flow management: which unit should export its matter stocks? To which other unit? Based on what calendar or event? Using which type of transport or labour? In what amounts? The approach was subsequently adapted by integrating biophysical models so as to simulate every type of biomass flow within dairy farms.

Based on a system management scenario, these models were used to test various improvement strategies, by proceeding gradually to change the management rules, physical elements and production methods used on farms. These mod-

ifications of increasing importance correspond to the questioning of very short-term operational choices (less than one cycle), medium-term tactical choices (at least one production cycle) and longer-term strategic choices (several production cycles). This demonstrated the merits of working on system dynamics rather than calculating annual balances for managing animal production effluent. In effect, simulation makes it possible to synchronize the dynamics of effluent supply and demand, which are not taken into account in annual balances.

Decision support models intended to help agricultural players are currently being validated under two projects: one on supplies to the treatment unit at Saint-Joseph agricultural college in Réunion, and the other on collective spreading plans in the Ille-et-Vilaine département (mainland France). Simulated management strategies have yet to be assessed in terms of their environmental impact, notably by integrating models that simulate flows towards the environment and using multicriteria environmental evaluation methods, such as life cycle analysis.

Contacts > François Guerrin, Jean-Michel Médoc, Jean-Marie Paillat, Environmental Risks of Recycling (UPR), francois.guerrin@cirad.fr

For further information

Aubry C., Paillat J.M., Guerrin F., 2006. A conceptual model of animal waste management in the Reunion Island. *Agricultural Systems*, 88: 294-315.

Lopez-Ridaura S., Guerrin F., Paillat J.M., van der Werf H., Morvan T., 2007. Agronomic and environmental evaluation of collective manure management for a group of farms. *In: Donatelli M. et al. (ed.), Farming Systems Design 2007*, 10-12 September 2007, Catania, Italy. Pavia: La Goliardica Pavese, p. 95-96.

Ralambondrainy T., Médoc J-M., Courdier R., Guerrin F., 2007. Tools to visualise the structure of multi-agent conversations at a macro level. *In: Modsim 2007*, 10-13 December 2007, Christchurch, New Zealand.

Vayssières J., Lecomte P., Guerrin F., Nidumolu U.B., 2007. Modelling farmers' action: decision rules, capture methodology and formalisation structure. A case of biomass flow operations in dairy farms of a tropical island. *Animal*, 1: 716-733.

Spreading pig manure in Brittany by injection, in the foreground, and spraying, in the background
© J.M. Paillat/CIRAD





Water governance on a catchment area scale in South Africa

Partners

Centre for Environmental Economics and Policy in Africa (CEEPA, South Africa), Department of Water Affairs and Forestry (DWAF, South Africa), Institut de recherche pour l'ingénierie de l'agriculture et de l'environnement (CEMAGREF, France), Institut national de la recherche agronomique (INRA, France), International Water Management Institute (IWMI, Sri Lanka), Ministry of Foreign Affairs (France), Rhodes University (South Africa), SupAgro Montpellier (France), Tshwane University of Technology (South Africa), University of Genoa (Italy), University of Pretoria (South Africa), University of Montpellier III (France), Water Research Commission (WRC, South Africa), World Bank (United States).

In South Africa, the National Water Act has introduced new decentralized organizations to manage the country's scarce water resources. However, despite a clear political will and considerable economic investment, these organizations are having difficulty getting off the ground. Their operation has so far been hampered by a lack of skills and information, and by conflicts of interest. CIRAD and its South African partners are working to consolidate these organizations by offering them tools and methods that should support them in conducting negotiations and making decisions.

●●●●● In South Africa, the 1998 **National Water Act** introduced new, decentralized management organizations: catchment management agencies and water users' associations. These organizations have encouraged the emergence of public policy networks, which operate based on negotiation between stakeholders. However, despite a clear political will and considerable economic investment, these mechanisms are having difficulty getting off the ground. Research has been conducted on the socioeconomic approaches, tools and methods that would enable stakeholders to negotiate and

make collective decisions more effectively, to ensure sustainable water management.

A partial equilibrium economic model has been developed to interpret the intersectoral competition in terms of demand for water on the Steelpoort catchment area level. It also makes it possible to calculate an equilibrium price for the resource. The economic value of water, for domestic and production use, has been estimated based on surveys in rural areas. Likewise, a precise typology of stakeholders and uses has been established for the Steelpoort, Kat River and Sekororo catchments. A dynamic system model (AWARE) and an educational role-playing game, derived from the model, have been used during training sessions organized for staff members from the Ministry of Water Affairs and Forestry, and added to training programmes for staff members from the new catchment management agencies. Using a companion modelling approach, the multisectoral water users' association established in Kat River has been able to draw up a catchment management plan in line with the new Water Act.

Experimental use of the role-playing game developed in the field at Kat River attempted to answer a very specific research question: the intrinsic lack of repeatability of adaptive modelling approaches, which makes it impossible to extrapolate information from one play session

The Kat River dam in South Africa: decentralization means involving stakeholders in managing artificial water reserves
© S. Farolfi/CIRAD





Irrigated smallholding in Sekororo, Limpopo: access to water is a determining factor in enabling rural households to practise subsistence or commercial farming
© S. Farolfi/CIRAD

to other situations. To address this issue, an experimental protocol was developed to test the economic hypotheses that emerged during role-playing game sessions. The problem of the repeatability of the approach is also being studied under another CIRAD project in South

Africa, aimed at building an abstract catchment area model and establishing an easily transferable approach that could be adopted on a larger geographical and institutional scale than that of small and medium-sized catchment areas.

Research is continuing: a project entitled ARISE has just been launched within the South African-French Network for Research in Water Science and Technology (SAFeWater), for a four-year period. It aims to develop ways of solving water resource governance problems in rural areas. It will also serve to strengthen cooperation between French and South African research teams, particularly in terms of university teaching.

Contact > Stefano Farolfi, Water Management Stakeholders and Uses (UMR G-EAU)
stefano.farolfi@up.ac.za

For further information

Banda B., Farolfi S., Hassan R., 2007. Estimating water demand for domestic use in rural South Africa in absence of price information. *Water Policy*, 9: 513-528.

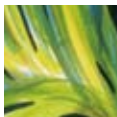
Dinar A., Farolfi S., Patrone F., Rowntree K., 2008. To negotiate or to game theorize: evaluating water allocation mechanisms in the Kat Basin, South Africa. *In: Game theory and policy making in natural resources and the environment*. Dinar *et al.* (ed.). Routledge.

Farolfi S., Mabugu R., Ntshingila S., 2007. Domestic water uses and values in Swaziland: contingent valuation analysis. *Agrekon*, 46: 157-170.

Farolfi S., Rowntree K., 2007. Accompanying local stakeholders in negotiation processes related to water allocation through simulation models and role-playing games: an experience from South Africa. *Empowers Insights*, 1: 5-7.

Website

www.ceepa.co.za/arise.html



Resolving disputes over water in periurban zones of Latin America

In periurban zones of developing countries, competition for water often leads to disputes. The Negowat project being conducted in Brazil and Bolivia should show how such situations can be alleviated by encouraging talks between stakeholders.

●●●●● **In periurban regions of developing countries**, water is now a scarce resource, and disputes often arise over its distribution between users. Competition is intensified by soil contamination and impermeability, which result in pollution and poorer water quality. While resource governance currently centres on concerted management, the relevant discussion

forums are often weakened by the under-representation of local communities, marked social inequality, and imbalances in terms of power and access to information.

The Negowat* project, which ran for four years, set out to calm the conflicts between various interest groups and encourage talks on improv-



A zone of periurban agriculture in the São Paulo region, in Brazil © R Ducrot/CIRAD

ing water management. It also aimed to include civil society in the collective decision-making process. It covered the fringes of Cochabamba, in Bolivia, and two catchment areas in the São Paulo metropolitan region: Guarapiranga and Alto-Tietê Cabeiceras. The merits and limitations of simulation tools and role-playing games were tested, either to strengthen the participants' skills or to come up with consensual solutions.

In Bolivia, mobilizing communities and improving stakeholder awareness

In Bolivia, the project comprised three operations. The first was aimed at setting up a platform to discuss a strongly criticized water and wastewater management project. It served to analyse the difficulties encountered by multi-stakeholder platforms in the event of imbalances in terms of power and access to information. The second aimed to develop a multi-stage approach to help community associations with technical, administrative and financial management. The four associations that tested the approach were able to draw up internal regulations, establish their legal status and negotiate special energy rates. Above all, their managers were able to improve their skills considerably, and their users to gain greater social control over their

operations. While the rates determined by the working party based on simulations were not validated collectively, the process did improve the financial situation and increase the legitimacy of the region's drinking water committees. The third operation set out to minimize the impact of urbanization on irrigation systems in two communities. The initial stages—diagnosis and awareness-raising—served to involve local communities, raise awareness among stakeholders, including the authorities, of the difficulties encountered, and discuss some solutions. Infrastructure projects and negotiated agreements have since been suggested, for shared infrastructure maintenance. While it proved impossible to find funding for the infrastructure projects, the operation did highlight the dual role—irrigation and drainage—of canals in periurban zones, and it changed attitudes to water among the various stakeholders. For instance, the town of Tiquipaya has since set aside a small budget to maintain irrigation canals, and the federation of irrigators' associations is now using the agreement drafted as the basis for talks with a view to negotiating a wider-ranging agreement.

In Brazil, negotiating and managing water quality more efficiently

In Brazil, an initial operation set out to build the negotiating power of local leaders using an adaptive modelling approach tailored to densely populated areas. It was based on a series of workshops, with a computer game developed and tested in two small zones. It served to change the interactions between the players concerned, and to improve their understanding of how the local water management system worked. It also demonstrated the difficulties institutions encounter in attempting to take account of the local players' true interests and in adopting less hierarchical planning approaches. The second operation aimed to make the members of a catchment area committee more aware of the need to manage water quality, and to trigger a discussion on the role and position of agriculture in this type of catchment area. It centred on a computer role-playing game. In particular, it served to provide a clearer understanding of the interdependencies within the system and thus the true significance

Partners

Agência Paulista de Tecnologia dos Agronegócios (APTA, Brazil), Associação Instituto Internacional de Ecologia e Gerenciamento Ambiental (AIIEGEA, Brazil), Centro de estudios de la realidad económica y social (CERES, Bolivia), Institut de recherche pour le développement (IRD, France), Instituto Polis, Natural Resources Institute (NRI, United Kingdom), Main University of San Simon (UMSS, Bolivia), State University of Campinas (UNICAMP, Brazil), University of São Paulo (USP, Brazil). This project was funded under the European Commission International Cooperation Programme (INCO), with the support of the Brazilian Ministry of Foreign Affairs.

of integrated water management. It led the players involved to look more closely at the reasons behind poorer water quality and triggered new research projects.

Over and above the knowledge acquired of water management systems in these regions, the project made it possible to analyse the limitations and merits of multi-stakeholder platforms for managing natural resources, to discuss the use of simulation tools, and to look at how natural resource governance can be approached on several levels. Monitoring and assessment of these operations showed that the local representatives had boosted their capacity to interact and negotiate with other organizations, and made institutional players aware of certain aspects of water management that had not been taken into account initially. However, the results and their dissemination are limited, as a result of the organizational and institutional weaknesses commonly seen in periurban zones.

* Negowat: Facilitation of negotiations concerning water use disputes in periurban regions

Contact > Raphaële Ducrot, Water Management, Stakeholders and Uses (UMR G-EAU), raphaelle.ducrot@cirad.fr

For further information

Butterworth J., Ducrot R., Faysse N., Janakarajan S. (ed.), 2007. Peri-urban water conflicts: supporting dialogue and negotiation. Delft, IRC, Technical Paper Series no. 50, 128 pp. (www.negowat.org).

Camargo M.E., Jacobi P.R., Ducrot R., 2007. Using role-playing game for capacity building on water and land management: comparing some Brazilian experiences. *Simulation and Gaming*, 38: 472-493.

Faysse N., 2006. Troubles on the way: an analysis of the challenges faced by multi-stakeholder platforms. *Natural Resources Forum*, 30: 219-229.

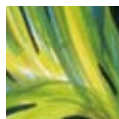
Quiroz F., Faysse N., Ampuero R. (ed.), 2006. Apoyo a la gestión de comités de agua potable: experiencias de fortalecimiento a comités de agua potable con gestión comunitaria en Bolivia y Colombia. Cochabamba, Etreus (www.negowat.org).

Website

www.negowat.org

A game session on the impact of urbanization on irrigation canals, on the outskirts of Cochabamba, in Bolivia © Vega





Strengthening producers' organizations in Costa Rica

Producers' organizations play a determining role in adapting agriculture to changing market demand. In response to trade globalization, more stringent consumer demands and environmental issues, they help farmers to adapt their production. In Costa Rica, a programme has been launched in partnership with CIRAD to help such groups step up their operations. It will be a long-haul project, combining training, improving the services provided, coordinating the various players and drawing up public policy.

Partners

Mesa Nacional Campesina (Costa Rica), Ministerio de Agricultura y Ganadería (Costa Rica), National University (Costa Rica), Unidad Regional de Asistencia Técnica (RUTA, Central America).

●●●●● Since 2003, a programme has been under way to support producers' organizations in Costa Rica, conducted by the Ministry of Agriculture and Livestock and national producers' organizations such as Mesa Nacional Campesina, in partnership with CIRAD. The programme is scheduled to run for several years and set out to train organization leaders and members, improve the services provided to producers, step up coordination between players within a given supply chain or territory, and draw up public policies favouring family farming.

sequences were defined to ensure a standard quality crop that could be exported to the United States and Europe. Likewise, for pineapple production, production practices and organization were adapted in order to obtain the EurepGap certification required by certain European supermarkets. This work was based on a research-action approach including surveying producers to determine their strategies and practices, organizing reporting meetings and exchanges of experience and helping producers' organizations plan their operations.

Defending family farming

For more than ten years, farmers' organizations in the Huetar Norte region had been looking for a way of defending their type of farming in the light of economic liberalization and the gradual withdrawal of State support, which triggered a serious crisis in family farming. In June 2003, 30 organizations took part in a discussion workshop, supported by CIRAD and the Ministry of Agriculture, which was to be the starting point for several years' joint work on their experiences and on the assets and weaknesses of their farms, their organizations and the region's supply chains. This collective work led to the drafting in 2005 of a plan of action shared by all the organizations in the region.

Subsequently, meetings were held between producers' organizations and support services in the eight regions of Costa Rica, in 2005 and 2006. They enabled an analysis of suc-



For pineapple production, production practices and organization have been adapted in order to obtain the EurepGap certification required by certain European supermarkets
© G. Faure/CIRAD

Building sociotechnical innovations

In the initial stages, work centred on developing sociotechnical innovations that would allow producers' organizations to respond to new demands from buyers: quantities and quality required, and delivery times. For instance, in the ornamental plant sector, crop management

Sendy Veerabadren, a student at the Institut des régions chaudes, won the top prize from the Union régionale des ingénieurs et des scientifiques du Languedoc-Roussillon (URIS-LR) for his study *Les producteurs face aux normes pour l'exportation d'ananas dans la région Huetar Norte au Costa Rica*.

In the ornamental plant sector, crop management sequences have been defined to ensure a standard quality crop that can be exported to the United States and Europe

© G. Faure/CIRAD



cessful operations to integrate markets and manage natural resources, and the drafting of economic plans. These meetings also provided the opportunity of collectively assessing the approaches taken by the various support services assisting farmers' organizations. They gave rise to a national conference, attended by more than 200 organizations, aimed at summarizing results and drawing up a national strategy for strengthening producers' organizations.

National strategy and services to producers

In 2007, under a project funded by the World Bank, two topics were tackled in response to requests from producers' organizations. The first concerned a national group of organizations that was keen to take the national strategy further based on an analysis of topics of common interest, such as development banks, water use regulation and support services for small and medium-sized enterprises. The aim was also to understand how some organizations

had managed to participate in public policy-making by establishing a dialogue with the government and striking strategic alliances. A workshop attended by some fifteen national organizations was held in November 2007, in the presence of the Minister of Agriculture, to foster exchanges between producers' and government representatives and plan accompanying measures for the free trade treaty signed with the United States.

The second topic was improving the services offered to producers: training, advice, credit, inputs, certification, project design and organizational support. Demand is strong, since new market opportunities have meant new requirements, and State withdrawal has meant that new ways

need to be found of providing such services. Under the project, case studies were used for an initial assessment of the situation: they revealed that supply and demand are social constructs that are specific to each situation, and that the market is rarely the mechanism that coordinates those two factors. Players came up with other modes of intervention, in which producers' organizations played a growing role in terms of services, either by providing them directly or by coordinating other service providers.

Alongside these studies, a service centre has been set up in the Huetar Norte region. It is managed by a young farmers' association and supports emerging organizations in the fields of management, market research and project design. Several young advisers have recently been recruited to coordinate the sustainable funding available for projects of an economic nature.

Contacts > Guy Faure, Innovation and Development in Agriculture and the Agrifood Sector (UMR INNOVATION), Jean-François Le Coq, Collective Action, Policies and Markets (UPR), guy.faure@cirad.fr

For further information

Faure G., Hocdé H., Meneses D., 2007. Réflexions sur une démarche de recherche-action : les organisations paysannes du Costa Rica construisent leur vision de l'agriculture familiale. *Cahiers Agricultures*, 16: 205-211.

Faure G., Le Coq J.F., Bouquet E., Rebuffel P., Pesche D., Wampfler B., 2007. Global service framework to family farms and rural households: an insight from CIRAD. *In: Réunion de Neuchâtel, 27-29 November 2007, Montpellier, France.*

Faure G., Maître D'Hôtel E., Le Coq J.F., Saenz F., 2007. Can supply chain's coordination mechanisms include small holders? Insight from an empirical work in Costa Rica. *In: 106th EAAE seminar, Montpellier, France, 25-27 October 2007, 21 pp.*

Maître D'Hôtel E., 2007. Participation et adaptation des organisations au changement institutionnel: les organisations agricoles au Costa Rica face aux politiques de libéralisation. Thesis, SupAgro, Montpellier.



Contracts for more profitable milk sales

In West Africa, the milk produced in rural areas is not widely used by the local dairy industry and faces stiff competition from imported powdered milk. To understand these market exclusion mechanisms, CIRAD and its partners have analysed the institutional arrangements underlying collection contracts in rural areas, notably regarding mini-dairies. Their work enabled a reinterpretation of previous failed attempts to launch industrial milk collection schemes.

●●●●● **In the Sahel, milk illustrates the difficulties** faced by the rural world in entering the market economy. In villages and encampments, milking punctuates the day, and the precious liquid is consumed and exchanged within families. It is abundant in the rainy season and may also be sold locally in the form of butter or fermented milk. However, this local milk accounts for just a limited share of the dairy products consumed in urban areas. It is primarily imported powdered milk that has invaded urban markets and is used by industrial dairies. African herdsmen and agropastoralists are thus largely excluded from the current industrialization process. To elucidate this paradox, CIRAD researchers have been working closely with teams in the region on a study of the complex relations between producers and urban markets.

A fragile, seasonal product with uncertain outlets

Milk is a fragile, seasonal product, and thus difficult to commercialize. Only rendered butter and fermented milk, which keep well, are sold on weekly markets, generally by women. These products are made on farms and are not used industrially. The various attempts to organize milk collection for processing units, which would have given farmers access to guaranteed markets, have generally failed.

In capital cities, an entire urban dairy processing industry has been built on cheap imported powdered milk. That industry has not properly

succeeded in organizing local milk collection. Among other things, this failure can be put down to the fact that the product's "farm" origin has not been promoted and that the rural areas are far away, which has not made it easy to introduce contract systems. Moreover, a "technicist" approach of collection systems has prevailed, which does not take sufficient account of the strategies adopted by the producers who would be supplying the milk.

Until the early 1990s, industrial dairy monopolies had hindered the emergence of private collection systems. Following the liberalization of the sector, small-scale farm milk collection and processing units appeared on the fringes of secondary towns. They gradually found a profitable niche market: fermented milk sold in portion bags of 0.1 to 1 litre. Milk is transported to those units by collectors on bicycles or mopeds.

Contracts that guarantee transactions

As the study of the relations between farmers and mini-dairies showed, collection is not limited to the purchase and transport of milk. It also means guaranteeing the transaction through various institutional arrangements: price and quality contracts or agreements, contracts including advances of either cash or inputs, and personal networks that act as a guarantee of good faith. Such coordination mechanisms, which serve to offset the uncertainty that can surround transactions, explain

Partners

Institut d'économie rurale (IER, Mali), Institut sénégalais des recherches agricoles (ISRA, Sénégal), Réseau de recherche sur les politiques laitières (REPOL), SupAgro Montpellier (France).

This research was supported by WECARD and French aid services.

the success of firms such as the mini-dairies that have now been set up in several secondary towns in West Africa.

Collection contracts between farmers and mini-dairies provide guaranteed outlets for milk. For farmers, this modifies their farming system. In particular, access to feed inputs boosts milk yields per cow. Using cottonseed, presscake or concentrated feed supplements the diet of lactating animals. Cash advances and monthly milk payments cover new types of expenditure. At the same time, collection networks provide jobs: staff are required for bicycle deliveries and in the mini-dairies.

Mini-dairies have had a marked positive impact: they boost incomes considerably around secondary towns, and are an easily reproducible technicoeconomic model. However, their development seems to be limited by their low collection capacity—between 200 and 1000 litres a day—and their difficulty in gaining a foothold on markets in large cities. At the same time, a new type of dairy industry is appearing in Mauritania, Senegal, Mali and Niger. The strategy behind it centres on local milk collection, based on similar types of contracts.

Collection contracts between dairy farmers and mini-dairies serve to guarantee milk outlets: a collector picking up the morning's milk in the Kolda region, Senegal
© G. Duteurtre/CIRAD



New hope for dairy supply chains

The current international situation seems to be offering industrial-scale collection a second chance. Whereas until the early 2000s, international agreements had made powdered milk more competitive, prices doubled between 2006 and 2007, which reversed the trend. As things stand, despite the fact that milk is abundant in rural areas, it is still rarely used by industry. It is therefore essential to introduce sectorial policies that encourage local supply chains to become more organized. The example to follow is that of the contracts signed between mini-dairies and the new rural dairy industries, backed up by appropriate tax and commercial policies. Several national workshops, in Burkina Faso, Mali and Senegal, have validated this. The participants stressed the fact that it was vital to guarantee outlets as soon as possible, to boost local dairy production.

Contact > Guillaume Duteurtre, Livestock Systems and Animal Product Management (UPR), guillaume.duteurtre@cirad.fr

For further information

Corniaux C., Duteurtre G., Dieye P.N., Pocard-Chapuis R., 2006. Les minilaiteries comme modèle d'organisation des filières laitières en Afrique de l'Ouest : succès et limites. *Revue d'élevage et de médecine vétérinaire des pays tropicaux*, 58: 237-243.

Dia D., Duteurtre G., Dieye P.N., 2007. Le rôle de l'élevage dans la lutte contre la pauvreté : l'exemple des filières laitières locales au Sénégal. *In: Agriculture, élevage et pauvreté en Afrique de l'Ouest*. Mbaye A. et al. (ed.). Dakar, Crea, p. 103-118.

Dieye P.N., 2006. Arrangements contractuels et performances des marchés du lait local au sud du Sénégal : les petites entreprises de transformation face aux incertitudes de l'approvisionnement. Doctoral thesis, SupAgro, Montpellier, 211 pp.

Website

www.repol.info

Olympe—decision support software for farmers

The agroeconomic performance of farms varies when their cropping systems are diversified. The performances of existing and innovative systems should be assessed under a broad range of different socioeconomic and agroecological settings in order to gain further insight into farmers' strategies and to be able to effectively advise them. The Olympe software package, which CIRAD has tailored to the specific features of plantation agriculture in tropical regions, simulates the functioning of these systems and their potential.

●●●●● **Three questions must be addressed** when evaluating technical and economic operations on farms for the purposes of decision support. What factors influence farmers in decision-making? What tool could be used to model production systems at the scale of the cropping system as well as at that of the region? What decision support software tools could be implemented to come up with technical and economic solutions that would suit both farmers and concerned decision-makers?

The Olympe software package provides scientists, advisors and farmers with answers to these questions. This software was developed by INRA for French farms and has been adapted by CIRAD and others for various contexts in developing countries, especially for farms that crop trees such as natural rubber, coffee, cocoa and oil palm.

Olympe can simulate technical and economic operations of one or several farms and assess the validity of crop management sequences that are being tested. It enables users to compare farm potentials and risks associated with tested economic and ecological innovations, while also proposing techni-

cal and economic solutions via direct collaborations with farmers.

Olympe is widely used by CIRAD scientists and partners in Africa, Madagascar and Asia, eg to evaluate technical options in coffee, cocoa and oil palm based systems, to compare sets of farms on which cocoa and natural rubber are the main crops, to simulate how farms operate under regional constraints (irrigated areas, erosion phenomena, etc), and finally to conduct prospective risk management analyses.

In addition to being a software package, Olympe is an international research and development network run by CIRAD, of researchers sharing

Home page of the Olympe website © CIRAD

The screenshot shows the home page of the Olympe website. At the top, there is a blue header with the OLYMPE logo and the text "SIMULATOR FOR TECHNICAL AND ECONOMIC MODELING OF FARMS". Below the header, there is a navigation menu with "EXTRAJET" selected. The main content area includes a welcome message, a description of the software's functionalities, and a list of partner organizations like CIRAD, INRA, and others. A "Last news" section is visible on the right side.

Partners

Bureau technique de promotion laitière (BTPL, France), Ecole supérieure d'ingénieurs et techniciens pour l'agriculture (ESITPA, France), Institut national de la recherche agronomique (INRA, France), Institut agronomique méditerranéen de Montpellier (IAMM, France), Institut de recherche pour le développement (IRD, France), Wageningen University and Research Centre (Netherlands).

the basis of the economic analysis and decision support method featured in the software. The aim is to transfer technology and disseminate knowledge: training scientists, extension agents, farmers and students; sharing software experience and development; coordinating international seminars; and publishing results on a broad range of different issues.

Contact > Didier Snoeck, Performance of Tree Crop-based Systems (UPR), didier.snoeck@cirad.fr

Website

www.olympo-project.net

For further information

Deheuvels O., Dubois A., Somarriba E., Malézieux E., 2007. Farmers' management and restoration of cocoa agroforestry systems in Central America: the role of the associated trees in the restoration process. *In: Agroforestry systems with perennial crops*, 17-21 September 2007, Turrialba, Costa Rica.

Glatard F., Enjalric F., Jagoret P., 2007. Characterization and assessment of cocoa based agroforestry cropping systems in Cameroun according to site conditions and

fertility management. *In: Agroforestry systems with perennial crops*, 17-21 September 2007, Turrialba, Costa Rica.

Ollivier J., Enjalric F., 2007. Des agrosystèmes performants à base de cocotier : une réponse aux attentes des planteurs. *In: Palmier à huile, cocotier*. Montpellier, CIRAD, 26 pp.

Penot E., Deheuvels O. (ed.), 2007. Modélisation économique des exploitations agricoles : modélisation, simulation et aide à la décision avec le logiciel Olympe. Paris, L'Harmattan, 182 pp.



The Olympe software package has been adapted for various contexts in developing countries, especially for farms that crop trees such as cocoa © C. Lanaud/CIRAD



Development-oriented agriculture: a new World Bank report

World Bank, 2007. World Development Report 2008: Agriculture for Development. Washington, World Bank, 384 pp.

Mercoiret M.R., Pesche D., Bosc P.M., 2007. Les organisations paysannes et rurales pour un développement durable en faveur des pauvres : compte-rendu de l'atelier de Paris, 30-31 October 2006. Montpellier, CIRAD, 45 pp.

www.worldbank.org/wdr2008

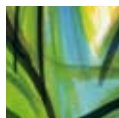
The World Bank's *World Development Report 2008* calls for greater investment in agriculture and warns that the sector must be placed at the centre of the development agenda if the Millennium Development Goal of halving the proportion of the population living in extreme poverty is to be reached by 2015. CIRAD participated indirectly in drawing up this report, focusing especially on farmers' organizations and fair trade.

The rise in farmers' organizations is one major change that has occurred in the agriculture sector in developing countries over the last 20 years. These organizations are now fully-fledged stakeholders with decision-making clout, and in some countries they can even participate in political discussions. During preparation of this report, CIRAD headed a workshop

on how smallholders' and rural organizations can promote pro-poor sustainable agricultural development. Around 20 farmers' organization representatives from three continents discussed this issue.

The fair trade movement has grown considerably in the last decade. This trend is increasingly marked on European and US markets and can now be assessed on its performances and future, according to three possible scenarios: successful market integration, stabilization as a niche market, or termination of the movement in its current form due to a lack of a clearly defined role and image.

Contact > Denis Pesche, Collective Action, Policies and Markets (UPR), denis.pesche@cirad.fr



Prototyping innovative crop management systems advised by experts

In a shaky macroeconomic setting, societal requirements regarding agriculture are complex and can be fulfilled through rapid shifts in farming techniques. Farmers and decision-makers must therefore have access to solutions tailored to specific situations and that have been achieved through integrated approaches. The crop management system prototyping method was developed by CIRAD and partners to meet this challenge.

Partners

Institut d'économie rurale (IER, Mali), Institut de recherche agricole pour le développement (IRAD, Cameroon), Institut national de la recherche agronomique (INRA, France), Institut national des recherches agricoles du Bénin (INRAB, Benin), SupAgro Montpellier (France).

●●●●● **Farming techniques are being diversified** through the rational use of production inputs and the increased range of criteria for their assessment. As new sustainable development guidelines are being enforced in developed and developing countries, production per available resource unit must be increased in order to design farming techniques that are less input-costly in the North and better adapted to local constraints in the South. Societal requirements regarding agriculture are thus complex and can be fulfilled through rapid shifts in farming techniques. Solutions developed through integrated approaches and tailored to specific situations are needed to meet this complex challenge. Could scientists and farmers contribute to addressing this issue and developing innovative crop management systems through their knowledge and expertise?

A crop management system prototyping method was thus developed by CIRAD researchers and partners in Benin, Cameroon and Mali to meet this challenge. This participatory and multidis-

ciplinary method is aimed at designing crop management sequences that could be suitable in situations involving specific combinations of constraints, production and marketing opportunities. There are four steps: assessment and definition of the specific requirements, development of a prototype, assessment and adjustment in the research station, and assessment and adjustment on farms. Proposed solutions are evaluated from agricultural, economic and environmental standpoints.

The first three steps of the method were tested and validated from 2001 to 2006. A crop management sequence was, for instance, designed and validated for late-sown cotton crops and was found to generate better yields than standard crop management sequences. This sequence was developed by experts, scientists and extension agents and included new earlier varieties, a higher planting rate, lower fertilizer dosages, rational pest control, and herbicide and growth regulator applications. It was tested over a 2-year period in a research station and was found to generate good yields under later sowing conditions—the gross margin of the crop was even enhanced by 20-35% and the labour productivity by 5-20%. Overall, these results highlight that the joint involvement of researchers and experts, sometimes with different but complementary ways of approaching agriculture, is advantageous in dealing with targeted research issues, eg rapid development of crop management sequences.

Prototyping crop management sequences has served to design and assess the performance of a cotton crop management sequence for late sowing

© J.Y. Jamin/CIRAD



Example of a crop management sequence request

A cotton smallholder has a farm in the Sudano-Sahelian region where the single yearly rainy season lasts five months, from May to October. The main crop pests in this region are two sucking-stinging insects (*Empoasca minor* and *Aphis gossypii*) and two bollworms (*Helicoverpa armigera* and *Spodoptera littoralis*). Bacterial blight (*Xanthomonas malvacearum*) is the primary cotton disease. This farmer has work peaks at the beginning of the crop season so he has to delay the sowing of some plots, and therefore hopes to cultivate a late-sown cotton plot on sandy ground and make a profit. This farmer has access to essential inputs—seed, fertilizer and pesticides—and will be able to sell his entire seed cotton crop at a price set by local ginning mills. Manpower is, however, relatively scarce at critical times, especially during the sowing and harvesting periods. In these conditions, technical interventions should mainly promote the emergence, installation and rapid development of the plant cover and crops, optimal but rational control of pest worms on the first bolls, as well as early and grouped boll opening.

Further improvements are now required to reduce the environmental impact of the system: use of earlier varieties, and more precise guidelines tailored to African conditions for the application of pesticides and growth regulators. Field experiments can also reveal the shortcomings of the crop management sequences designed by experts and highlight new aspects that could be the focus of future research.

Contact > Jacques Lançon,
Annual Cropping Systems (UPR),
jacques.lancon@cirad.fr

For further information

Lançon J. *et al.*, 2007. An improved methodology for integrated crop management systems. *Agronomy for Sustainable Development*, 27: 101-110.

Rapidel B., Defèche C., Traoré B., Lançon J., Wery J., 2006. In field development of a conceptual crop functioning and management model: a case study on cotton in southern Mali. *European Journal of Agronomy*, 24: 304-315.

Rapidel B., Traoré B.S., Sissoko F., Lançon J., Wery J., 2008. Application of the prototyping approach to design and assess cotton management systems in Mali. *Agronomy for Sustainable Development* (*submitted*).

Sêkloka E., Lançon J., Gozé E., Hau B., Lewicki S., Thomas G., 2008. Breeding new cotton varieties to fit the diversity of cropping conditions in Africa: effect of plant architecture, earliness and effective flowering time on late-planted cotton productivity. *Experimental Agriculture*, 44 (*in press*).



Fragile states: birth of an international consensus

In 2005, following two high-level meetings of development-assistance bodies, the fragile states concept became a structuring framework for assistance policies concerning Organization for Economic Cooperation and Development (OECD) countries and the World Bank. This concept was developed further to initiatives undertaken at the dawn of the new millennium to identify or differentiate a set of countries that could potentially become assistance beneficiaries even though they do not fulfil the current requirements: responsibility (ownership) and partnership in the development and implementation of poverty alleviation policies. For these “non-compliant” countries, this primarily involves defining specific intervention conditions for development assistance agencies to enable them to fulfil their poverty curbing objectives. The consensus on the fragile states concept reflects a substantial shift in agency strategies. In addition to poverty alleviation, the capacity of states to ensure law and order has now become a goal in itself.

A multidisciplinary book entitled *Etats et sociétés fragiles : entre conflit, reconstruction et développement* includes contributors from a broad range of

different fields. The research of these authors highlights the complexity of this new field of international debate and action, at the interface between the post-9/11 period and fundamental changes in theory concerning links between “security” and development. It showcases many studies, including those conducted by CIRAD researchers concerning the development of an international consensus on this concept. Through an analysis of the progress of the international debate—first at the OECD Development Assistance Committee and then in USA, UK and finally at the World Bank—they strive to clarify the fragile states concept and assess the extent of recent international consensus and implications with respect to donors’ policies. They then discuss three “issues” encountered by assistance agencies: the efficiency of aid, the post-9/11 security issue, and finally the emerging donor countries (China, Brazil, India). The fragile states concept is situated at the “interface” of these issues.

Contact > Benoit Daviron, Markets, Organizations, Institutions and Operators’ Strategies (UMR MOISA), benoit.daviron@cirad.fr

Châtaigner J.M., Magro H. (ed.), 2007. *Etats et sociétés fragiles : entre conflit, reconstruction et développement*. Paris, Karthala, 566 pp.

Daviron B., Giordano T., 2007. *Etats fragiles : genèse d’un consensus international*. In: *Etats et sociétés fragiles : entre conflit, reconstruction et développement*. Châtaigner J.M., Magro H. (ed.). Paris, Karthala, p. 23-40.



GAMEDE: a global model to assess farm operations

Cattle production is an essential activity in developing countries, but also has negative effects: biodiversity loss, pollution and greenhouse gas emission. Dense livestock farm concentrations and daily farming practices often aggravate these effects. Scientists and professional stakeholders thus require models of these systems that integrate all decisions made by farmers on a daily basis. CIRAD has built such a model on the basis of dairy farm operations in Réunion. It simulates all farm activities and concomitant flows.

●●●●● **Livestock is a key component of agriculture** in developing countries in terms of its production, savings and credit potential, as well as providing organic matter and traction for cropping. Cattle production also has many negative environmental impacts: diversity loss, air and water pollution, direct and indirect greenhouse gas emission. In addition, the extent of these environmental stresses often depends on the concentration of livestock farms in the area and on the daily farming practices. The release of excess nitrogen into the environment is, for instance, directly linked with livestock rearing practices and their impact on the environment varies substantially according to the farming methods implemented. Researchers and professional livestock producers thus require a model that can simulate farmers' daily decisions concerning farming operations, as well as the impacts

on overall farm operations and on the technical and environmental performances. GAMEDE*, a flow dynamics model, was developed on the basis of experience gained on dairy farms in Réunion. It provides in-depth descriptions of each activity on a dairy cattle farm and of all biomass and nitrogen flows on the farm and between the farm and the environment.

A complex system to manage and model

Dairy farming is clearly a very complex system to manage and, consequently, to model. It resembles a set of resources linked by flows of different types of biomass (livestock, milk, wastes, fodder, etc). Some flows are the result of interventions directly carried out by the farmer ("actionable flows"), while others are the result of natural biophysical processes that

A dairy farm on the Cafres plain in Réunion
© J. Vayssières/CIRAD



Partners

Agence de l'environnement et de la maîtrise de l'énergie (ADEME, France), Association réunionnaise interprofessionnelle du bétail, de la viande et du lait (ARIBEV, France), Fédération régionale des coopératives agricoles de la Réunion (FRCA, France), Sicalait (France), SupAgro (France). This research was also conducted under the ANR-ADD SPADD and DISCOTECH programmes.

cannot be directly altered by farmers ("biophysical flows"). The GAMEDE model integrates a decision-making system that simulates 19 different operations along with a complex biophysical system consisting of six modules representing animal- and plant-based biological mechanisms. Complementary aspects of the disciplines had to be focused on and standard modelling methods modified to be able to model this complex integration process.

Six livestock farmers representative of the range of different local decision-making profiles were directly involved in designing the model. Research inspired by ethnography approaches was carried out and gave rise to operational decision-making guidelines relative to each technical operation. Bimonthly follow-up results were then used to draw up guidelines concerning changes in the status of the livestock production systems, ie fodder stocks, herd compositions and grass growth on plots. Guidelines and tools were developed previously, but these partial models had to be adapted to the local situation and combined into a global biophysical system.

GAMEDE, a model that simulates the overall activities of dairy farms

GAMEDE was programmed in a dynamic hybrid system. The input variables concern the farm structure (herd size, plot pattern), the agroclimatic environment of the farm, and the livestock farmer's strategy described according to decision-making guidelines and seasonal input availability (fodder, organic fertilizer).

The decision-making system simulates all of the farmer's daily activities according to the decision-making guidelines, the status of the production system and its environment. The biophysical system reflects the technical interventions in actionable flows and simulates the biophysical flows, which are both affected by daily meteorological conditions. GAMEDE's unique feature is that it can dynamically simulate (in a daily or several-year time step) all operations on the farm, along with the state of the flows and biomass stocks. It has been validated under field conditions, and the simu-

lations were also compared with the views of livestock producers, researchers and technicians.

The model is currently being used to interpret biomass flows in terms of nitrogen flows and to calculate environmental (nitrogen balance and efficacy), social (labour times and constraints) and technical (pasture and dairy productivity) indicators. An economic assessment module and an energy consumption simulation module will soon be added to the package.

GAMEDE has a broad application scope. It can be used in collaboration with farmers to assess the impacts of technical choices or innovations that could be introduced to help farmers adapt to the rapid agricultural transformations currently under way. The conceptual framework of the model is generic, and it can be applied to other types of livestock production and combined crop-livestock farming situations simply by modifying the parameterization and sometimes adding other crop modules.

* GAMEDE: Global activity model for evaluating the sustainability of dairy enterprises

Contacts > Philippe Lecomte, Jonathan Vayssières, Livestock Systems and Animal Product Management (UPR), philippe.lecomte@cirad.fr

For further information

Vayssières J., Bocquier F., Lecomte P. GAMEDE, a global activity model for evaluating the sustainability of dairy enterprises: interactive simulation of various management strategies. *Agricultural Systems* (submitted).

Vayssières J., Guerrin F., Paillat J.M., Lecomte P. GAMEDE, a global activity model for evaluating the sustainability of dairy enterprises: whole-farm dynamic model. *Agricultural Systems* (submitted).

Vayssières J., Lecomte P., 2007. Modéliser les pratiques décisionnelles et les flux d'azote à l'échelle globale de l'exploitation : cas de l'élevage bovin laitier en contexte tropical insulaire. *In* : XIV^e congrès 3R : rencontres autour des recherches sur les ruminants, 5-6 December 2007, Paris, France. Paris: Institut de l'élevage, p. 45-48.

Vayssières J., Lecomte P., Guerrin F., Nidumolu U.B., 2007. Modelling farmers' action: decision rules capture methodology and formalisation structure: a case of biomass flow operations in dairy farms of a tropical island. *Animal*, 1: 716-733.



Streamlining our approaches to family farming

Agriculture is changing as a result of environmental modifications and new market conditions. Farming techniques and structures are being transformed to keep pace with these changes. There has also been a renewal of research strategies, which must now focus on all stakeholders of these new activity systems.

●●●●● **In most developing countries,** family farms have to cope with a competitive economic environment and quality standards set by importing countries or the retailing and distribution industry. They are also forced to adjust to the deterioration in farming conditions associated with climate change and to the rise in input prices, which has increased their production costs. CIRAD conducted a series of studies in sub-Saharan Africa, Central America and North Africa on the functioning of farms, their environment and interactions with other production stakeholders.

Pluriactivity—a response to environmental change

Active family members are diversifying their activities (pluriactivity) to an increasing extent to cope with the changing situation, especially the lack of land, eg combining trading, handicrafts, processing and small animal farming. In many cases, these activities require a temporary move or investment in non-agricultural equipment, and raw materials and markets must also be located in the vicinity. This pluriactivity trend is more substantial around towns, especially in regions with a low production potential, such as in central Senegal or on the central plain of Burkina Faso. Conversely, in cropping areas where farmers still manage to achieve a regular substantial income, non-agricultural activities are less common or only undertaken on certain farms, eg some farms in southern Cameroon are specialized in red palm oil production. These non-agricultural activities are the result of individual initiatives and do not always involve the head of the farm.

These new forms of organization (“activity systems”) within families prompt job reorganization and reduce the investment capacity of the farm, eg to purchase equipment or land. Ever-expanding activity areas, corresponding to hubs for new urban-rural relationships, are associated with these systems. This pluriactivity trend may sometimes revitalize the economy or alter conventional land and natural resource management rules. For instance, farmers may overlap fuelwood resources in their processing activities or accelerate the transformation of wetlands into market gardens, without gauging the potential impacts of these activities on biodiversity and water quality.

Adapting to new market requirements

New forms of production organization also arise when family farms become part of marketing subsectors or channels that are more demanding in terms of production quality and regularity. The farm has to modify its practices and change the way its production system is managed. This is, however, not enough to boost the performance, which often requires collective initiatives managed by farmers’ organizations that serve as intermediaries between the farms and the buyer-processor, and that take care of the primary collection, quality control, staggered planting, etc. The resulting capital gain can be shared between all stakeholders of the sector who have participated in the process. CIRAD carried out studies to improve coordination between these different stakeholders, by integrating incentive, control and advice tools.

Partners

AgroParisTech (France), Ecole nationale de formation agronomique (ENFA, France), Institut agronomique et vétérinaire Hassan II (IAV, Morocco), Institut national de la recherche agronomique (INRA, France), Pôle de recherche appliquée au développement des savanes d’Afrique centrale (PRASAC, Cameroon, Central African Republic, Chad), SupAgro Montpellier (France).

Active family members are increasingly opting for pluriactivity, to cope with the changing situation, especially the lack of land: trading, handicrafts, processing and small animal farming
© P. Dugué/CIRAD



These results change the perception of the rural community and necessitate research adaptation. Systems to provide support and advice for farmers should involve all stakeholders and not just the heads of farms, ie youths and women who manage specific activities, managers of farmers' organizations and irrigated areas, as well as agrifood and retailing and distribution industry managers who purchase the produce.

Finally, this agricultural duality trend—family farm vs corporate enterprise—is now taking effect in developing countries. Research should thus look at the possibilities of developing methods for coordinating these two types of often competing production system.

Contact > Patrick Dugué, Innovation and Development in Agriculture and the Agrifoods Sector (UMR INNOVATION), patrick.dugue@cirad.fr

For further information

Chia E., Dugué P., 2006. L'exploitation agricole familiale : mythe ou réalité ? Cahiers agricultures, special issue, 15.

Faure G., Veerabadren S., Hocdé H., 2008. L'agriculture familiale mise sous normes : jusqu'où les producteurs d'ananas du Costa Rica pourront-ils relever le défi ? Revue d'économie rurale (*in press*).

Gafsi M., Dugué P., Jamin J.Y., Brossier J. (ed.), 2007. Exploitations agricoles familiales en Afrique de l'Ouest et du Centre : enjeux, caractéristiques et éléments de gestion. Paris, QUAE, collection Synthèses, 456 pp.

Le Gal P.Y., Kuper M., Moulin C.H., Puillet L., Sraïri M.T., 2007. Dispositifs de coordination entre industriel, éleveurs et périmètre irrigué dans un bassin de collecte laitier au Maroc. Cahiers agricultures, 16: 265-271.



Agrifood enterprises and poverty alleviation in sub-Saharan Africa



Dried fish stall in Ghana
© E. Cros/CIRAD

Ensuring food security, alleviating poverty and reducing inequalities are key priorities for international development-oriented cooperation in sub-Saharan Africa. Operations undertaken to fulfil this need do not, however, pay sufficient heed to the role and potential of micro- and small-scale agrifood enterprises, despite the marked development of these individual/collective and rural/urban commercial activities in all agrifood commodity chains. They provide town dwellers, especially those with low incomes, with products tailored to their purchasing power, food habits and ways of life. They generate thousands of jobs, especially for women, and make effective use of their knowledge and skills, while also

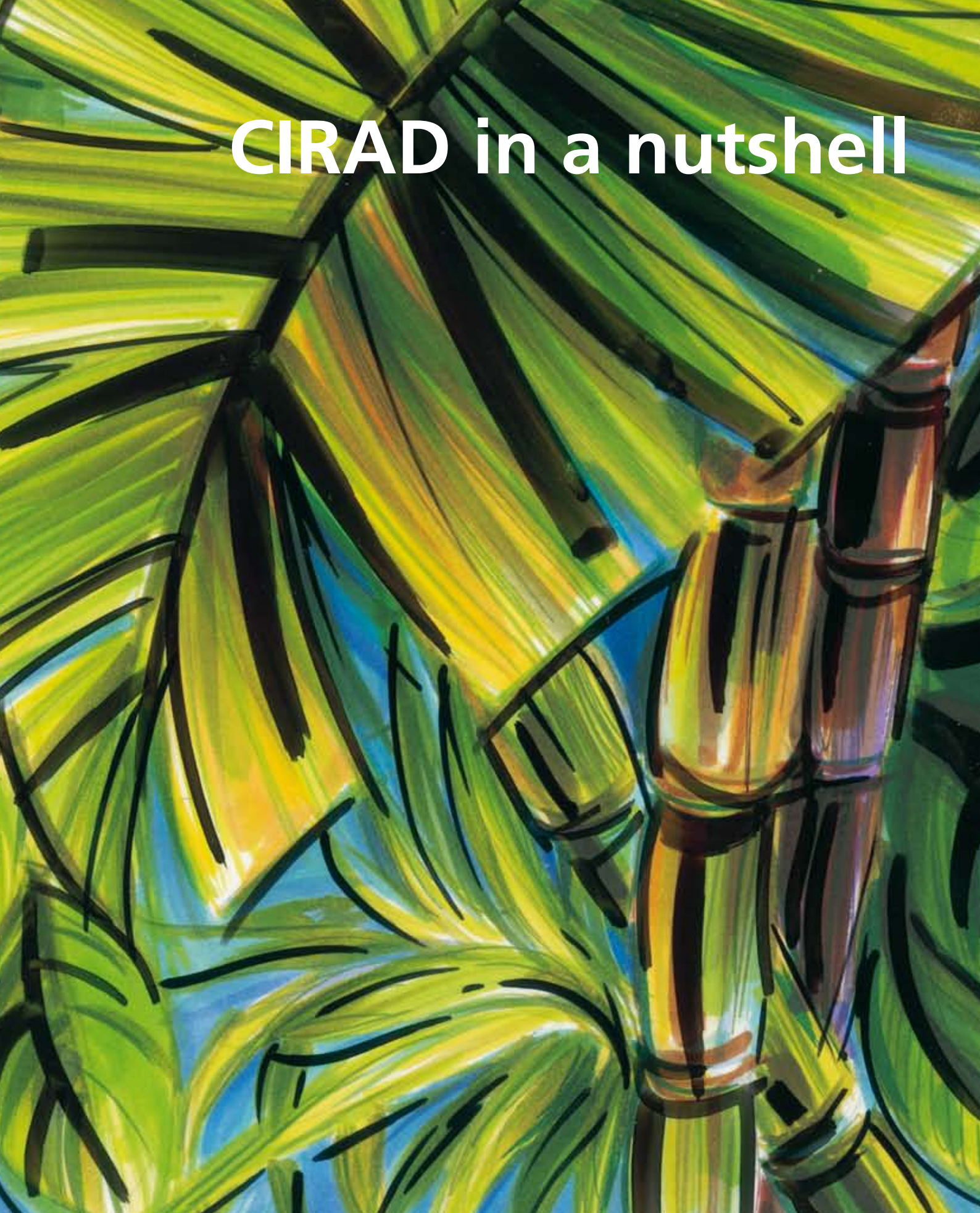
substantially contributing to the income and capacities of the poorest households.

Based on an original typological classification of the sector and an analytical grid, the authors of the book *Agroalimentaire et lutte contre la pauvreté en Afrique subsaharienne* analyse the role of these enterprises in ensuring food security and reducing inequalities, in addition to their constraints. They put forward proposals for greater recognition of this sector and propose methods and indicators to clarify poverty alleviation criteria.

Contact > Nicolas Bricas, Markets, Organizations, Institutions and Operators' Strategies (UMR MOISA), nicolas.bricas@cirad.fr

Broutin C., Bricas N., 2006. *Agroalimentaire et lutte contre la pauvreté en Afrique subsaharienne*. Paris, GRET, 128 pp.

CIRAD in a nutshell

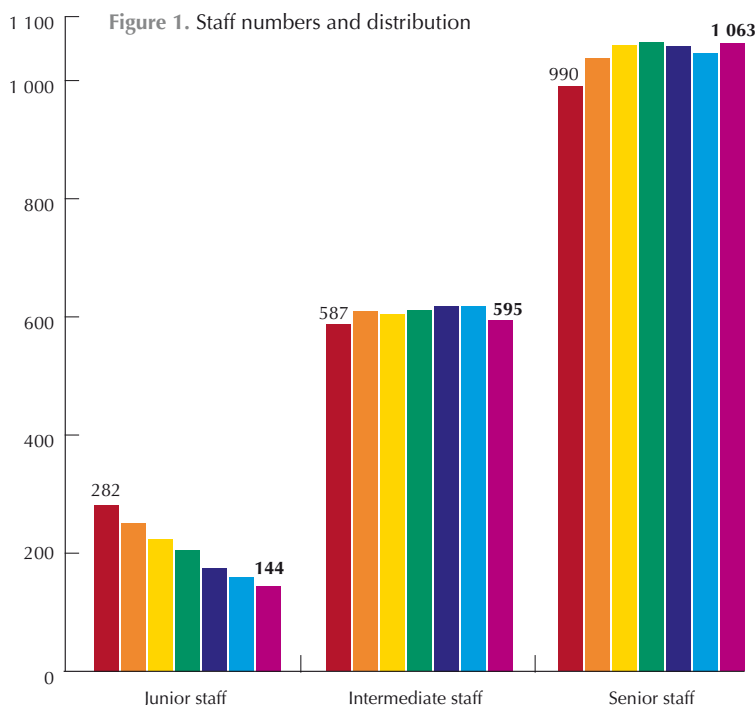


Indicators

Three elements characterize the indicators for 2007: their scope, reporting methods, and the results obtained. As regards their scope, CIRAD is continuing to work on the indicators laid down in the contractual agreement for the period 2001-2005. The new contractual agreement, which is being finalized, will mean new indicators as of 2008. Indicator reporting was made both more secure and more reliable in 2007, notably through a new human resources information system. The results obtained tally with CIRAD's scientific refocusing: more senior scientific staff members, directors of research, and publications in ISI impact-factor journals. Quoting some indicators at research unit level, and setting their managers contractual targets, should improve CIRAD's performance in the coming years.

Human resources

Overall staff numbers continued to fall in 2007, from 1825 to 1802, albeit with a major change in relation to the pattern in recent years. The fall in the number of senior staff members, which began in 2004 in the aftermath of a "strategic rethink", has now stopped. Numbers rose from 990 in 2001 to 1065 in 2004, but fell to 1047 in 2006; the 2007 figure in 2007—1063—was almost back to the 2004 level. A similar, albeit opposite, change was seen for intermediate staff members: while their numbers had previously continued to grow, from 587 in 2001 to 618 in 2006, they fell back in 2007, for the first time in six years, to 595. The number of junior staff members is continuing to fall, but less markedly than in the past (figure 1).



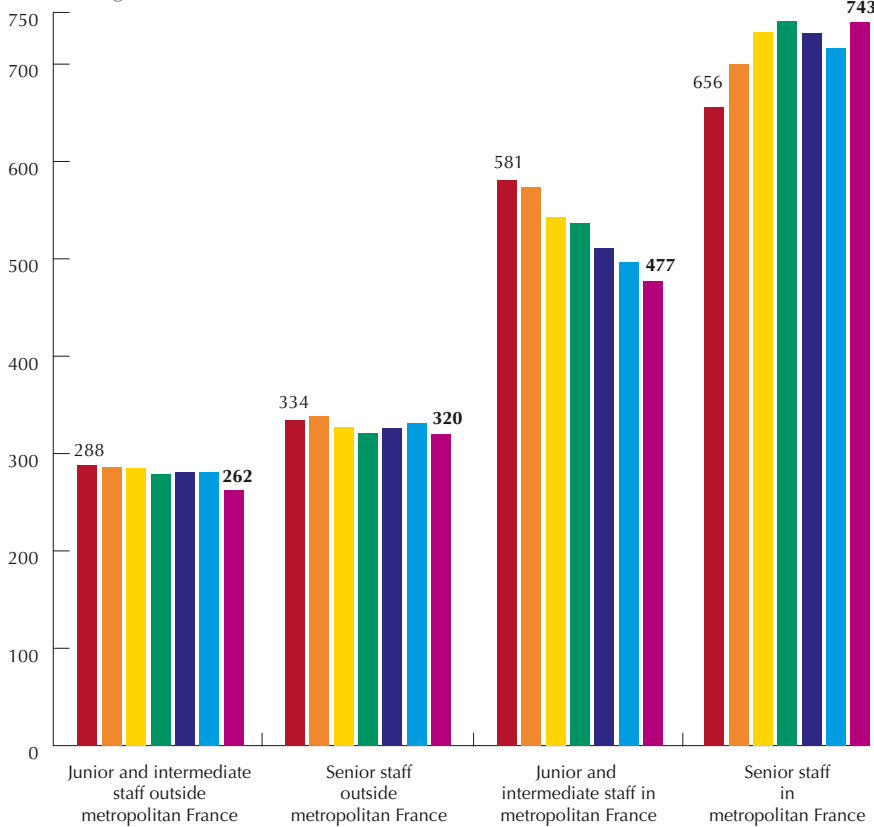
The increase in the number of senior staff members is not linked to the drop in the number of intermediate staff members. In fact, internal promotion levels were the same in 2006 and 2007, and the increase in the number of senior staff members in 2007 was solely due to a better net balance between the number of staff members who left CIRAD and the number recruited.

The changes in staff numbers differed widely from one place to another. The number of junior staff members and intermediate staff members fell to a similar extent overseas and in metropolitan France, but while that of senior staff members rose significantly in metropolitan France (from 716 to 743), it fell, albeit to a lesser extent, overseas: from 331 to 320. This reduction concerned the French overseas regions (–6), Asia and Oceania (–7) and Latin America (–2). At the same time, numbers were up slightly in Africa (+2) and industrialized countries (+2) (figures 2 and 3).

The number of missions fell in much the same way as the geographical distribution of staff numbers, with a significant drop in Asia, Oceania and the French overseas regions (figure 4).

The increase in senior staff numbers concerns senior scientific staff members, whose numbers rose from 788 in 2006 to 808 in 2007. Moreover, CIRAD is still supported by associate senior staff members, including ten assigned by INRA and eleven by the Ministry of Agriculture. Fur-

Figure 2. Location of CIRAD staff



therefore, it also contributes to operations at eleven CGIAR (Consultative Group on International Agricultural Research) centres, to which it assigned 25 researchers in 2007, five more than in 2006.

After falling slightly in 2006, the number of researchers of European origin is back to its 2005 level, at 39. Overall, the proportion of European researchers is stable: 3.7% since 2002, following a recruitment campaign in 2000-2002 (figure 5).

The increase in the proportion of female senior staff members continued in 2007: the number reached 300, representing 28.2% of the total number of senior staff members, as against 21.8% in 2001 (figure 6).

The pattern for the number of PhD holders and directors of research (HDRs) was the same as that for scientific staff members in 2007. In relative terms, after a drop in 2004, the proportion of PhD holders has risen for the third year running, to 50.9%. The proportion of directors of research has also grown steadily, from 7.1% in 2001 to 9.2% in 2007 (table I).

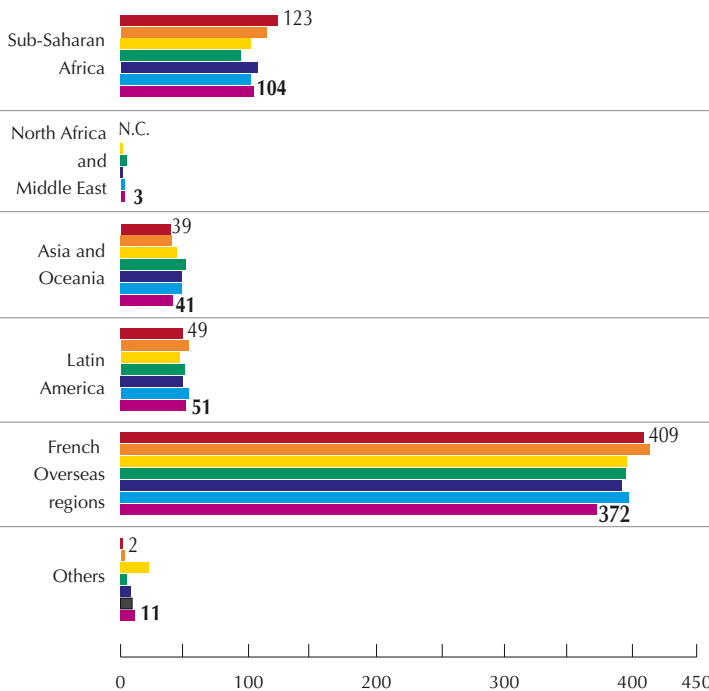


Figure 3. Distribution of assignments (numbers)

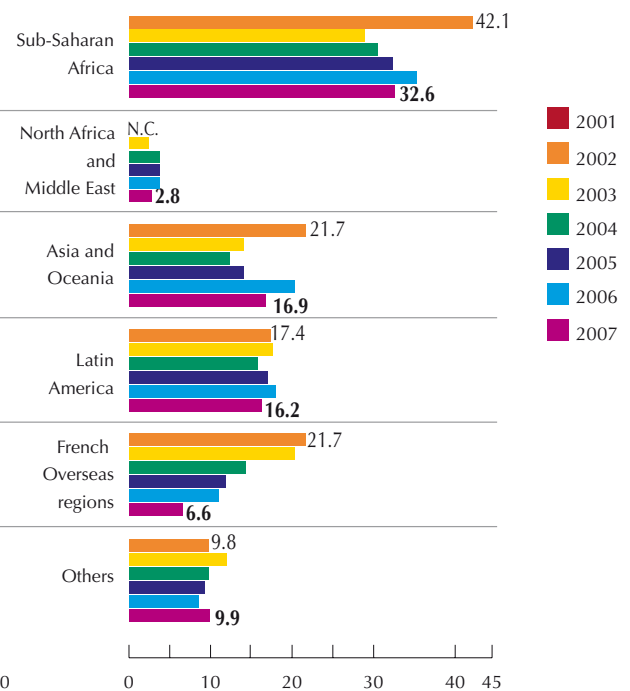


Figure 4. Distribution of missions (full-time post equivalents)

2001
2002
2003
2004
2005
2006
2007

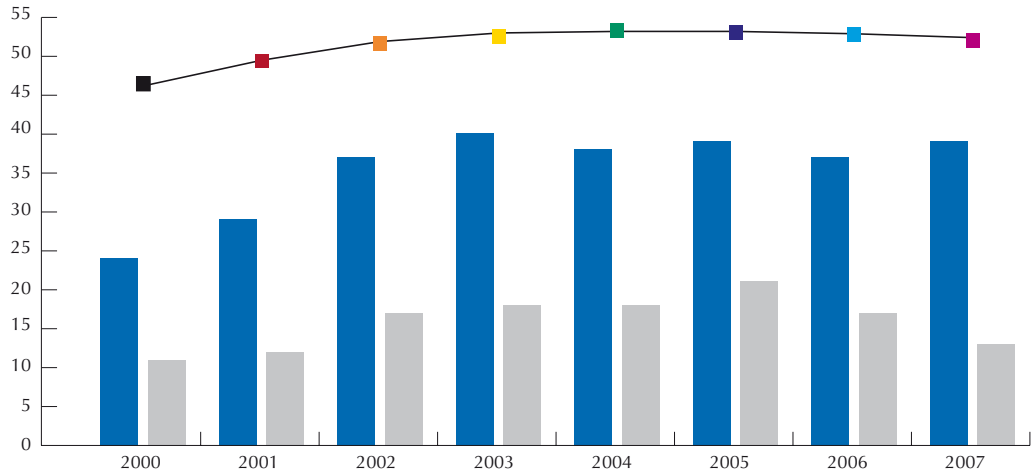
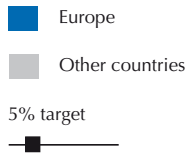


Figure 5. Changes in the number of senior staff members and target for senior staff members from the European Union

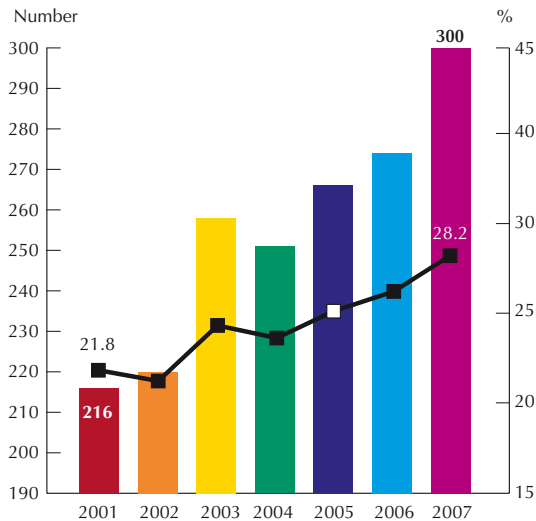


Figure 6. Changes in the number of women on the senior scientific staff

Table I. Scientific qualification levels from 2001 to 2007

	2001	2002	2003	2004	2005	2006	2007
Senior staff members	818	842	899	878	878	856	896
PhD holders							
number	408	419	465	439	436	430	456
percentage	49.9	49.8	51.7	50.0	49.7	50.2	50.9
HDRs							
number	58	67	72	68	75	76	82
percentage	7.1	8.0	8.2	7.7	8.5	8.9	9.2

In 2007, CIRAD was associated with 22 joint research units, two more than in 2006. The number of researchers involved in such units is up considerably, from 200 to 285. Four units account for half the total number of researchers: DAP (58 researchers), QUALISUD (47), TETIS (22) and INNOVATION (22). The proportion of researchers in joint research units is up from 25% in 2006 to 33% in 2007 (figure 7).

Intellectual property

CIRAD has a portfolio of 34 patents, half of them held jointly with at least one partner. By the end of 2007, it had registered 44 softwares, 34 plant variety protection certificates (PVPCs), ten brands, a design and model, and a dossier technique secret (trade secret).

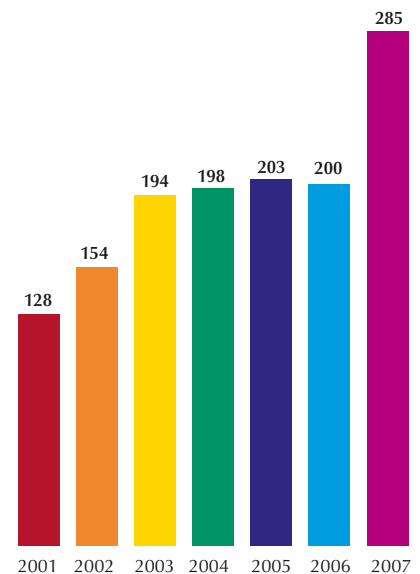


Figure 7. Changes in the number of CIRAD researchers working for joint research units

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. Due to the time that elapses before actual publication, only 50 to 70% of 2007 publications had been recorded by 31 January 2008, so by convention, the annual indicators quoted concern publications in both 2006 and 2007.

The total number of publications (journal articles, books, book chapters, conference proceedings and papers, and theses) has fallen since 2004. 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 8).

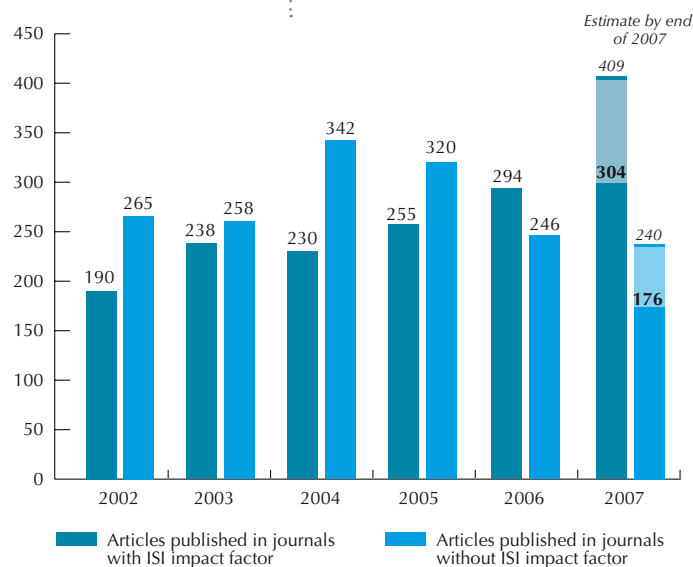


Figure 8. Changes in the number of articles published in journals

For the period 2006-2007, 598 articles were published in ISI impact-factor journals, or 27% of the total number of publications (figure 9). Of those, 524 (88%) were written jointly with authors from outside CIRAD.

The co-authors were primarily working in Europe (376 articles and 72% of joint publications) and Africa (155 articles and 30% of joint publications) (figure 10). They were mainly from organizations based in France (62% of joint publications), the United States (6%), Brazil (5%), and Burkina Faso, Senegal and Mali (4% each).

The co-authors came from a wide range of organizations: research organizations (68%), universities (44%) and elite colleges (11%). The research organizations most widely represented in these joint publications were INRA, IRD and CNRS in France, IER in Mali, IRAD in Cameroon, CNRA in Ivory Coast and ISRA in Senegal.

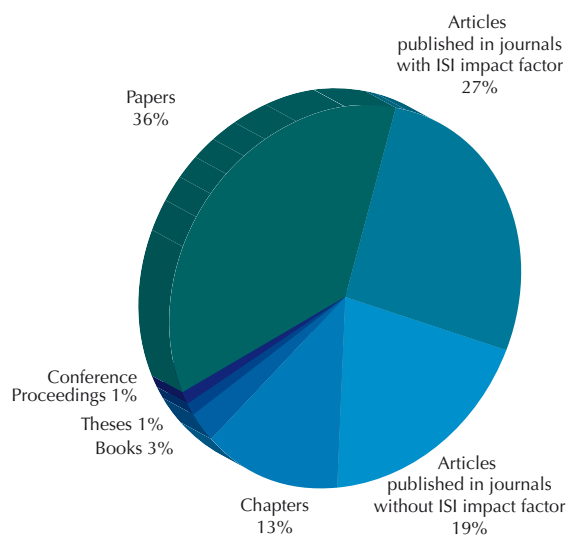


Figure 9. Distribution of publications according to the type of document

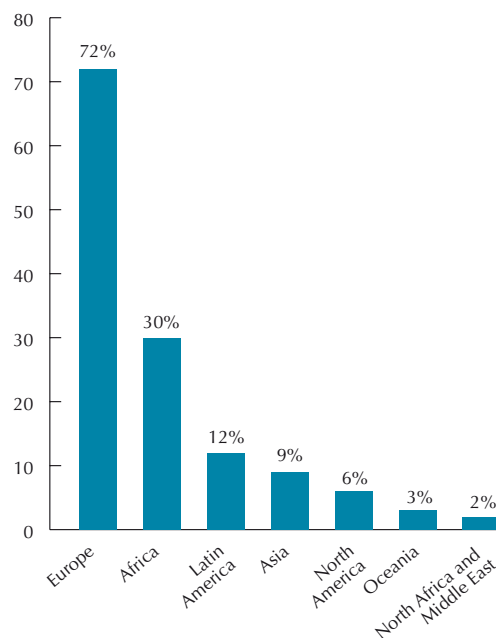


Figure 10. Geographical origin of co-authors of articles published in ISI impact-factor journals

Scientific events

In 2007, CIRAD organized or co-organized some twenty conferences and seminars. Of those, several were international, including "ICOPE 2007", on palm oil and the environment, organized with Smart Agribusiness and Food and the WWF, "Stakes and Perspectives of Biofuels for Africa", organized with the International Institute for Water and Environmental Engineering (Burkina Faso), "Pro-Poor Development in Low Income Countries", a European Association of Agricultural Economists seminar, organized with the University of Montpellier, and "Does Control of Animal Infectious Risk Offer a New International Perspective?", an Association of Institutions for Tropical Veterinary Medicine (AITVM) conference.

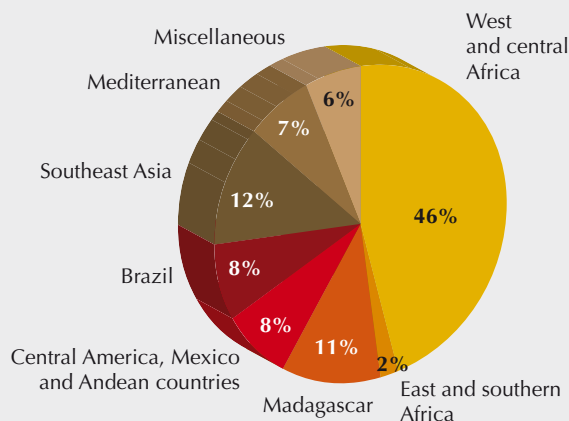
It also participated in several exhibitions, including the Paris International Agricultural Fair (SIA), where it organized a stand, events and a conference on "Coconut, oil palm: trees of life, crops for the future", and the "Energaia" Renewable Energies Exhibition in Montpellier.

Training, an essential mandate

Training, be it technical or scientific, academic or on-the-job, is one of CIRAD's main mandates. In 2007, CIRAD received 225 doctoral students in its laboratories, including 135 from outside France. It also organized 130 short-stay scientific courses for researchers from developing countries, in its laboratories in metropolitan and overseas France.

Generally speaking, CIRAD is strengthening its links with educational establishments, to ensure that agricultural research is part of their activities and to encourage students to commit themselves to CIRAD's research topics. It is now involved in 16 postgraduate courses, in partnership with universities or elite colleges in France and abroad. CIRAD's Research and Strategy Office has also taken the initiative of funding theses by students from organizations working with CIRAD. Around forty subjects were chosen in 2007, and the budget is to be carried over into 2008.

Distribution of foreign PhD students according to geographical origin in 2007



New Masters in "Animal Production Operations"

Teaching and training are a big part of CIRAD's mandate. In the field of animal production and veterinary medicine, it has a long history, since the first certificate courses in tropical animal production date back to the early 1920s. More recently, CIRAD organized a university diploma with the Universities of Paris XII and then Montpellier II. In 2005, a Masters in Animal Production in Hot Regions (PARC) was launched. It is overseen by both the University of Montpellier II (Masters open to allcomers) and SupAgro, the Montpellier higher agricultural college ("Duby" Masters course for foreigners and French students with at least three years' professional experience). Around thirty students are accepted each year, out of sixty applicants. As a result of moves to rehabilitate Masters courses and to tailor teaching operations to the students' origins—agronomists, academics and veterinary surgeons—and to changes in the jobs available in the sector, two new courses will be on offer as from September 2008. One, "Animal Production in Developing Countries: Environment and Development (EPSSED)", is a university course, while the other, "Animal Production in Hot Regions (PARC)", is offered by SupAgro. CIRAD specialists are heavily involved in both courses, and will be providing their expertise and field experience, for both common and specific modules.

Contact > Christophe Dalibard,
Capacity Building for Livestock Management (US),
christophe.dalibard@cirad.fr

www.cirad.fr/ur/formation_elevage

Financial resources

Coverage of operating costs by the public service operating budget (SCSP) was down from 62.4% in 2006 to 61.6% in 2007 (figures 11 and 12).

Contractual resources with co-contracting, which totalled 54.8 million euros, are quoted in figure 13, per source of funding.

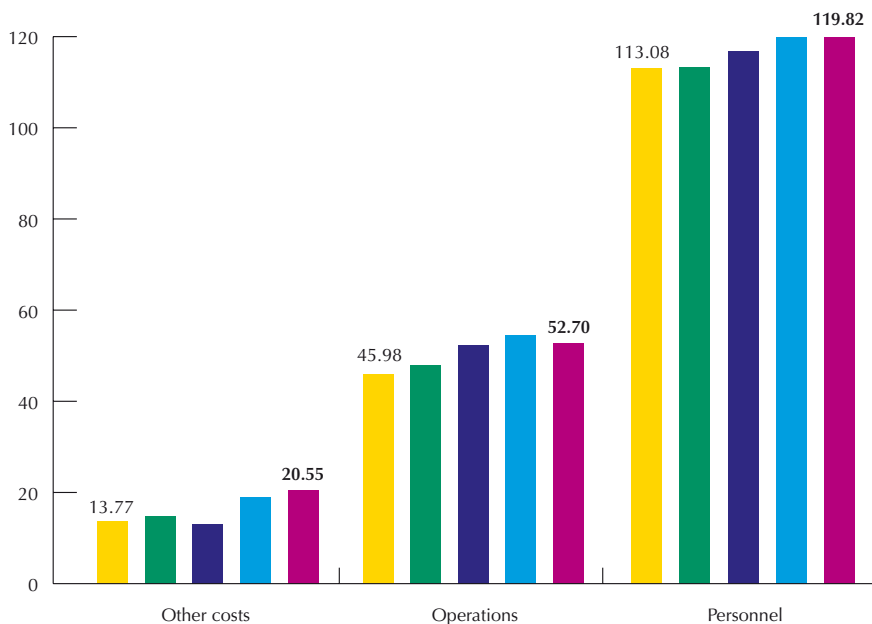


Figure 11. Operating costs, in million euros

Contractual resources without co-contracting amounted to 47.3 million euros in 2007. They were stable compared to 2006 (47.4 million euros). Co-contracting on contracts of which CIRAD is the coordinator fell from 9.2 million to 7.5 million euros, primarily due to the fact that the contracts signed under the European Union's FP6 have expired, whereas those under FP7 have not yet started.

An analysis of contractual resources without contracting, per source of funding, confirms the major changes seen in recent years. The European Union now represents 22.4% of CIRAD's turnover, split between research and development funding (11.1%) and structural funding (11.3%). Other sources (the private sector and funding of various origins), which have not been affected due to their lesser individual importance, accounted for 34% of turnover. In particular, this included oil palm seed sales, which amounted to 4 million euros in 2007 compared to 3.6 million in 2006.

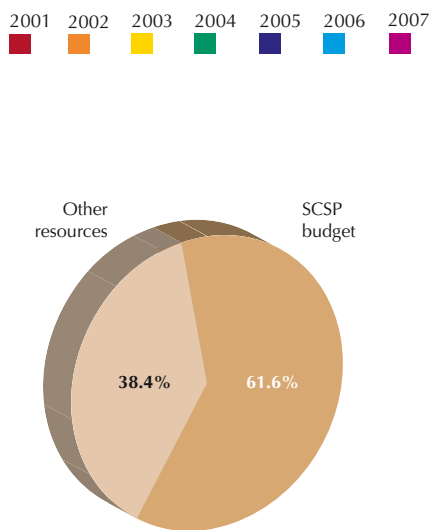


Figure 12. Cost coverage by the public service operating budget (SCSP)

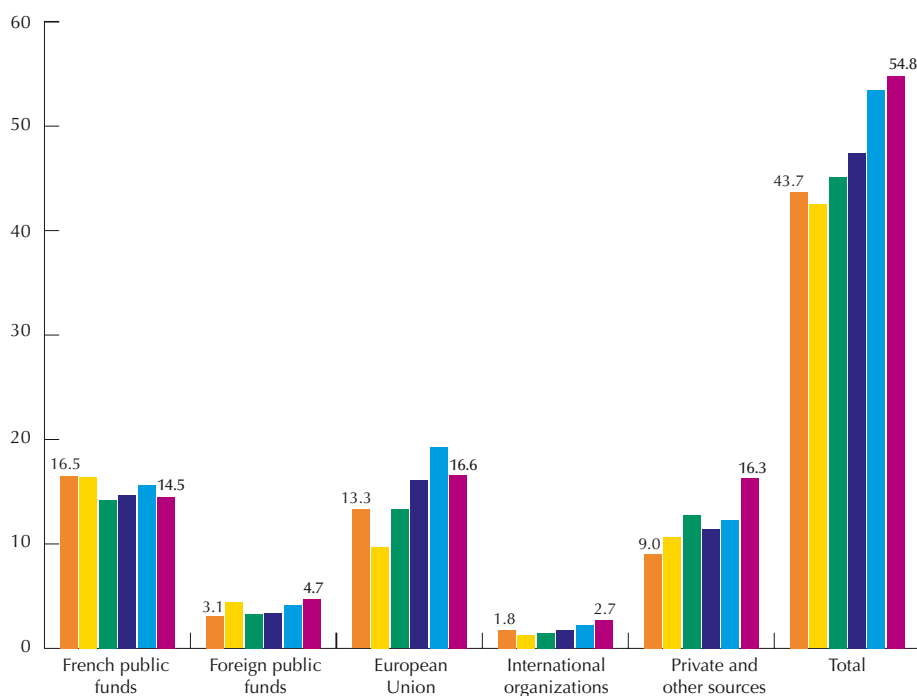


Figure 13. Origin of contractual resources with co-contracting, in million euros

Quality: a priority for research

CIRAD's Director General issued a statement on quality policy on 7 February 2007. 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 research support staff.

In 2007, the first joint research unit (UMR BGPI) was certified. In all, twelve structures, including ten research unit laboratories, representing 375 employees (more than 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.

CIRAD's quality policy concerns its operations and laboratories in metropolitan France and the French overseas regions, and also overseas 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 and reputation of its research teams by improving the quality of their work.

Certified or accredited structures

Structures	Type of standard	Numbers	Certification or accreditation date
Agricultural analysis laboratory, Montpellier	ISO 9001	21	Pre-2004
Agricultural analysis laboratory, Réunion	ISO 9001	8	Pre-2004
Wood preservation testing laboratory, Montpellier	CTBA* certification (ISO 17025)	8	Pre-2004
Wood preservation testing laboratory (Production and Processing of Tropical Woods), Montpellier	ISO 17025 (COFRAC accreditation)	8	2005
Environmental management system (Animal Production and Veterinary Medicine Research and Service Units, Baillarguet), Montpellier	ISO 14001	180	2005
Natural rubber quality laboratory, Montpellier	ISO 9001	4	2006
UMR: Biology and Genetics of Plant-Pathogen Interactions for Integrated Protection (BGPI), Montpellier	ISO 9001	74	2007
Animal health laboratory, Montpellier	ISO 17025	43	Pending
Animal health laboratory, Guadeloupe	ISO 17025	10	Pending
Seed and genetic resources laboratory (LSRG), Rice biological resources centre (BRC), Montpellier	ISO 9001 (BRC accreditation as per OECD specifications**)	6	Pending
Coffee sensorial analysis and chemistry laboratory (UMR QUALISUD), Montpellier	ISO 17025	8	Pending
Cotton quality laboratory, Montpellier	ISO 17025	13	Pending

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

** OCDE: Organization for Economic Cooperation and Development.

Partnerships

Incentive operations

There are 13 programmed thematic projects (ATPs) involving researchers from several departments and units over a period of around two years (table II). Of the six federative projects that existed in 2006, five have now been completed, leaving ARPEGE (plant root architecture; environmental and genetic factors) due to run until the end of 2007.

Table II. Programmed thematic projects in 2007

Characterization and assessment of the agroecological performance of multispecific cropping systems in the humid tropics	Leader: F. Enjalric
Design of innovations and role of partnerships	Leader: M. Dulcire
Development of biological feed vaccines against exotic and emerging animal diseases	Leader: L. Dedieu
Animal production, globalization and territories: role of institutions in the competitiveness and market access of animal production regions	Leader: G. Duteurtre
Integrated assessment of the performance of annual crop-based multispecific agroecological cropping systems in the tropics	Leader: E. Scopel
3-D imaging and geometric modelling of meristems: towards a virtual meristem	Leader: J.L. Verdeil
Regional integration and food security in West Africa	Leader: F. Lançon
RNA interference, a way of inducing resistance in plants and animals	Leader: M.L. Caruana
Mediation between stakeholders for land allocation (Réunion and Senegal)	Leader: A. Botta
Sanitary standards, commercial relations and aquacultural supply chains in Southeast Asia	Leader: L. Dabbadie
Phenotypical plasticity of perennial crop plantings under water stress in the field	Leader: J.M. Gion
Reproducing plants, reproducing society	Leader: C. Leclerc

Agence nationale de la recherche projects

In 2007, CIRAD participated in 22 projects funded by the Agence nationale de la recherche (ANR). It received three million euros of funding for projects on biodiversity, biomass energy, emerging diseases, sustainable development in emerging countries, etc, in partnership with other research organizations, universities and private firms (table III).

Table III. Projects funded by the ANR in 2007

Biodiversity and plant and microbe adaptation strategies of ultramafic systems in New Caledonia (ULTRABIO)	Leader: M. Lebrun
Community ecology of rodents and their pathogens in South-East Africa: effects of biodiversity changes and implications in health ecology (CEROPATH)	Leaders: R. Frutos, A. Tran
Understanding the emergence of plant fungal diseases: towards an estimate of the risks linked to global change (EMERFUNDIS)	Leader: J. Carlier
Construction of a high-density RH panel and map of tilapia (PERCIMAP)	Leader: J.F. Baroiller
Collective movements in gregarious vertebrates: experimental study, control and modelling of the dynamics of sheep flocks (PANURGE)	Leader: A. Ickowicz
Territorial dynamics on the fringes of cities in developing countries (PERISUD)	Leader: P. Moustier
Large-scale study of ruminant mycoplasma genomes: evolution and adaptation of minimal bacteria to complex hosts (EVOLMYCO)	Leader: F. Thiaucourt
Evolution of the diversity of domesticated genetic resources in the Lake Chad Basin (PLANTADIV)	Leader: H. Joly

Table III. *Continued*

Exploration of enzyme biodiversity for an understanding of the <i>Trichoderma reesei</i> secretome so as to improve lignocellulose hydrolysis (E-TRICEL)	Leaders: A. Zaremski, P.M. Coutinho
Genetics and genomics of rubber tree resistance to <i>Microcyclus ulei</i> (GENESALB)	Leader: M. Seguin
Impact on modes of access to seed (IMAS)	Leaders: D. Bazile, J. Chantereau
Fires and ecosystem biodiversity in New Caledonia (INC)	Leader: L. Maggia
Increasing the potential of biofuel production from ligno-cellulosic biomass of grasses through genetic and genomic approaches of cell wall based on maize as a model system (GRASSBIOFUEL)	Leader: J.F. Rami
Role of emerging countries in governing sustainable development: contestation, conservation or reform? (BICS)	Leader: T. Voituriez
Modelling dynamic landscapes with spatial, temporal and multiscale primitives (STAMP)	Leader: D. Lo Seen
Eco-innovative process for multifunctional treatments to preserve and fireproof woods by bi-oleothermy (PIBOLEO)	Leader: J. Gérard
Protection against insect pests provided by expression of the pea pa1 gene in cereals: application of the rice PA1 model to wheat and maize (CEREALPROTECT)	Leader: J.C. Breitler
Rural micro-finance and employment: do processes matter? (RUME)	Leader: E. Bouquet
Stabilizing yield under abiotic constraints: functional characterisation of orphan genes in <i>A. thaliana</i> and application in rice (FROG)	Leader: E. Guiderdoni
Structural and functional annotation platform supported by comparative genomics and dedicated to plant and bio-aggressor genomes (GNPANNOT)	Leader: S. Sidibe-Bocs
Symbiosis, digestion and reproduction as aphid physiological processes to identify new targets for insecticides (APHICIBLES)	Leader: J.C. Breitler
Using sawmill waste and under-used silvicultural resources in French Guiana: assessment of the industrial potential of extractible molecules (XYLOTECH)	Leader: N. Amusant

European projects

The year 2007 was marked by the start of the 7th European Community Framework Programme for Research and Development (FP7). The disappearance of the INCO budget that funded research projects conducted with developing countries under FP5 and FP6, the few topics on offer in 2007 that were specifically open to international cooperation, and the strong competition between European research teams to respond to calls for proposals had repercussions for CIRAD's participation in FP7.

Of the 33 proposals to which CIRAD contributed, ten were chosen for funding (table IV). However, none of them were coordinated by CIRAD. Nevertheless, CIRAD's results were satisfactory as regards its success rate in terms of responses to calls for proposals (30%) and the European Commission's financial contribution to those projects. CIRAD is a partner in an ERANET on the Mediterranean and in research projects and coordination operations under the topics of "Health" and "Agriculture, food and biotechnologies". It is also involved in targeted INCONETs for Latin America, Southeast Asia and Africa, under the Capacity programme. It will thus be helping to define important research topics to be addressed, for these regions, under future calls for proposals issued by the Cooperation programme.

In 2008, the FP7 Cooperation programme should offer more opportunities and enable CIRAD to build and coordinate projects on subjects of interest to its partners in both developing countries and Europe, which will feed its own scientific strategy.

Table IV. European projects selected in 2007

Coordination and advancement of sub-Saharan Africa-EU Science and Technology Cooperation Network (CAASTNET)	Contact: J. Ganry
Coordination of agricultural research in the Mediterranean (ARIMNET)	Contact: M. Trebel
Enhancement of pest risk analysis techniques (PRATIQUES)	Contact: B. Reynaud

Table IV. *Continued*

EU-based production and exploitation of alternative rubber and latex sources (EU-PEARLS)	Contact: S. Palu
European Union-Latin American research and innovation networks (EURALINET)	Contact: A. de Courville, M. Sers
Evaluating and controlling the risk of African swine fever in the EU (ASFRISK)	Contact: E. Albina
Facilitating the bi-regional EU-ASEAN science and technology dialog (SEA-EU-NET)	Contact: J. Sainte-Beuve, S. Saletes
International network for capacity building for the control of emerging viral vector borne zoonotic diseases (ARBO-ZOONET)	Contact: C. Cetre-Sossah, V. Chevalier
Portable automated test for fast detection and surveillance of influenza (PORFASTFLU)	Contact: E. Albina
Sustainable aquaculture research networks in sub-Saharan Africa (SARNISSA)	Contact: J. Lazard

Research platforms in partnership and international research units

A fifth overseas research platform in partnership (PCP) has now been approved, the first in Latin America. These platforms bring together researchers and resources from various organizations, working on a common topic related to development issues (table V). They provide those researchers with an ideal long-term environment in which to conduct their research and maintain their position in the international scientific community. They foster 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 and is involved in project design. Projects are written into national research programmes, and are geared towards the transfer of skills, access to information, and the publication and shared use of results.

Table V. Research platforms in partnership

Savannah ecosystem management (GESED), Mali	Partners: Institut d'économie rurale (IER, Mali), Institut polytechnique rural (IPR, Mali)
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)
Markets and agriculture linkages for cities of Asia (MALICA), Vietnam	Partners: Centre for Agrarian Systems Research and Development (CASRAD) of the Food Crop Research Institute (FCRI), Research Institute for Fruits and Vegetables (RIFAV), Rural Development Centre (RUDEC) of the Institute of Policy and Strategy for Agriculture and Rural Development (IPSARD), Vietnam Agricultural Science Institute (VASI)
Intensification of animal production systems PRISE), Vietnam	Partners: Hanoi Agricultural University (HAU), National Institute for Veterinary Research (NIVR), National Institute of Animal Husbandry (NIAH), Rural Development Centre (RUDEC) of the Institute of Policy and Strategy for Agriculture and Rural Development (IPSARD)
Tree-based agroforestry systems, Costa Rica	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)

There are also three international research units (URPs), in Madagascar and Senegal, (table VI), 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 VI. International Research Units

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

Regional platforms and centres

CIRAD's overseas operations also rely on regional and international platforms and centres. These include the members of the Consultative Group on International Agricultural Research (CGIAR) and, in South America, CATIE (Centro Agronómico Tropical de Investigación y Enseñanza) or, in Southeast Asia, AIT (Asian Institute of Technology). In Africa, the regional scientific coordination centres are inter-country coordination units governed by regional economic communities, which associate national agricultural research systems. PRASAC, the *Pôle régional de recherche appliquée au développement 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 Ministry of Foreign Affairs 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: the Centre international de recherche pour le développement de l'élevage en zone sub-humide, in Burkina Faso (CIRDES); the Centre africain de recherche sur la banane plantain (CARBAP), in Cameroon; the Centre d'études et de recherches sur l'adaptation à la sécheresse (CERAAS), in Senegal; and the Unité de recherche sur la productivité des plantations industrielles (UR2PI), in Congo.

Organization in April 2008

Board of Trustees

President

Patrice Debré, professor

Didier Hoffschir, representing the Minister with responsibility for Higher Education and Research

Antoine Grassin, representing the Minister with responsibility for Cooperation and Development

X, representing the Minister with responsibility for the Budget and State Reform

Jean-Louis Buër, representing the Minister of Agriculture and Fisheries

Pierre Brunhes, representing the Minister for Overseas Departments and Territories

Jean-François Girard, President, Institut de recherche pour le développement

Marion Guillou, President, Institut national de la recherche agronomique

Christiane Lambert, Vice-President, Fédération nationale des syndicats d'exploitants agricoles; President, Vivea

Haïdara Lansry Nana Yaya, Commissioner for Food Security, Mali

Jean-Michel Severino, Director General, Agence française de développement

Laurence Tubiana, Director, Institut du développement durable et des relations internationales

Martine Antona

Michel Benoit-Cattin

Patrick d'Aquino

Tristan Durand-Gasselín

Laurent Maggia

Philippe Vaast

Secretary

Jean-Louis Muron

Science Council

Chair

Bernard Chevassus-au-Louis, INRA, France

Bonnie Campbell, University of Quebec, Canada

Marie-Christine Cormier-Salem, IRD, France

Bernard Delay, CNRS, France

Yaye Kene Gassama Dia, Ministry of Research, Senegal

Gnissa Konate, INERA, Burkina Faso

Yves Savidan, IRD, France

Claudine Schmidt-Lainé, CEMAGREF, France

Serge Svizzero, University of Réunion, France

Marie-Line Caruana

Jacques Lançon

Raphaël Morillon

Laurence Ollivier

Vincent Ribier

INRA-CIRAD Joint Consultative Committee on Ethics in Agricultural Research

Chair

Louis Schweitzer, Chair, Haute autorité de lutte contre les discriminations et pour l'égalité

Charles Babinet †, Institut Pasteur

Fifi Benaboud, North-South Centre, Council of Europe

Soraya Duboc, agrifood scientist with a private firm

Jean-Michel Besnier, University of Paris VI

René Blanchet, University of Nice-Sophia Antipolis

Gilles Bœuf, Pierre et Marie Curie University,

Chair of the Science Council of the Museum National d'Histoire Naturelle

Marcel Bursztyn, University of Brasilia

Claude Chéreau, former Ambassador to the FAO

Didier Fassin, University of Paris XIII, Ecole des hautes études en sciences sociales

Guy Paillotín, Académie d'agriculture de France

Gérard Toulouse, Ecole normale supérieure

Dominique Vermersch, Rennes Agrocampus

Heinz Wismann, Ecole des hautes études en sciences sociales

Office of the Director General

G rard Matheron, Director General
Jean-Louis Muron, Adviser
Alain Weil, Adviser
Jacques Pages, Adviser
Gilles Mandret, Regional Director, R union-Mayotte

Office of the Director of Research and Strategy

Etienne Hainzelin, Director
Gilles Saint-Martin, Associate Director, Head of European and International Relations
Dany Griffon, Coordinator, Evaluation
Martin-Eric Loffeier, Coordinator, Strategic Operations
Hubert Omont, Coordinator, Tropical Supply Chains
Claudie Dreuil, Coordination, Incentive Operations
Mireille Mourzelas, Coordinator, International Scientific Exchanges
V ronique Vissac-Charles, Coordinator, Technology Transfer and Development

Office of the Director of Finance and Administration

Herv  Deperrois, Director of Finance and Administration
Patrick Herbin, Deputy Director of Finance and Administration, Legal Adviser
Marc G lis, Manager, Accounts and Finance
Vincent Fabre-Rousseau, Manager, Human Resources

Philippe Godon, Regional Director, West Indies-French Guiana
L andre Mas, Quality Officer
Anne H bert, Coordinator, Communication
Jo l Sor, Coordinator, Information Systems
Anne-Yvonne Le Dain, Coordinator, Evaluation

Marie-Claude Deboin, Coordinator, Scientific and Technical Information
Pierre-Luc Pugliese, Coordinator, French Overseas Regions
Hubert Gu rin, Coordinator, Africa and Indian Ocean
Andr  de Courville, Coordinator, Latin America and Caribbean
Michel Tr bel, Coordinator, Mediterranean Countries and Near East
Catherine Marqui , Coordinator, European Community
Christian Hoste, Coordinator, European and International Agricultural Research Systems

Didier Servat, Technical Manager, Installations and Maintenance
Andr  Nau, Management Supervision Officer
Marie-Gabrielle Bodart, Archives Officer
Aleth de Sartiges, Safety Office

Departments and Research Units**Biological Systems Department**

Jean-Christophe Glaszmann, Director
Dominique Berry, Deputy Director
Xavier Mourichon, Associate Director
Jean-Marc Deboin, Financial Affairs Manager

Research Units*

Agricultural Service Unit (US), French Guiana, Jean-Louis Pradon

Agrobiodiversity in Savannah Environments (UPR), Jacques Chantereau

Biology and Genetics of Plant-Pathogen Interactions for Integrated Protection (UMR BGPI), Jean-Loup Notteghem, SupAgro (SupAgro, INRA)

Botany and Computational Plant Architecture (UMR AMAP), Daniel Barth l my, INRA (CNRS, INRA, IRD, University of Montpellier II)

Capacity Building for Livestock Management (US), Christophe Dalibard

Center for Biology and Management of Populations (UMR CBGP), Denis Bourguet, INRA (SupAgro, INRA, IRD, University of Montpellier II)

Centre of Evolutionary and Functional Ecology (UMR CEFE), Jean-Dominique Lebreton, CNRS (CNRS, Universities of Montpellier I, II and III, SupAgro, EPHE)

Coconut Lethal Yellowing and Citrus Greening (UPR), Michel Dollet

Controlling Pests and Diseases in Tree Crops (UPR), Christian Cilas

Diversity and Adaptation of Cultivated Plants (UMR DIAPC), Serge Hamon, IRD (IRD, SupAgro, INRA, University of Montpellier II)

Emerging and Exotic Animal Disease Control (UPR), Dominique Martinez

Genetic Diversity and Breeding of Forest Species (UPR), Jean-Marc Bouvet

Genetic Improvement of Vegetatively Propagated Crops (UPR), Robert Domaingue

Genotype Plasticity and Crop Performance (UPR), Michael Dingkuhn

Laboratory of Tropical and Mediterranean Symbioses (UMR LSTM), Bernard Dreyfus, IRD (SupAgro, INRA, IRD, University of Montpellier II)

Locust Ecology and Control (UPR), Michel Lecoq

Oil Palm Breeding (UPR), Tristan Durand-Gassel n

Plant Communities and Biological Invaders in Tropical Environments (UMR PVBMT), Bernard Reynaud (University of R union)

Plant Development and Genetic Improvement (UMR DAP), Fran oise Dosba, SupAgro (SupAgro, INRA, IRD, University of Montpellier II, CNRS)

Planting Material Sales (US), Christian Picasso

Plant Resistance to Parasites (UMR RPB), Michel Nicole, IRD (IRD, University of Montpellier II)

Rice Breeding and Management (UPR), Nourollah Ahmadi

Trypanosomes (UMR), G rard Cuny, IRD (IRD)

**Performance of
Tropical Production
and Processing Systems
Department**

Robert Habib, Director
Marcel de Raïssac, Deputy Director
André Rouzière, Associate Director
Jacques Nolin, Financial Affairs Manager

Research Units*

Agropolymer Engineering and Emerging Technologies (UMR IATE), Stéphane Guilbert, SupAgro (SupAgro, INRA, University of Montpellier II)
Annual Cropping Systems (UPR), Florent Maraux
Aquaculture and Aquatic Resource Management (UPR), Jérôme Lazard
Banana, Plantain and Pineapple Cropping Systems (UPR), François Côte
Biomass and Energy (UPR), Christian Sales
Cattle Rearing (UMR ERRC), François Bocquier, SupAgro (SupAgro, INRA)
Direct Seeding and Cover Crops (UPR), Francis Forest
Environmental Risks of Recycling (UPR), Hervé Saint Macary
Functioning and Management of Tree-Based Planted Ecosystems (UPR), Jean-Pierre Bouillet

Horticulture (UPR), Philippe Vernier
Integrated Food Quality System (UMR QUALISUD), Jean-Pierre Pain, University of Montpellier II (Universities of Montpellier I and II, SupAgro)
Integrated Fruit Production (UPR), Rémy Hugon
Performance of Tree Crop-Based Systems (UPR), Jean-Luc Battini
Process Engineering and Bioproduct Development (UMR GPED), Alain Grasmick, University of Montpellier II (ENSIA, SIARC, Universities of Montpellier I and II)
Production and Processing of Tropical Woods (UPR), Jean Gérard
Quality of Tropical Fruits and Vegetables (UMR QUALITROP), Louis Fahrasmane, INRA (INRA, Antilles-Guyane University)
Sustainable Farming and Rice Cropping Systems (URP SCRID), Julie Dusserre (FOFIFA, University of Antanarivo)
Tropical and Mediterranean Cropping System Functioning and Management (UMR SYSTEM), Jacques Wery, SupAgro (SupAgro, INRA)
Water, Soil and Plant Analysis (US), Alain Aventurier

**Environment
and Societies
Department**

Patrick Caron, Director
Bernard Mallet, Deputy Director
Brigitte Nésius, Financial Affairs Manager

Research Units*

Animal and Integrated Risk Management (UPR), François Monicat
Center for International Research on Environment and Development (UMR CIRED), Jean-Charles Hourcade, CNRS-EHESS (CNRS, EHESS, ENGREF, ENPC)
Collective Action, Policies and Markets (UPR), Jacques Marzin
Dynamics of Natural Forests (UPR), Sylvie Gourlet-Fleury
Ecology of the Forests of French Guiana (UMR ECOFOG), Bernard Thibaut, CNRS (CNRS, ENGREF, INRA, Antilles-Guyane University)
Forest Resources and Public Policies (UPR), Alain Billand
Innovation and Development in Agriculture and the Agrifood Sector (UMR Innovation), Hubert Devautour (SupAgro, CNEARC, IAMM, INRA)

Livestock Systems and Animal Product Management (UPR), Didier Richard
Management of Madagascan Forests and of their Biodiversity (URP Forêts et biodiversité), Pascal Danthu (FOFIFA, University of Antanarivo)
Management of Renewable Resources and Environment (UPR), Martine Antona
Markets, Organizations, Institutions and Operators Strategies (UMR MOISA), Jean-Louis Rastoin, SupAgro (SupAgro, INRA, CIHEAM, IRD)
Pastoralism (URP), Amadou Tamsir Diop, ISRA (ISRA, UCAD, CSE, ENRA)
Spatial Information and Analysis for Territories and Ecosystems (UMR TETIS), Pascal Kosuth, CEMAGREF (CEMAGREF, ENGREF)
Water Management, Stakeholders and Uses (UMR G-EAU), Patrice Garin, CEMAGREF (CEMAGREF, ENGREF)

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

CIRAD worldwide

France

Ile-de-France

Patrick Herbin, Regional Director,
42, rue Scheffer, 75116 Paris
Tel.: +33 1 53 70 20 21
patrick.herbin@cirad.fr

Languedoc-Roussillon

Emmanuel Camus, Regional Director,
Avenue Agropolis, 34398 Montpellier Cedex 5
Tel.: +33 4 67 61 58 01
emmanuel.camus@cirad.fr

Corsica

Dominique Agostini, Director
Station de recherche agronomique INRA
20230 San Giuliano
Tel.: +33 4 95 59 59 21
agostini@corse.inra.fr

Réunion-Mayotte

Gilles Mandret, Regional Director,
Station de La Bretagne, BP 20
97408 Saint-Denis Messageries Cedex 9, Réunion
Tel.: +262 2 62 52 80 00 / +262 6 92 76 30 69
gilles.mandret@cirad.fr

Africa

Central Africa

Sylvie Lewicki-Dhainaut, Regional Director
BP 2572, Yaounde, Cameroon
Tel.: +237 2 21 25 41 / +237 96 33 75 37
sylvie.lewicki-dhainaut@cirad.fr

Yves Nouvellet, Correspondent
BP 1292, Pointe-Noire, Congo
Tel.: +242 94 47 95 / +242 524 69 48
yves.nouvellet@cirad.fr

Coastal West Africa

Georges Subreville, Regional Director,
37, avenue Jean XXIII, BP 6189, Dakar-Etoile, Senegal
Tel.: +221 33 822 44 84 / +221 77 637 18 78
georges.subreville@cirad.fr

Patrice de Vernou, Correspondent
C/O SCAC, Ambassade de France
BP 570, Conakry, Guinea
Tel.: +224 30 45 50 52 / +224 63 35 24 95
patrice.de_vernou@cirad.fr

Continental West Africa

Michel Partiot, Regional Director,
01 BP 596, Ouagadougou 01, Burkina Faso
Tel.: +226 50 30 70 70 / +256 70 20 57 45
michel.partiot@cirad.fr

Patrick Prudent, Correspondent
08 BP 1077, Centre de tri postal, Cotonou, Benin
Tel.: +229 21 38 80 86 / +229 97 44 57 75
patrick.prudent@cirad.fr

Bernard Dolacinski, Correspondent
BP 1304
97600 Mamoudzou, Mayotte
Tel.: +269 61 21 21
bernard.dolacinski@cirad.fr

West Indies-French Guiana

Philippe Godon, Regional Director,
Station de Neufchâteau, Sainte-Marie
97130 Capesterre-Belle-Eau, Guadeloupe
Tel.: +590 5 90 86 17 90 / +06 94 45 10 22
philippe.godon@cirad.fr

Sylvie Mouras, Regional Representative
BP 701, avenue de France
97387 Kourou Cedex, French Guiana
Tel.: +594 5 94 32 73 52
sylvie.mouras@cirad.fr

Christian Chabrier, Regional Representative
BP 214
97285 Le Lamentin Cedex 2, Martinique
Tel.: +596 5 96 42 30 44
christian.chabrier@cirad.fr

Alain Renou, Correspondent
BP 1813, Bamako, Mali
Tel.: +223 221 10 15 / +223 675 01 50
alain.renou@cirad.fr

East and Southern Africa

Denis Depommier, Regional Director,
C/O ICRAF, United Nations Avenue
Gigiri, PO Box 30677, 00100 Nairobi, Kenya
Tel.: +254 20 722 46 53 / +254 723 274 069
denis.depommier@cirad.fr

Stéfano Farolfi, Correspondent
Centre for Environmental Economics and Policy in Africa
(CEEPA)
University of Pretoria, 0002 Pretoria, South Africa
Tel.: +27 12 420 4659 / +27 79 495 2155
stefano.farolfi@cirad.fr

Sébastien Le Bel, Correspondent
French Embassy
37, Acturus Road Highlands, PO Box 1378
9, Balmoral Road, Borrowdale, Harare, Zimbabwe
Tel.: +263 4 44 34 22 / +263 912 352 384
sebastien.le_bel@cirad.fr

Madagascar

Thierry Goguey-Muethon, Regional Director,
Ampandrionomy, BP 853, Antananarivo
Tel.: +261 20 22 406 23 / +261 32 07 114 22
thierry.goguey_muethon@cirad.fr

America

Brazil

Philippe Petithuguenin, Regional Director,
SHIS-QI 23, Bl. B. Ed. Top 23
71660-120 Brasilia DF
Tel.: +55 61 33 66 11 32 / +55 61 81 38 98 65
philippe.petithuguenin@cirad.fr

Central America

Bruno Rapidel, Correspondent
CATIE, 7170 Apartado 3, Turrialba, Costa Rica
Tel.: +506 558 25 99 / +506 93 82 98 39
bruno.rapidel@cirad.fr

Asia

China

Zheng Li, INRA-CIRAD Permanent Representative
507 Tower A, Fuhua Mansion
8, Chaoyangmen North Avenue
100027 Beijing
Tel.: +86 10 6554 1871
zhengliinra@sohu.com

Continental Southeast Asia

Jean-Charles Maillard, Regional Director,
Cirad Representative Office, 3rd floor
35, Dien Bien Phu Street, Hanoi, Vietnam
Tel.: +84 4 734 6775 / +84 9 12 25 89 02
jean-charles.maillard@cirad.fr

Antoine Leconte, Correspondent
Cirad Office, Research and Development Building
4th floor, Kasetsart University, 10900 Bangkok, Thailand
Tel.: +66 29 42 76 27 / +66 89 888 5415
antoine.leconte@cirad.fr

United States

Jill Barr, CIRAD Correspondent assigned to the World
Bank and the Inter-American Development Bank
Development Research Associates
8313, Woodhaven blvd
Bethesda 20817, Maryland
Tel.: +1 301 365 68 55
jbarr@cirad.fr

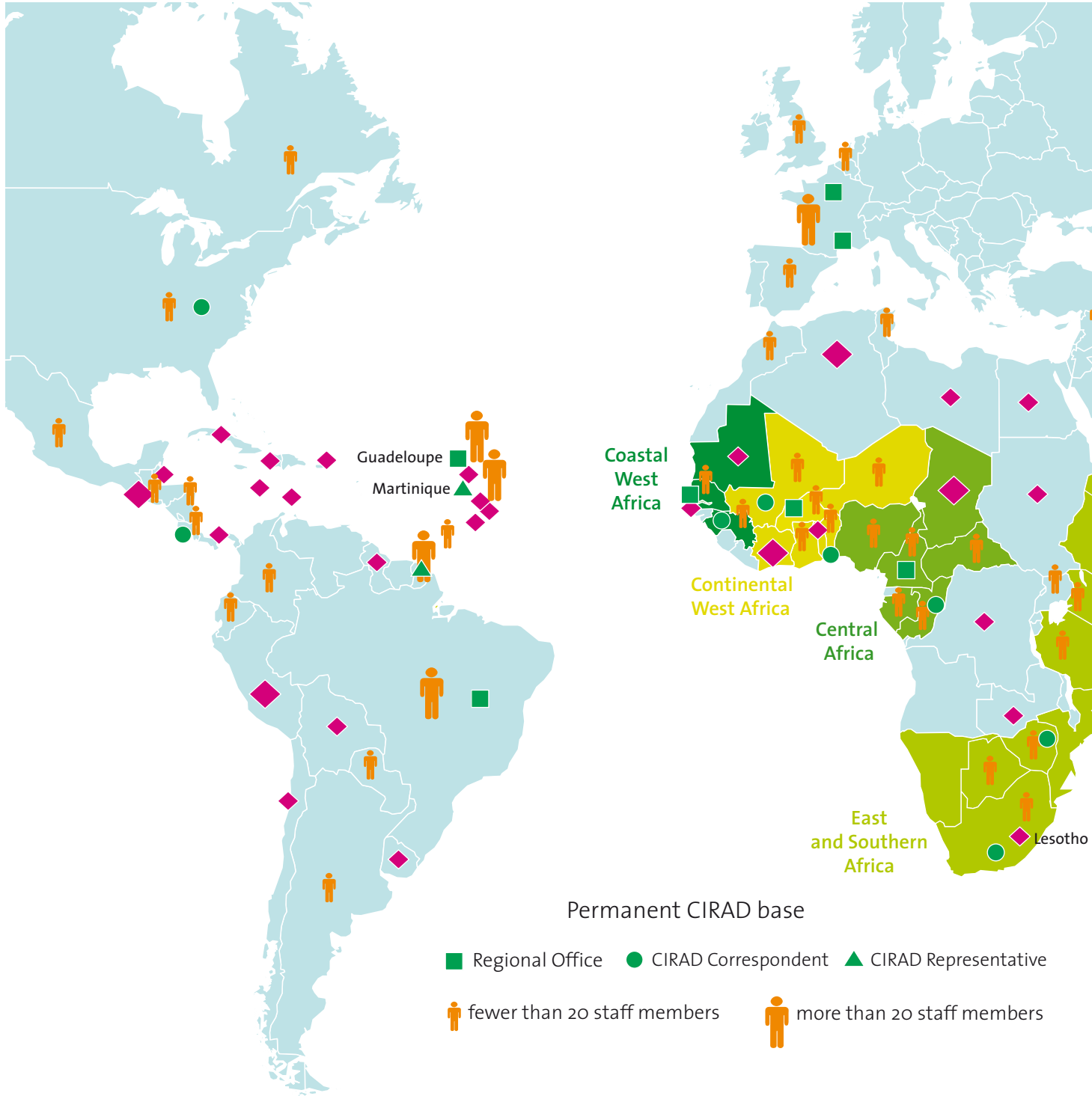
India

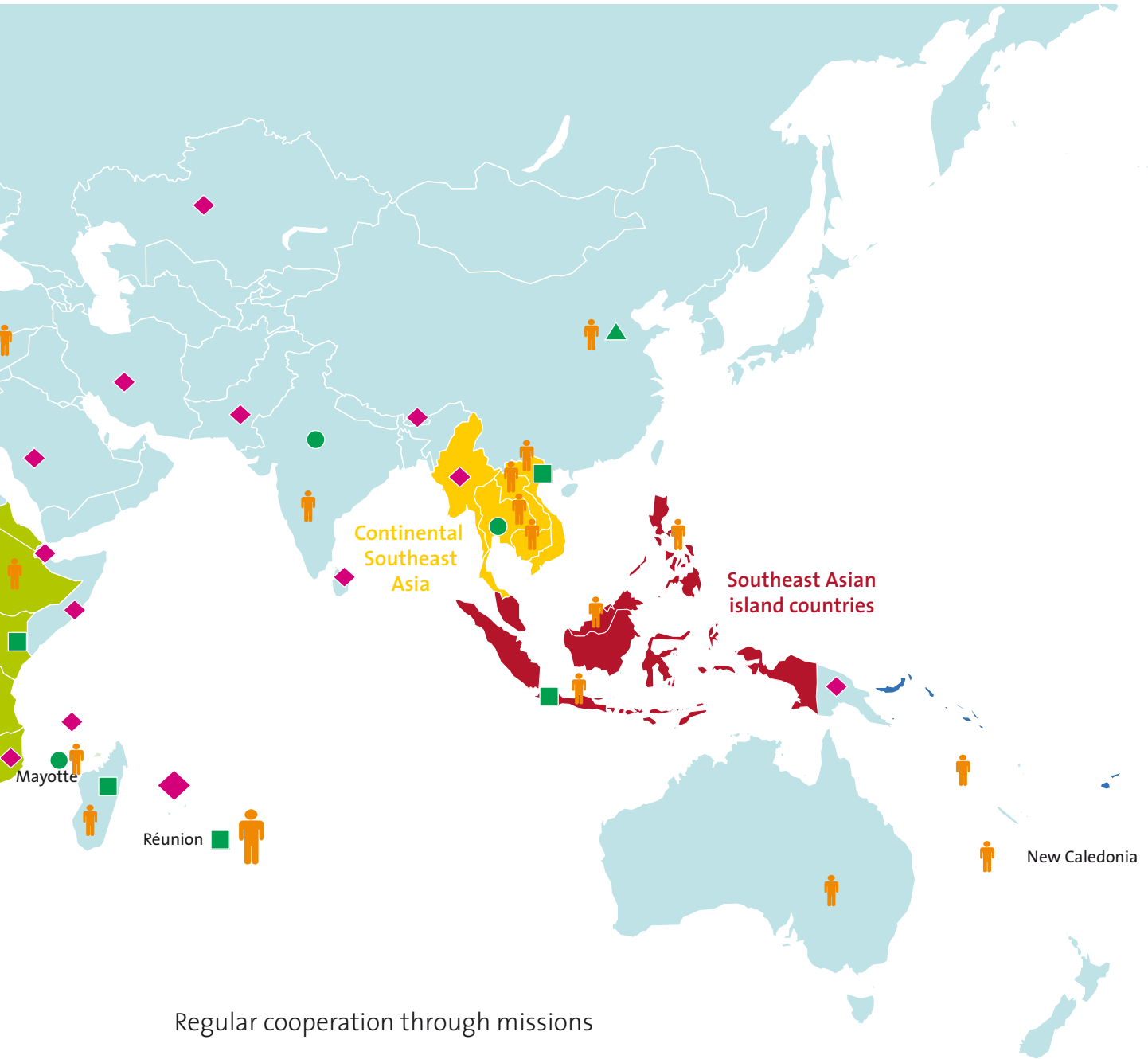
Lucie Cheynier, INRA-CIRAD Correspondent
Scientific Department of the French Embassy in India
2, Aurangzeb Road
110 011 New Delhi
Tel.: +91 11 30 41 00 08 / +91 99 58 54 99 91
lucie.cheynier@hotmail.fr

Southeast Asian island countries

Jean-Guy Bertault, Regional Director,
Plaza Bisnis Kemang, 3rd Floor
Jalan Kemang Raya 2
12730 Jakarta Selatan, Indonesia
Tel.: +62 21 719 90 67 / +62 816 19 100 12
jean-guy.bertault@cirad.fr

Map of CIRAD operations





Regular cooperation through missions

- ◆ fewer than 10 missions
- ◆ more than 10 missions

Production: Communication Service
Coordination: Helen Burford-Buttazzoni, Martine Lemaire
French text: Martine Lemaire with the help of Cécile Fovet-Rabot, Nicole Pons and Christine Rawski
Translation: Helen Burford-Buttazzoni, David Manley
Proofreading: Anya Cockle
Graphic design and layout: Patricia Doucet
Cover illustration: Nathalie Le Gall
Distribution: Renée Graulières
Printing: Impact Imprimerie, Saint-Gély-du-Fesc (Hérault)
Vegetable inks – Printed on paper from sustainable forests



Legal deposit: June 2008