Climate change and agriculture

THE ISSUES FOR THE ENVIRONMENT AND FOOD SECURITY

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Climate Change and Agriculture

The issues for the environment and food security

CIRAD, December 2009

CONTENTS

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Introduction

Climate change is a global process, of recent origin in its current form, and largely manmade. In the near future, the dynamic of which it is a part is set to cause long-lasting changes in global agriculture. At the same time, agriculture is recognized to be one of the main manmade causes of the process. The expected exhaustion of fossil fuel resources, population growth, and the rapid development of certain countries in which demand for energy is high (China, Brazil, India, etc) have triggered behaviour that has only made matters worse. The emergence of bioenergies as a major new agricultural outlet and the land grabbing phenomenon are both signs of and exacerbating factors in the shortages affecting food security and the environment—and the very stability of societies and the major global equilibria—and compound the threats linked to climate change. This is why climate change calls for unprecedented efforts on the part of the international scientific community.

The main challenge is ensuring the food security of the world's poorest people. However, it is important not to restrict the debate to the issues traditionally addressed by research for development, or to be content with merely proposing more efficient production technologies, such as those of the green revolution, or the doubly green one, in order to ensure ecological intensification. Technology transfers and economic support from "North" to "South" will be not only inadequate, but simply largely irrelevant. In effect, the expected changes will be truly global, radical and structural, and will force a fundamental rethink of the paradigms that guide research for development. CIRAD, with its global network of partners in more than 90 countries, is taking up this challenge.

> CIRAD and the climate change issue

CIRAD is a French research centre working with developing countries to tackle international agricultural and development issues. With those countries, it works to generate new knowledge, support agricultural development, and contribute to the debate on the main global issues concerning agriculture, food and rural territories. The issues linked to climate change are thus at the heart of its mandate.

Its research structure incorporates various disciplines and expertise, in support of its scientific strategy: biotechnologies, genetic improvement and ecophysiology of cultivated plants; agronomy and agro-ecology of production systems; ecology and functioning of forestry, agropastoral and animal production systems; plant and animal pathology; human and social sciences and the sciences of complexity. This experience enables it to address a range of issues on the relevant level, from molecule to agricultural policy.

As a result of its history and its international mandate, CIRAD has developed a unique philosophy of partnerships with public and private organizations: a large proportion of its staff is assigned to its partners, creating a research infrastructure that is very close to the reality in the field, backed up by advanced laboratories in France.

Cirad in a nutshell

- 800 researchers, including 200 expatriates and 200 full-time post equivalents of missions in more than 90 countries;
- research centres in Montpellier, Guadeloupe, French Guiana, Martinique, Mayotte, Réunion and New Caledonia;
- six priority lines of research: Ecological intensification; Biomass energy and societies in the South; Accessible, quality food; Animal health and emerging diseases; Public policy, poverty and inequality; and Agriculture, the environment, nature and society;
- 25 research platforms in partnership overseas;
- an annual budget of 203 million euros.

CIRAD is playing an active role in building the French and European agricultural research area. In particular, it is a driving force in the emergence of networks between research and training establishments and universities. It has built scientific partnerships with international organizations specializing in agricultural research and with regional and national organizations within 25 research platforms in partnership overseas, and has seven scientific centres with a regional vocation in the French overseas regions. As a result, it is a major player in the dialogue between Europe and developing countries. It is involved in large-scale multi-partner projects relating to climate change issues, in particular funded by the European Union; within these

projects, its excellent relations with its partners provide a global dimension that is of vital importance to this universal challenge.

This partner-based infrastructure and multidisciplinary expertise are the ideal conditions in which to develop and implement innovative approaches. CIRAD is using these assets to tackle the challenge of climate change.

CIRAD's operations as regards climate change are presented in the sheets in this report. In particular, they cover:

- assessment of the impact of climate change on agriculture, the environment and rural societies;
- genetic improvement of cultivated plants, to ensure better adaptation to environmental constraints, notably in terms of temperature and water, associated with climate change; operations are backed up by in-depth genetic and agro-ecological studies, and by in-depth analyses of in situ and ex situ agrobiodiversity;
- adaptation of production systems, with the aim of reducing the vulnerability of these systems to climate change;
- development and assessment of possibly radical technical and institutional innovations aimed at alleviating the impact of climate change on production system performance, and notably at better anticipating the risks and managing them more effectively;
- the negative and positive effects of farming practices on climate change;
- development and assessment of agro-environmental innovations (such as agro-ecological techniques that foster carbon sequestration) and institutional and political instruments, so as to reduce the adverse effects of farming practices on climate change;
- support of the implementation of such approaches so as to assess and structure the supply, maintenance and funding of environmental services, and assessment of the impact of that support on the state of the environment and on development, following in the footsteps of the Clean Development Mechanisms relating to carbon.

This is a constantly changing field. Operations will be adapted to the new research for development paradigms that will emerge from the debate under way at CIRAD and its partners, taking account of and integrating the discussions at the main international conferences, particularly in Copenhagen, and also contributing to them.

> Rethinking targeted research strategies in line with forecasted changes

Rethinking targeted research strategies and objectives in line with the constraints (and opportunities!) linked to the next major transition in global agriculture is no easy task. To begin with, it means a detailed diagnosis of the state of thinking, the received or generally accepted ideas sometimes prompted by a conservative instinct, and the factors driving current or future transitions, an analysis that cannot afford to restrict itself to the direct effects of climate change on crops, production systems and markets. The following factors need to be taken into account: retroactions in the form of tactical and strategic adjustments to the systems concerned, and interactions with the other factors driving agricultural transitions (new supply chains such as biofuels, land grabbing, etc), which affect markets and production conditions. Each of these factors is associated with uncertainty and a degree of variability, both of which are often difficult to quantify. However, each and every stakeholder will base their decisions on their perception of that uncertainty and their analysis of their environment.

In fact, climate change does not only affect average biophysical conditions (temperature, rainfall), but also intra- and inter-annual variability and the occurrence and frequency of extreme events. The increase in the risks associated with any decision, whether by a producer, an insurer or a policy-maker, is an argument in favour of implementing new economic and biophysical resilience mechanisms.

An integrative, systemic approach is the only way of drawing up effective development strategies in the light of climate change and the factors associated with it. Targeted scientific research will have to be more relevant if its operations and outputs are to contribute to changes on the part of decision-makers and producers. It will systematically have to take account of the uncertainty of and the methods to be used for forecasting, simulating and conducting foresight studies of complex systems. Strategies, objectives and methods will have to change if we are to ensure food security and sustainable agro-ecosystems.

> Prospects

The targeted research prospects for CIRAD hinge on an analysis of the issues, projects and operations by other stakeholders in relation to this issue, and the investments already made (scientific projects, partnerships, human and material resources). Even though the distinction between mitigation and adaptation is relevant as regards the biological and ecological processes at play, and is thus useful from an analytical point of view, although it involves distinct scales, it is not always relevant in determining the future topics in which to invest. In fact, it is not always the key to supporting or even designing innovation processes. Conversely, it is important to take account of the complexity of the problem and make use of a range of heterogeneous knowledge and information.

This debate is being tackled from four angles, on different scales (supply chains, regions, ecosystems, etc), and also through transverse approaches:

- understanding the processes at play, particularly the biological and ecological processes involved in the relation between agricultural change and climate change; this will also concern economic and social mechanisms;
- rethinking technical action, and its technical and organizational aspects, on different scales, by developing the capacity to assess the performance of and the effects generated by actions aimed at managing the living world (criteria, indicators);
- supporting the organization of environmental supply chains by producing or testing standards, certification procedures, stakeholder coordination mechanisms, political frameworks, and mechanisms enabling payment for environmental goods and services, taking account of the relations between food supply chains and environmental supply chains;
- covering the interactions generated with other concerns, and the way in which the climate-agriculture pairing contributes to them, in particular in the fields of health and energy.

Adaptation of cultivated plants to climate change

The ability of plants to adapt to climate change has long been exploited by farmers. However, in the light of current risks and increasingly frequent extreme events, thought is being given to new approaches.

Terraced rice fields in Bali
© G. Trebuil/CIRAD

The origin of the adaptation may be genetic (used in breeding), agronomic (management), geographical (zoning) or temporal (cropping calendars, ideally backed up by climate forecasts decision support tools). CIRAD's research aims to boost our knowledge of the relations between plants and their environment on a plant, crop and, by extrapolation, regional level. Modelling, backed up by field and controlled experiments, serves to integrate the various scales and processes and express them in terms of impact in the field.
The factors with the greatest impact are water stress (primarily drought, but also excess water) and temperature stress (heat, cold). Water stress disrupts phenology (leaf formation, flowering, etc), growth and filling. Temperature affects phenology (cycle length, etc) and potential yields (number of fertile flowers or ears, fruit or grain size, quality, etc). Research is focused on rice, sorghum and oil palm. Adaptation to drought is also being studied in detail in rubber, citrus fruits, etc.

Research on the effect of atmospheric CO_2 on plants implies the use of specific experimental structures, established in collaboration.

Some work is also geared towards climate change mitigation: the SweetFuel project ("FFF" [Food-Feed-Fuel] multi-use plants), for instance, is looking at the potential of energy crops (as alternatives to fossil fuels) that are tolerant of both heat and drought.

> Activities and results

- Detailed analysis of adaptation characters: functioning, genetic control, interactions with the environment;
- Phenotyping of those characters to characterize the genetic diversity and identify genes and alleles of interest, and useful markers;
- Modelling those characters on the relevant scales (plant, plot, etc) to measure their adaptive and agronomic value;
- Comparing virtual plants (improved ideotypes) with regional-scale climate change scenarios through modelling;
- Practical applications: developing new varieties and introducing agricultural forecasting tools.
- Products:
- operational knowledge of the biological bases of adaptation to climate change;
- tools for breeding (molecular and physiological markers);
- new varieties better adapted to climate change.

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Sorghum varieties
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See also

http://publications.cirad.fr

> Research projects

- Adaptation of agriculture and manmade ecosystems to climate change (ADAGE, French project, ANR);
- Development of FFF (Food-Feed-Fuel) sorghums suited to dry environments (SweetFuel, EU FP7 project);
- Multidisciplinary analysis of the African monsoon (AMMA, EU FP6 project);
- Analysis and modelling of rice and sorghum adaptation to climate change factors (RISOCAS, German GTZ-BMZ project);
- Phenotyping and genetic analysis of rice adaptation characters to water and temperature stress (ORYTAGE, CIRAD thematic action);
- Phenotyping and genetic analysis of rice under water stress (Gen-Phen GCP, CGIAR Generation Challenge Program).

> Partners

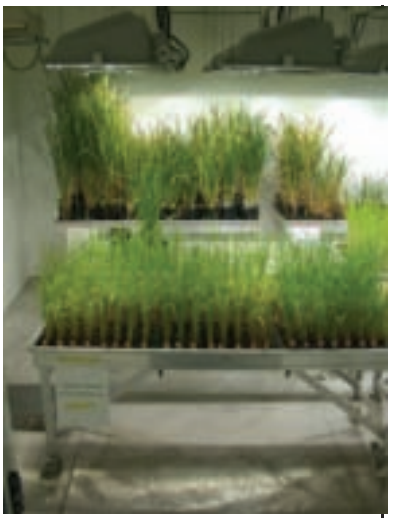
- Adaptation of plants through genetic improvement, CGIAR institutes: International Rice Research Institute (IRRI); International Crops Research Institute for the Semi-Arid Tropics (ICRISAT); Africa Rice Centre (WARDA), Centre International d'Agriculture Tropicale (CIAT); Institut d'Economie Rurale (IER, Mali);
- FFF plants adapted to drought: Empresa Brasileira de Pesquisa Agropecuária (EMBRAPA, Brazil); Corporacion Colombiana de Investigación Agropecuaria (CORPOICA, Colombia); Germany; Italy; India; Mexico; South Africa; Mali;
- Modelling of plant adaptation: Universities of Hohenheim (Germany), Wageningen (Netherlands), Queensland (Australia), Tuskuba (Japan); Commonwealth Scientific and Industrial Research Organization (CSIRO, Australia); China Agricultural University (CAU) and China Academy of Science (CAS); WARDA (Senegal); National Centre of Applied Research and Rural Development (FOFIFA, Madagascar); IER (Mali), etc; palm oil producers in Southeast Asia;
- Modelling on a regional scale: AGHRYMET, a Comité permanent inter-Etats de lutte contre la sécheresse dans le Sahel (CILSS) centre.

> Prospects

- Improved knowledge of the genetic control of adaptation characters will make it possible to develop more robust, productive varieties.
- Radical new technologies, such as adapting entirely new plants for cultivation, are to be developed.
- By modelling the effects of climate change on crops more precisely, it will be possible to propose new plant improvement strategies. It is also important to adapt decision support systems to current issues.
- The new CGIAR Challenge Program, Climate Change, Agriculture and Food Security (CCAFS) is one of the emerging networks in which CIRAD is involved.

Plant genetic improvement and agrobiodiversity management

It is by making intelligent use of plant genetic diversity that human societies have succeeded in adapting to the changes and unforeseeable variations in climatic conditions. Integrative biology, backed up by the genomics and informatics revolution, should make it possible to continue that adaptation.



Research into drought resistance markers in rice
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Making intelligent use of plant genetic diversity has always relied on at least two components: the intrinsic adaptive value of each plant, variety and crop species, which is linked to their genetic heritage, and the adaptive value of their spatiotemporal organization, which relates to agrobiodiversity management.

Improved knowledge of the biological and manmade processes that govern these adaptive values will make it possible to create varieties and develop agrobiodiversity management methods tailored to the effects of climate change, whether the effects be predictable (water stress, higher temperatures, etc) or less so (pathogen cycles, soil salinity, etc). The aim is to forecast the negative impacts of change, notably water and temperature constraints, on plant phenology, biomass production and harvest index, and on product organoleptic and technological quality. There is a second objective: to rationalize how plant varieties and species are organized in time and space, so as to boost the resilience of agrarian systems in the face of the effects of climate change.

> Activities and results

At CIRAD, adaptation to water and temperature constraints is being studied for a wide range of annual plants (groundnut, cotton, rice, sorghum, etc) and perennial plants (citrus fruits, banana, coffee, rubber, eucalyptus, etc) on various scales, from molecule to plant stand through cell, tissue, organ and individual. The studies involve:

- phenotyping and genotyping of genetic resources (panel of accessions representative of the diversity of the species, cross progenies, mutants, etc) suitable for the genetic breakdown of adaptive responses (almost all the plants quoted above);
- analyses of differential gene expression, in the absence and the presence of the constraint under study (citrus, coffee, rice, etc);
- analyses of the genetic and evolutionary bases of adaptation linked to the heterogeneity of selection pressure (spatial, temporal) within manmade ecosystems (rice, sorghum etc);
- studies of the evolution of genomes and comparative genomics;
- bioinformatics research, which, through mass representations of information and data, facilitate multi-scale integration: genome, cell, plant, population and environment.

Genetic resources that carry adaptive characters and genomic regions involved in the expression of those characters have been identified, along with the underlying metabolic pathways and the ways in which they are regulated.

The knowledge acquired will be reused to speed up the creation of new, better adapted varieties under the programmes CIRAD is conducting with its Africa, Asian and South American partners.

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See also

http://publications.cirad.fr

> Research projects

- Phenotypic plasticity and response to water stress of perennial crops (CIRAD PTA);
- Pan-genomic association study for rice adaptation to water and temperature stress (CIRAD PTA);
- Improving rice productivity in lowland ecosystems of Burkina Faso, Mali and Nigeria through Marker Assisted Recurrent Selection for drought tolerance and yield potential;
- (GCP-Rice Challenge Initiative);
- Improvement of sorghum productivity for semi-arid environments in Mali, by marker-assisted recurrent selection (GCP-Syngenta);
- Enhancing sorghum grain yield and quality for the Sudano-Sahelian zone of West Africa using the Backcross Nested Association Mapping (BCNAM) approach (GCP-Sorghum Challenge Initiative);
- Sustainable management of agricultural biodiversity in the farming systems of Mali (FFEM);
- Dissection of the genetic bases of drought tolerance within the genus *Arachis*. Construction and characterization of a population of chromosome segment substitution lines (GCP-CIRAD);
- Crop adaptation to climate change: genetic and evolutionary processes involved in the phonological response of *Medicago truncatula*, millet and rice (Fondation Agropolis-CIRAD);
- Developing drought-tolerant cereals to support efficient water management in the Mediterranean area (EU Cedrome project 015468);
- Genetic transformation of cotton for resistance to drought and salinity (Eureka “Cotton Stress” project, CIRAD-Evogène);
- QTL approach regarding the genetic determinism of growth, latex production and quality (Genmap).

> Partners

- Varietal improvement: CGIAR centres (CIAT, Africa Rice Centre, ICRISAT); regional research centres (CATIE, CARBAP); national centres (FOFIFA, Madagascar; IER, Mali ; ISRA, Senegal; CENARGEN, Brazil ; IRAD, Cameroon; INRAB, Benin; IAN, Paraguay; RRIT, Thailand; IBRIEC, Indonesia) agricultural interprofessional organizations (ITBAN-UGPBAN, Guadeloupe; Domaines Kabbage, Morocco); private firms (Evogène, Israel; Ecom, Mexico and Nicaragua);
- Genetics and genomics: French partners, European universities (IVIA, Spain; CSIC, Spain; CRA, Italy), international research centres (IRRI, CIAT, ICRISAT); other universities and research centres (NIAs, Japan; BRI, China; INAT, Tunisia).

> Prospects

The extent of the current changes and future requirements, which are difficult to predict, mean that genetic improvement needs to be more flexible, precise and rapid.

Understanding the adaptation dynamics of cultivated plants during the domestication process will make it possible to support future adaptation operations more effectively.

Integrating knowledge obtained through functional analyses of adaptive characters on various scales, throughout the plant life cycle, will serve to speed up the identification of characters and genes of use in adaptation to environmental constraints.

Intraspecific diversity will probably not be sufficient to satisfy all the new requirements generated by climate change. Thought should be given to using genetic transformation.

Characterization of environmental services and indicators of ecosystem functioning

How can the services rendered by tree crop plantations and tropical natural forests be boosted sustainably? These ecosystems play a major role in carbon sequestration and the water cycle.

Coffee under Inga densiflora *(legume), Costa Rica*
© J-M. Harmand/CIRAD

Tropical planted ecosystems, forest and rubber plantations, agroforestry systems and tropical natural forests can play a major role in mitigating climate change. Furthermore, natural forests and agroforests often harbour a broad diversity of species, and are an important source of income for local people. Climate change and land use pressure risk causing the rapid degradation and fragmentation of these ecosystems and, in turn, the loss of the functions and services they ensure.

The main issue for research is understanding the biological, physical and socioeconomic laws that ensure the sustainability of these ecosystems and their functionalities. There is a second challenge: characterizing the changes in their functioning as a result of the global changes—ie climate and land use changes—that have affected them, or are likely to in future, on various temporal and spatial scales.

Knowing more about the ecology of the plant species that form the backbone of natural forests, and thus their susceptibility to global change, is a prerequisite for developing adaptation strategies for forest areas. As regards tree crop ecosystems, progress is expected from complex plantings, associating species or genotypes with complementary properties so as to boost water use efficiency and make such agrosystems more resilient.

> Research projects

- CIRAD is leading one of the few African sites (Congo, eucalyptus) at which flux measurements and greenhouse gas balances are being recorded: Quantification, understanding and prediction of carbon cycle, and other GHG gases in Sub-Saharan Africa (Carboafrica, EU FP6-2005 STREP project);
- Replacement of coke with charcoal for steel mills (case of eucalyptus plantations in Congo and Brazil) - water, carbon and mineral balances, from a local level (plot) to a regional level (millions of ha): Ultra Low CO_2 Steelmaking (ULCOS, EU integrated project);
- Evaluation and indicators of the environmental services rendered by coffee agroforestry systems: Sustainability of Coffee Agroforestry Systems in Central America: coffee quality and environmental impacts (CASCA, EU INCO-Dev/2001 project). Coffee agro-forestry in Central America, East Africa and India (CAFNET: follow-up to CASCA, EU EuropeAid/ENV/2006 project);
- Impact of past climate change on the structure and functioning of the dense forests of the Congo Basin, the world's second largest tropical rainforest (CoForChange, EU ERA-NET Biodiversa project, Agence nationale de la recherche);
- Carbon sequestration capacity of the forests of the Congo Basin. The work is backed up by a long-term research installation in the Central African Republic and the support project for the preparation of forest management plans (PARPAF);

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Natural forest in Indonesia (Kalimantan) © CIRAD

- Bilateral projects: Soil and carbon balance of rubber ecosystems (Hubert Curien partnership, Thailand); water, C and mineral balances in eucalyptus plantations (Ministry of Foreign Affairs, Brazil and Eucflux – Brazilian firms); evaluation and optimization of cocoa agroforestry systems (Grand Sud Cameroun research platform in partnership); development of environmental impact indicators for oil palm (plantation firms).

> Activities and results

A unique network of sites is being used for studies of the key processes involved in carbon, water and nutrient fluxes in tree-based cropping systems (Congo – eucalyptus/acacia plantations compared to savannah grasslands; Brazil – eucalyptus/acacia plantations; Vanuatu – coconut plantations; Thailand – rubber plantations; Indonesia – oil palm plantations; Costa Rica – coffee agroforestry systems; Cameroon – cocoa agroforestry systems):

- studies of the biotic and abiotic factors influencing water and carbon cycles and GHG emissions (sensitivity of primary production and soil respiration to climate change, role of plant species, soil organisms, management and logging practices in stabilizing or degrading soil organic matter, etc);
- study of the biotic and abiotic factors influencing nutrient cycling to ensure more efficient use of soil resources (role of plant species, mixed cropping systems and management in nutrient bioavailability and in changes in mineral balances, etc);
- optimization of cropping practices in tree crop ecosystems (eg fertilization to balance mineral outputs);
- modelling of soil-plant system functioning under the effect of global change and management practices and spatialization of C, water and nutrient balances.

For **natural forests**, research is aimed at:

- identifying the relations between plant communities, environmental factors and past disruptions;
- explaining and predicting the possible changes in African tropical forests;
- studying the relations between environmental factors, disruptions and carbon sequestration by forests;
- developing decision support tools so as to mitigate the effects of global change.

CIRAD's tropical sites are a rare, highly sought-after resource for continental and global analyses and modelling of GHG emissions, as they make it possible to extend the analysis range to cover the world's most extreme biomes.

Examples of results

- The water and nutritional efficiency of eucalyptus plantations can be increased: to preserve resources, it is better to plant on smaller areas with sufficient fertilization than to maintain extensive plantations on larger areas.
- In Brazil, evapotranspiration in eucalyptus plantations after two years is equal to rainfall: as in natural forests, the quantity of water transferred to the atmosphere is significant, but water table replenishment has decreased in relation to the original vegetation (degraded pasture); therefore non-wooded areas between plantations need to be maintained in order to reduce this adverse effect.
- In the Sahel, African acacia species boost carbon and nitrogen sequestration in the soil and nitrogen bioavailability.

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See also

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- Coffee agroforestry systems, which serve to buffer temperature variations at coffee plant level and to maintain soil fertility, are theoretically more resilient than pure plantations.
- More productive coffee varieties suited to higher temperatures, with good cup quality, have been bred.

> Partners

- **European research organizations**: Max Planck Institute (Germany); University of Tuscia (Italy); Edinburgh Centre for Ecology and Hydrology, University of Leeds and University of Wales (United Kingdom); Ecole polytechnique fédérale, Zurich (ETH, Switzerland); University of Wageningen (Netherlands), Swedish Faculty of Agricultural Sciences, etc;
- **Outside Europe**: North Carolina State University, United States Department of Agriculture;
- **In developing countries**: national research centres (CRDPI-Congo, IRET-Gabon, RRIT-Thailand, EMBRAPA-Brazil, IRAD-Cameroon), regional research centres (CATIE, Costa-Rica), international research centre (TSBF-CIAT-Kenya, ICRAF-Kenya), universities (São Paulo-Brazil, Kasetsart-Thailand, Bangalore-India, Gadjah Mada-Indonesia). Some are involved in CIRAD research platforms in partnership (Hevea Research Platform in Partnership, Thailand; Agroforestry Systems with Perennial Crops, Costa Rica; Centre de recherche sur la durabilité et la productivité des plantations industrielles, Congo; PCP Grand-Sud Cameroun);
- Development partners: Ministries of Water and Forests and forestry concession holders (Central African Republic and Congo); Eucalyptus fibre Congo; PTSM/IPEF-Brazil, ORRAF-Thailand; Promecafe-Central America; CRF-East Africa, CBI-India; plantation firms: Indonesia, Ivory Coast, Ghana, Nigeria, Cameroon, Brazil, Ecuador and Colombia, etc;
- The CoForChange project has 14 partners: seven European (Universities of Aberdeen and Oxford, Faculté des sciences universitaires de Gembloux, DG-JRC ISPRA, IRD, CNRS, FRM), six African (Universities of Bangui, Yaounde I, Marien Ngouabi, DG Recherche Congo, CRDPI, Congo, IRET Gabon), and one international (CIFOR).
- National and international networks: Ore F-ORE -T, ex-CIFOR network "Site management and productivity of tropical plantation forests", Fluxnet, AsiaFlux, CarboAfrica, IRRDB, NGARA.

> Prospects

- Evaluation of environmental services (hydrological and carbon sequestration) on a catchment area level;
- Development of an ecological approach of soil functioning focusing on the role of soil organisms and plants in the main biogeochemical cycles;
- Optimization of management practices in tree crop ecosystems, combining productivity, reduction of environmental impacts, and social acceptability;
- Coupling of carbon, water and nutrient cycling in functional models of tree crop ecosystems at plot scale and upscaling to broader scales;
- Extension of work on forests to the natural forests of West Africa: building bridges with projects in Amazonia (in particular with UMR ECOFOG, IRD and INRA on the history of the forests of French Guiana);
- Strengthening CIRAD's involvement in continental and global networks (CarboAfrica, Fluxnet, etc) and meta-analyses (comparison of sites on a regional, major biome and global scale) concerning CO2 and H_20 flux.

Global environmental assessment of agricultural and food products of tropical origin

Of all the human activities that affect the environment—air, soil and water—, food production is the most important. That production will have to grow by 57 to 100% between now and 2050. CIRAD has decided to invest massively in studying these impacts, using an international procedure: life cycle analysis.

Mango © CIRAD

Understanding–and if possible quantifying–the effects of our food production and consumption habits on the environment, in terms not only of the greenhouse effect but also of more local effects (ecotoxicity, eutrophication, water use, etc) is now vital if we are to change our food systems. France recently embarked upon an environmental labelling programme for all the products sold in supermarkets (Grenelle de l'environnement). Within this framework, environmental assessments of foods, whether produced in France or imported (tea, coffee, cocoa, fresh and tinned fruits and vegetables, cotton, meat, etc) have to be conducted as consistently as possible.

The Life Cycle Analysis (LCA) method is now an international reference, covered by an ISO standard (14044, 2006), which serves to make an overall assessment of the functions necessary to man. This powerful conceptual framework encompasses the notions of function (and functional unity), the life cycle of a function, and multicriteria analysis, and makes it possible to show possible pollution transfers between two stages in the life cycle of a product, or between two environmental impacts (eg greenhouse effect – eutrophication). However, using it for agricultural and food systems, which are particularly complex and variable, poses various scientific challenges that research has been tackling for over a decade now. Its application to tropical situations is more recent and even more complex, due to the lack of available data on these systems (shortage of publications on LCA of tropical products), and also to the lack of fundamental knowledge of their interactions with the environment.

CIRAD has decided to invest massively in this new challenge, in an attempt to answer the scientific questions posed by applying LCA to tropical agricultural and food product systems:

- In view of the lack of data and the extreme variability of the systems concerned, how can we define, design and describe typical agricultural and food systems that are representative on a given scale?
- How can we conduct reliable environmental inventories?
- How can we adapt environmental impact characterization models to tropical situations?
- What indicators are there for the predominant impact categories that are nevertheless not usually taken into account, such as biodiversity, water use, soil quality and landscapes?
- How can we take account of and quantify the uncertainty linked to LCA results?

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Publications

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Basset-Mens C. *et al.,* 2007. Methods and data for the environmental inventory of contrasting pig production systems. Journal of cleaner production, 15 (15): 1395-1405.

See also

http://publications.cirad.fr

> Activities and results

CIRAD's operations as regards global environmental assessment of foods, with the development of life cycle analysis models, have begun with the main standard products (tomato, citrus, banana, palm oil, rice, coffee, cocoa, etc), identifying the methodological issues specific to the fields of application, and the establishment of projects in partnership. It is important to note the multidisciplinary aspect of the projects currently being or already established. Moreover, cohesion and internal supervision are ensured by building transverse projects; a project is being established to acquire LCA data for each major supply chain and develop an LCA database for tropical products at CIRAD.

> Research projects

- Promotion of supply chains that fit in with sustainable development, using a decision support tool that combines three key elements of the fruit and vegetable market: environmental sustainability, nutritional quality, socioeconomic aspects (FLONUDEP, ANR project);
- African Food Tradition Revisited by Research (AFTER, EU FP7 project, 2009-2013);
- Environmental assessment by LCA of some of the major tropical products imported into and consumed in France (fruits, coffee, cocoa, Thai rice, palm oil) (Agri-BALYSE project: within the framework of the environmental labelling project included in the Grenelle de l'environnement ADEME funding).

> Partners

- Europe: Agroscope laboratory, Zürich (Switzerland), Swedish Institute for Food and Biotechnology (SIK), Institut de Recerca i Tecnologia Agroalimentaries (IRTA, Spain);
- Asia: Asian Institute of Technology (AIT), University of Kasetsart (Thailand);
- Latin America: partners in the Eco-ALCUE-FOOD project: Instituto Nacional de Tecnologia Agropecuaria (INTA, Argentina), Centro Agronomico Tropical de Investigaciones y Ensenanza (CATIE, Costa Rica);
- Scientific Committee of an international conference: Life Cycle Assessment in the Agri-food Sector, 22-24 September 2010, Bari, Italy.

> Prospects

Life cycle analysis is a powerful tool for comparing different types of agricultural practices and for the eco-design or a priori analysis of prospective, innovative systems.

A harmonized life cycle analysis database for tropical products is currently being compiled.

The effects of toxicity in crops, notably on horticultural products, are to be given greater consideration.

Climate change and emerging animal diseases

Diseases transmitted by vectors (insects, ticks, molluscs, rodents, bats, etc) are highly susceptible to environmental change, as are those for which wildlife acts as a reservoir (avian influenza, bovine tuberculosis, African swine fever, etc). CIRAD's role is to understand the epidemiological dynamics at play so as to offer ways of preventing, monitoring and controlling such diseases.

Commercial cattle herd in a temporary pond in Ferlo, a seat of Rift Valley fever transmission
© R. Lancelot/ CIRAD

Climate change has a direct effect on the habitat and movements of man, animals, pathogens and their possible vectors. At the same time, today's world is marked by unprecedented population growth and animal production, and also by health crises linked to emerging diseases. Social and environmental change and increased travel and trade mean a more rapid spread of such diseases, and are exacerbating their sanitary and economic impact. Every country worldwide is concerned, but developing countries, with their limited health systems and economic resources, are particularly vulnerable.

In this context, CIRAD's role is to understand the biological and ecological processes at play, and determine the corresponding climatic, environmental, economic and social factors. Understanding the interactions between hosts, vectors and pathogens, combined with analyses of epidemiological dynamics, serves to provide solutions for preventing, monitoring and controlling emerging diseases. Modelling those processes makes it possible to test environmental change scenarios and assess on a computer the effect of control measures. The aims are to provide partners with better control and sanitary decision support tools and methods: vaccines, diagnostic tests, surveillance methods, health networks and ongoing observatories of emergence risks.

Capacity building (teaching, training) has a fundamental role to play, as do technology transfer (diagnostic kits, vaccines, models, etc) and international expertise (reference laboratories for diagnosis and epidemiology of emerging diseases, mobilisation of expertise in the event of a crisis).

> Research projects

- Scientific and technical support in animal health agreement with the Direction générale de l'alimentation, 2008-2011;
- Montpellier "vector and emerging disease" network (State-Region project contract, 2007-2013);
- Emerging vector-borne diseases in a changing European environment (EDEN: 24 countries in Europe, North Africa and sub-Saharan Africa);
- Biology and control of vector-borne infections in Europe (EDENext: 46 participants in Europe, North Africa and sub-Saharan Africa);
- Climate change and impact research: the Mediterranean environment (CIRCE): case study of bluetongue and African horse sickness;
- Epizootic disease diagnosis and control (EPIZONE), European network of excellence on animal diseases;
- Surveillance network of bluetongue and African horse sickness, in the Mediterranean basin and Europe (MEDREONET, FP6), on diseases transmitted by *Culicoides*; 21 countries in Europe and North Africa;
- Project on the ecology and epidemiology of avian influenza and Newcastle disease (GRIPAVI, French Ministry of Foreign and European Affairs), nine partners for six observatories in sub-Saharan Africa and Southeast Asia;
- Ecology of influenza viruses and surveillance: RIVERS and ECOFLU projects, Southeast Asia;

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Publications

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The Sahelian part of Africa is particularly susceptible and exposed to climate change
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Minet C. *et al.* (2009). Infections à Morbillivirus chez les ruminants: la peste bovine en voie d'éradication et la peste des petits ruminants en extension vers le nord. Virologie, 13 (2) : 103-113.

See also

http://publications.cirad.fr

- Ecology of rodent-borne diseases in Southeast Asia (CEROPATH, ANR project 2008-2010);
- Epidemiology of Rift Valley Fever (RIFT-OI) in Indian Ocean.

> Activities and results

- Establishment and coordination of the national *Culicoides* surveillance network, which serves to determine the periods of vectorial inactivity for bluetongue and thus to authorize commercial live animal movements;
- Establishment and contribution to coordinating regional vector and emerging disease surveillance networks and observatories (Southern African, Caribbean, Indian Ocean, Euro-Mediterranean, Southeast Asian animal health network, etc);
- Establishment and coordination of a network of observatories of the ecology and epidemiology of bird-borne diseases (influenza, West Nile) in sub-Saharan Africa and Southeast Asia;
- Epidemiology and modelling, surveillance and risk analysis of Rift Valley Fever, West Nile virus and animal trypanosomiases;
- Ecological and epidemiological studies on Wildlife-Livestock-Human interfaces in Southern African countries;
- Ecology of rodent and bat-borne diseases in Asia and Africa (Gabon).

> Partners

- **International**: Food and Agriculture Organization of the United Nations (FAO), World Organization for Animal Health (OIE), World Health Organization (WHO), nongovernmental organizations, etc;
- **Europe**: national and international institutions in 20 countries;
- **Africa**: North Africa (Tunisia, Algeria, Morocco) – Euro-Mediterranean animal health network; sub-Saharan Africa – Centre International de recherche-développement sur l'élevage en zone subhumide (CIRDES), Ecole inter Etats des sciences et médécine vétérinaires de Dakar (EISMV, Senegal), Centre international de recherches médicales de Franceville (CIRMF, Gabon), research centres in Senegal, Mali, Ethiopia, Cameroon; southern Africa – Zimbabwe, South Africa; Indian Ocean – Centre de Recherche et de Veille sur les maladies émergentes dans l'Océan Indien (CRVOI), Madagascar, Comoros and Mayotte;
- **Asia**: Institut Pasteur in Cambodia, University of Kasetsart (Thailand); GREASE, joint skills network on management of emerging risks in Southeast Asia;
- **Caribbean**: CaribVet network and INRA-CIRAD animal health and emerging disease observatory, based in Guadeloupe.

> Prospects

Building skills, methods and generic tools to cope with emerging and re-emerging diseases;

Strengthening surveillance and health networks in Europe and the South: Euro-Mediterranean animal health network, European Centre for Disease Prevention and Control (ECDC) VBorNet network, regional animal health centres (Africa, Middle East, Southeast Asia) and international networks (OIE-FAO network of expertise on animal influenza, OIE-FAO-WHO Global Early Warning and Response System, etc);

Consolidating alliances with the main European teams;

Strengthening national platforms, networks and alliances, since France is particularly well placed in this field, with the Montpellier "vectors and emerging diseases" network;

Formalizing and coordinating a network of transdisciplinary observatories of climate change and environmental services encompassing, among other things, emerging animal and zoonotic diseases.

Climate change and plant health

On a global level, the areas occupied by pests and diseases are expected to spread, or even to shift, leading to the colonization of new regions, or local modifications. CIRAD's geographical structure enables it to monitor the spread of pests on a global level and develop ways of managing the risks they represent.

Bactrocera invadens *fruit fly on mango*
© J-F. Vayssières/CIRAD

The local emergence of new crop pests and diseases can have repercussions for human health, for instance due to increased pesticide use, out of ignorance. Furthermore, in view of the fragility of developing countries, we can expect the risks of food shortages to become more acute in the event of the arrival of particularly aggressive pests.

CIRAD's bases throughout the tropics make it a prime player in studying and developing tools and methods for diagnoses, modelling epidemics, integrated pest management, etc, in a range of situations. The aim is to build substantial, appropriate capacity to anticipate (warning-prevention), so as to respond rapidly to problems as soon as they emerge. In this respect, the approaches and partnerships favoured by CIRAD enable it to implement predictive and preventive operations.

> Main activities and results

Research centres on understanding how pests and diseases adapt to climate change and chemical-type selective constraints within agrosystems. The approaches adopted and the partnerships built favour predictive operations (notably modelling).

The main models of fungal pests on which CIRAD is working concern the dynamics of *Mycospharella fijiensis* on banana and *Magnaportae oryzae* on rice. The models concerning vector insects are looking at the spread across Africa and the Mediterranean of fruit flies of the genus *Bactrocera*, and the spread and diversity of *Bemisia tabacci*, the tomato yellow leaf curl virus (TYLCV) vector.

These studies call for the development of diagnostic tools and approaches for modelling epidemics and population dynamics (evolutionary potential), so as to develop integrated pest management strategies for various situations. This research is enabling CIRAD to build useful warning and prevention skills that should allow it to find relevant, sustainable responses to pest problems as soon as they emerge.

> Research projects and partnerships

- Diversifying crop protection (Endure, EU FP6 network of excellence, 2007-2010): Associated partners in the South: Zhejiang Academy of Agricultural Science (ZAAS, China), Instituto Nacional de Tecnologia Agropecuaria (INTA, Argentina), Institut national de la recherche agronomique (INRA, Morocco), Centre Régional Bananiers et Plantains (CRBP, Cameroon), Empresa Brasileira de Pesquisa Agropecuária (EMBRAPA, Brazil);
- Analyses of phytosanitary risks: Enhancements of pest risk analysis techniques (PRATIQUE, EU SCP consortium). Twelve European countries + CRCNPB (Australia) and Bioprotection (New Zealand);
- Understanding the emergence of plant fungal diseases: towards an estimate of the risks linked to global change (Emerfundis, ANR project, 2008-2010);

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Publications

Duyck, P.-F., P. David, *et al.* (2006). Climatic niche partitioning following successive invasions by fruit flies in la Réunion. *J Anim Ecol,* 75: 518-526;

Reynaud, B., H. Delatte, *et al.* (2009). Effects of temperature increase on the epidemiology of three major vector-borne viruses. *Eur J Plant Pathol,* 123: 269-280.

See also

http://publications.cirad.fr

- Studies of inferential and software methods for evolution (EMILE, ANR project, 2009-2012);
- Phytosanitary crises linked to bioinvasions: the emblematic case of the *Bemisia* virus risk in sheltered cropping systems in the Mediterranean (Bemisiarisk, ANR project, 2007-2009);
- Better understanding the biological and molecular factors and mechanisms involved in the emergence of plant bacteria and viruses (on three models: *Ralstonia*, *Xanthomonas* and TYLCV) (Réunion regional Biorisk project, ERDF, 2008-2010);
- Diversity and evolutionary history of *geminivirus* populations in the islands of the southwestern Indian Ocean: a study model for the emergence of pathogens transmitted by vectors (EmerGe, CRVOI regional funding, 2008-2011).

> Prospects

The Mediterranean is a particularly strategic zone for both Europe and France. An integrated Mediterranean protection network is currently being built with the International Centre for Agricultural Research in the Dry Areas (ICARDA) and national research organizations in Syria, Lebanon, Tunisia, Algeria and Morocco; this initial hub is to be extended to other Mediterranean partners (Launch meeting in Aleppo, 1 September 2009).

Modelling and sanitary risks in the Mediterranean (animal health and plant health) (Emergences, CIRAD project, 2010-2012) are being addressed through a partnership with INRA, AFSSA and the Institut Pasteur (France) and research organizations in the Mediterranean.

CIRAD is involved in continuing the activities of the ENDURE network beyond 2010: it is helping to set up regional networks (including the Mediterranean, but also China, South America, sub-Saharan Africa, etc).

It has launched a think tank with a view to understanding the effects of pathogen biodiversity on crops in the light of climate change. It has submitted a project aimed at studying the impact of agriculture on plant virus biodiversity in a wild ecosystem, Cape fynbos (South Africa), and understanding how the existing biodiversity should be taken into account in disease emergence in neighbouring agrosystems (FYNBOS, FRB 2009 call for proposals). Its partners are the University of South Africa, the CNRS, the CEA and the Noble Foundation (USA), the current leaders in this field.

Adapting irrigated cropping systems

Climate change evolution scenarios are much less precise when it comes to water than they are for temperatures. Generally speaking, however, the irrigated agriculture sector will have to adapt to conditions in which water is increasingly scarce, with more frequent uncertainties (droughts, floods). CIRAD involves stakeholders in its research in order to explore acceptable solutions.

Irrigation canal in North Africa
© CIRAD

Crop evapotranspiration and water requirements increase with temperature. Furthermore, extreme events, such as droughts and floods, are becoming increasingly frequent. However, there is still considerable uncertainty about future rainfall levels in many regions, including the most fragile and vulnerable, such as the Sahel. Farmers are above all marked by extreme events (drought, flooding), which vary considerably from one regions to another.

In this context, irrigation is one way of making agriculture less vulnerable to climatic hazards by securing access to water. This was shown in North Africa, where rainfall levels have fallen steadily over the past twenty years, while in West Africa, the great droughts of the 1970s-80s prompted the development of small-scale irrigation. However, irrigation also implies intensification of agriculture, which means that extreme events may in some case be more harmful than in non-irrigated areas.

Other changes are also under way, and are much more rapid than climate change; urbanization, industrialization, development of tourism or hydroelectricity all significantly reduce the amount of water available for agriculture. These sectors often take priority in most countries, and it is thus agriculture that is expected to reduce its water requirements, while maintaining or even increasing the food production.

These modifications are prompting the use of "new" water resources: alongside surface water (rivers and reservoirs), it is underground water (natural or refilled water tables) and alternative water resources (reuse of waste water, desalination) that are now being called upon.

Lastly, irrigated agriculture also plays a role in climate change, particularly irrigated rice paddies, due to methane emissions.

CIRAD is involving stakeholders in the search for solutions that respond both to global and national issues (producing more with less water) and local objectives (improved income, employment, etc).

> Research projects

International: CIRAD is involved in the CGIAR Challenge Program on Water and Food, through two projects:

- Tools for integrated water resources management: implementation in Limpopo, Mekong and Niger basins (Echel'Eau, CPWF, French Ministry of Foreign Affairs priority solidarity fund [FSP MAE]);
- Payment for environmental services aimed at encouraging farmers to adopt more environmentally friendly practices in the Mekong region (PES Mekong) (CPWF).

In the Mediterranean:

- Water demand management knowledge base for the Mediterranean (WADEMED, EU project, 2003-2006);

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- Mitigation of water stress problems through new approaches to integrating management, technical, economic and institutional instruments (Aquastress; EU project, 2004□2008);
- Water economy in irrigation systems in North Africa (SIRMA; FSP MAE bilateral project, 2004-2009);
- Participatory design of adaptive groundwater management strategies and instruments in Mediterranean coastal water scarce areas as a response to climate change (Aquimed; ERA-NET project).

In Indonesia:

- Organization of a platform for industrialist-farmer consultations on water management (Danone Indonesia).

Participation in other, more general projects:

- ADAGE (Foresight workshop on the adaptation of agriculture and manmade ecosystems to climate change);
- AMMA (multidisciplinary analysis of the African monsoon).

> Main activities and results

Water resource governance: mechanisms for resource sharing and negotiation between different sectors of activity (agriculture, industry, drinking water, tourism, mining) competing for water (eg South Africa, Indonesia).

Irrigation techniques that save water (for instance conversion to drip irrigation in North Africa).

Support of technical change by facilitating the creation and training of agricultural cooperatives and irrigation associations; dissemination of innovations (eg North Africa, Mali, Réunion).

Use of groundwater resources (eg North Africa, Brazil).

Results: significant improvements in irrigation performance are possible, but they mean considering the whole of the irrigation system, and not just the technical aspects of water consumption. It is crucial to involve farmers and other stakeholders in these processes in order to ensure that innovations are adopted and disseminated. Groundwater resource governance requires specific tools, since those resources are invisible and farmers know little about how they function.

> Partners

International centres (IWMI, IRRI, ADRAO) and international educational establishments (2iE, IWEGA, AIT, IAV Hassan II). Challenge Program on Water and Food (CPWF) network.

National centres and universities in the South (Brazil, South Africa, Burkina Faso, Ethiopia, Mali, Mozambique, Morocco, Algeria, Tunisia, Vietnam, Thailand, Indonesia). Universities in the North (Wageningen, Leuven).

Publications

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Hammecker C. et al. (2009). Simulating the evolution of soil solutions in irrigated rice soils in the Sahel. *Geoderma*, 150: 129-140.

See also

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> Prospects

One of the main challenges in the early years of this century is improving water resource availability and use and fostering the development of additional resources (UN-Water, 2009). CIRAD's work is devoted to achieving these aims in Mediterranean and tropical countries, notably by working on:

- analysing the changes in water resources and use in the light of global change;
- stakeholder behaviour and vulnerability in the face of risks;
- multi-criteria and multi-scale analyses of irrigated system performance;
- analyses of physical processes with a view to designing irrigation equipment that saves water;
- operational management of irrigation schemes;
- support of technical and institutional innovations in irrigated areas;
- debate on public action, regulation and governance on every level.

Adapting agriculture-animal production systems

Pressure on the resources available to agropastoral and agro-silvopastoral ecosystems increases their vulnerability. Furthermore, such ecosystems contribute to climate change, due to their high greenhouse gas emissions. Work is under way to find conservatory methods so as to reduce losses

Draught animals in a cotton planting. © CIRAD, M. Berger

A large proportion of rural inhabitants in poor countries—80% in Africa—depend on rainfed agriculture. In such systems, carbon losses as a result of deforestation, erosion and leaching, along with fragility and soil fertility, are a major problem. Organic matter decomposition generates large quantities of greenhouse gases (CO_2, methane, nitrogen protoxide).

Agricultural research is helping to identify biophysical and socioeconomic indicators of the vulnerability of such ecosystems and the rural societies that live in them. Cropping and animal production systems vary according to their performance, resilience and effects on the water, carbon and greenhouse gas balance. It is therefore important to understand how crop and animal farmers perceive climate variability and change, make decisions, and manage natural resources, on an individual farm level (soil fertility management, tillage, animal feeding, fertilization) and a community level (grassland and communal forest management, social networks).

To mitigate the effects of such systems, carbon sequestration and storage in the soil is a priority. Some techniques have already proved their worth in specific situations (conservation agriculture). It is now vital to adapt these techniques to a range of situations and to assess them, in collaboration with stakeholders (farmers and natural resource and service managers). The methods used leave ample room for observation, surveys, process analyses and modelling, with a view to integrating various quality and quantity aspects, scales and players.

It is apparently essential to design an economy linked to carbon management, but this is a difficult undertaking. It assumes the existence of technical and institutional capacity, knowledge of the reality, and an ability to represent that reality using reliable tools (maps, indicators, etc). Research has to come up with such tools so as to support public policy and governance structures.

> Research projects

- Perception, adaptation and support of populations faced with climate, environmental and social change (PAAPCES, AIRD project, RIPIESCA priority solidarity fund, MAE);
- No-till systems, Brazil, Madagascar (PEPITES, ANR);
- Smallholder Conservation Agriculture Promotion in Western and Central Africa (SCAP, AFD-MAE multi-partner project);
- Information system on pastoralism in the Sahel (SIPSA, MAE project, Chad, Niger, Burkina Faso, Mali, Senegal, Mauritania);
- Assessment of the impact of mulch-based planting systems on farm performance. Multi-country support programme for agro-ecology (PAMPA, AFD-MAE, Madagascar, Cameroon, Brazil);
- Modelling polyculture-animal production farm functioning in cotton-growing regions (CORUS bilateral project, MAE-Burkina Faso);
- Foresight workshop on the adaptation of agriculture and manmade ecosystems to climate change (ADAGE, ANR, 2009);

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- Carbon in the pastures of French Guiana and greenhouse gases: characterization of carbon dynamics, changes in fertility and GHG flux in grassland systems, in association with forest areas (CARPAGG, EU ERDF project, 2007-2013;
- Animal production, climate and societies (ECliS, ANR project, 2009-2011).

> Activities and results

CIRAD's work has shown that it should be possible to improved carbon rates in tropical soils, notably by reducing, if not eliminating, tillage and using mulch-based systems (conservation agriculture or CA). Water and mineral balances can also be improved using CA.

The potential of CA techniques to improve water storage in the soil by reducing runoff, and to increase annual biomass production, has been confirmed in Brazil and Africa. Returning a major share of biomass to the soil can improve nitrogen availability to crops and contribute to nett carbon sequestration in the soil.

However, the performance of such systems may fall short of local systems, depending on soil and climate conditions, particularly if water is not the main limiting factor. The effects of other techniques practised at the same time should also be taken into account, for instance anti-erosion techniques such as ridging. Furthermore, little is yet known about the opposing effects of stored C (positive effect) and N_20 emitted (negative effect). In Africa, one of the main challenges in storing more carbon in the soil is to maintain harvest residues on the soil surface in plots: the residues can no longer be used to feed animals and deprive animal farmers and mixed farmers of a fodder source.

Acceptable comprises therefore have to be found. In complex agricultural landscapes, large quantities of C are stored in the perennial vegetation found on small subsistence farms. On such farms, there is a strong correlation between carbon sequestration in plant biomass and plant biodiversity levels. This factor therefore also needs to be taken into account.

Practical tools are now available to farmers, including an educational kit on how to manage mulch-based cropping systems and supply fodder for dairy cows, produced and distributed in Madagascar.

Lastly, information systems are available to local communities to predict short-term climatic crises and analyse long-term trends in the agrosilvopastoral systems of the Sahel.

> Partners

- **International centres**: International Maize and Wheat Improvement Centre (CIMMYT), Tropical Soil Biology and Fertility (TSBF), International Centre for Research in Agroforestry (ICRAF), International Livestock Research Institute (ILRI), International Center for Agricultural Research in the Dry Areas (ICARDA), Centro Agronómico Tropical de Investigación y Enseñanza (CATIE);

- **National centres**: Institut d'Economie Rurale (IER, Mali), Institut de l'environnement et de recherches agricoles (INERA, Burkina Faso), Institut national de recherche agricole du Bénin (INRAB, Benin), Institut National de Recherches Agronomiques du Niger *(*INRAN*,* Kenya), Agricultural Research Institute (KARI), Kenya Sugar Research Foundation (KESREF), Savanna Agriculture Research Institute (SARI, Ghana), Empresa Brasileira de Pesquisa Agropecuária (EMBRAPA, Brazil), Institut de Recherche Agricole pour le Développement (IRAD, Cameroon), National Centre of Applied Research and Rural Development (FOFIFA, Madagascar), Commonwealth Scientific

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Lahmar *et al.* (2006). Opportunités et limites de l'agriculture de conservation en Méditerranée. Les enseignements du projet KASSA. In: Third Mediterranean Meeting on No Tillage, Zaragoza: CIHEAMIAMZ, 11-18.

See also

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and Industrial Research Organisation (CSIRO, Australia), AgResearch (New Zealand);

- **International networks**: ACT, Soil Fertility Consortium for Southern Africa (SOFECSA), African Network for Soil Biology and Fertility (AfNET), CANSEA, Conservation agriculture network in South-East Asia;

- **Universities**: Wageningen (Netherlands), Zimbabwe, Kenyatta (Kenya).

> Prospects

Searching for sustainable ways of intensifying agriculture in the buffer zones around the main biodiversity reserves (transcontinental project).

Developing a model of pastoral vulnerability in the Sahel, so as to monitor and target the most at-risk populations.

Characterizing the changes in the mobility of pastoral systems, and their capacity to adapt to crises.

Analysing the contribution made by public policy to the fight against rural inhabitants' vulnerability.

Using the case of Réunion for a global study of carbon sequestration in tropical agro-ecosystems, with the support of spatialization and modelling tools including urban aspects.

Understanding soil fertility degradation in the cotton-growing zones in crisis in central and West Africa: establishment of win-win collaborations between the world of mineral fertility and that of organic matter.

Animal production and climate change

Animal production will have to develop in order to satisfy growing demand from consumers in the South. This means adapting systems on a territorial scale. On a global scale, mitigating the impact of animal production on resources and the climate is a major challenge for scientists

Semi-intensive chicken rearing in Cambodia
© M. Berger/CIRAD

With regard to climate change, the global animal production sector directly or indirectly accounts for 18% of global greenhouse gas emissions, according to the FAO.

Animal production systems worldwide vary significantly, and ensure a range of functions and services (food, capital, cash flow, labour force, fertilization, religion, donations, etc). They make a major contribution to poor economies. With a view to sustainable development, boosting animal production will mean adapting systems on a territorial scale.

The tendency to concentrate animal production operations in periurban areas has led to surpluses and latent pollution. Conversely, in cropping systems, carbon and soil fertility losses, the fragility of the systems and the demand for organic inputs are still a major problem. Increased fertilizer costs, greenhouse gas emissions for production and transport, and the increasing scarcity of resources such as phosphorus are all arguments in favour of looking for ways of integrating animal production and agriculture more closely.

As regards climate change, animal production is not directly a carbon sink. However, it can contribute indirectly to its sequestration if the system uses covered cultivated areas and grasslands. According to working groups on climate change, C sequestration in soils has the highest potential for reducing emissions (90%) in the agricultural sector. Grasslands and rangelands have a C storage capacity of around 0.9 tonne per hectare, per year, although this varies depending on the farming method, region and climatic conditions.

> Research projects

Foresight workshop on the adaptation of agriculture and manmade ecosystems to climate change (ADAGE, ANR, 2009);
Animal production systems and sustainable development (SPADD, ANR, 2007-2010);
Guide: Fodder, no-till, mulch-based systems and dairy farming in the highlands of Madagascar (Fourrages Mada; IO interregional project, 2007-2009);
Adaptation of perimediterranean fodder and animal production systems to climate change (Climfourel, State-regions, 2008-2010);
Environmental impact of camel rearing in Tassili (MAE, 2009-2012);
Environmental efficacy and animal production for sustainable development (EPAD, ANR project, 2009-2013);
Workshop on foresight study and adaptation of agriculture and manmade systems to climate change (DAGAR, ANR, 2009);
Carbon in the pastures of French Guiana and greenhouse gases (CARPAGG, EU ERDF-French Guiana OP project, 2007-2013;
Research in partnership to improve food security by boosting soil fertility in Tuy province (Ferti-Partenaire, EU project, 2008-2012);

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Summary

Adaptation au changement climatique Biomes prairies-savanes et filières élevage (ARPAGE, 15 p.)

Publications

Vayssières J. *et al*. (2009). Gamede: A global activity model for evaluating the sustainability of dairy enterprises Whole-farm dynamic model - Interactive simulation of various management strategies with diverse stakeholders. *Agricultural Systems,* 101: 128-151.

Integrated management of farms and animal production chains (CIEEL, EU ERDF-Réunion Op project, 2008-2013);
Animal production, climate and societies (ECliS, French ANR project, 2009-2012).

> Activities and results

Assessments, impacts

CIRAD has 120 experimental plots in Réunion for long-term research (N recycling, effluent and C sequestration in grasslands). It establishes energy, carbon and greenhouse gas emission balances for animal production chains (180 balances established, CIEEL 2, Réunion).

Tools for modelling biomass, greenhouse gas and carbon flux on animal farms.

Databases for predicting methane production using the near-infrared spectra of ruminant digestates in tropical environments.

Functioning indicators (carbon sequestration in soils and biomass, fertility maintenance).

Use of emission flux measuring equipment and C sequestration protocol for grasslands in French Guiana.

Assessment of the impact of dairy cattle in polyculture-animal production systems in Madagascar: biomass flux modelling.

Economic modelling of interactions between cropping and animal production systems on a farm and territorial scale (Réunion and Madagascar).

Adaptation of systems

Multi-criteria assessment of the sustainability of Mediterranean and tropical pastoral animal production systems: methodological research and comparative approach for systems and territories (INRA-CIRAD).

Interactions between decision-making practices regarding management and energy flux in localized animal production systems: case of dairy farming in contrasting situations (INRA-CIRAD).

Genetics and adaptation of species and landraces: characterization of heat adaptation physiological responses in pigs (INRA-CIRAD). Drafting of protocols in Guadeloupe and Réunion.

Establishment of the Animal Change Consortium: integrating mitigation and adaptation options for sustainable livestock production under climate change (EU FP7 Knowledge-Based Bio-Economy project).

> Partners

- **International**: Centro Agronómico Tropical de Investigación y Enseñanza (CATIE), Centre International de Recherche-Développement sur l'Elevage en Zone Subhumide (CIRDES), European Association for Animal Production (EAAP), Food and Agriculture Organization of the United Nations (FAO), International Livestock Research Institute (ILRI), International Center for Agricultural Research in the Dry Areas (ICARDA);

- **National centres**: AgResearch (New Zealand), Centre wallon de recherches agronomiques (CRA-W, Belgium), Consejo Superior de Investigaciones Científicas, (CSIC, Spain), Commonwealth Scientific and Industrial Research Organisation (CSIRO, Australia), Empresa Brasileira de Pesquisa Agropecuária (EMBRAPA, Brazil), National Centre of Applied Research and Rural Development (FOFIFA, Madagascar), ISRA (Senegal), Institut d'économie rurale (IER, Mali), University of Wageningen (Netherlands).

Publications

Vigne M., *et al*. (2009). Energy use efficiency and greenhouse gases emissions of dairy farms of an isolated territory: case of Reunion Island from 2000 to 2007 Ag-SAP Conference 10-12/03 2009, Egmond aan Zee, the Netherlands. p. 430-431.

Proceedings of the Livestock & Global Climate Change International Conference, Hammamet, Tunisia, 17-20 May, 2008 281 pp. Online.

Dutilly-Diané C., *et al.* (2007). Could payments for environmental services improve rangeland management in Central Asia, West Asia and North Africa? Washington: IFPRI, 42 pp. (CAPRI Working paper, 62)

Dutilly-Diané C. (2006). Economics of pastoralism Study of current practices in North Africa (WISP Outcome 1). Final report.

Educational kit: Conduite des systèmes de culture sur couverts végétaux et affouragement des vaches laitières : guide pour les Hautes Terres de Madagascar. Published by ARP, 90 pp., 7 posters, 9 thematic sheets.

See also

http://publications.cirad.fr

> Prospects

On an international scale, in recent years, animal production and its market prospects, roles and effects have raised new questions that pose challenges for research and call for substantial new investment in research and training in the South.

The national structure's main asset is its almost unique research and development potential in terms of animal production issues. Few countries have such significant human resources available to address questions relating to animal production in warm regions, in terms of either research or appraisals.

Demand for knowledge concerning the major issue of adapting animal production systems and their role in mitigating climate change is certain to grow.

Biomass energy

Primary energy consumption depends on biomass (non-fossil source) in many developing countries. How can the production and renewal of this resource be fostered while ensuring that this benefits people in those countries, where consumption is set to increase significantly?

Eucalyptus nursery © CIRAD

Developing countries consume just 35% of primary energy worldwide, whereas they account for more than 75% of the population. Many experts are forecasting that their consumption will rise significantly in the next 50 years.

Fuels produced from biomass, all origins combined, account for a major share of domestic energy: up to 90% in sub-Saharan Africa, 70% in rural households in China, and between 30 and 90% in Latin America (IEA, 1997). This situation has resulted in pressure on resources and forest degradation, particularly in the areas supplying towns and cities.

However, in countries with available land and the right climatic conditions, biomass can be a good opportunity for rural populations to develop new activities, including for uses other than domestic. Nevertheless, such a switch will have consequences for resource management (biomass, water, soils, etc) and lead to competition between activities.

On a global level, biomass can satisfy requirements and increase the energy self-sufficiency of tropical countries, with a limited impact on climate change. Furthermore, local development of economic activities relating to biomass energy production and use can improve living conditions in rural areas. CIRAD's work consists in optimizing production processes and defining the optimum conditions for the development of such a production chain in developing countries.

> Activities and results

CIRAD has made biomass energy one of the priority lines of research in its scientific strategy. It is looking at how to ensure that the emergence and development of bioenergies benefits people in developing countries, in other words:

resource availability: estimating the areas available worldwide, in-depth analysis of three global regions;
genetic improvement and agronomy of dedicated energy crops: sorghum, physic nut, sugarcane, forest plantations;
sustainable management of producing forests, rehabilitation of degraded forests;
studies of production organization systems (family agriculture, industrial crops) and fuelwood supplies to towns; assessment of their socioeconomic impact;
environmental impacts of production chains, carbon balance analysis, studies of access to Clean Development Mechanism (CDM) or Reducing Emissions from Deforestation and Degradation (REDD) type funding;
development of appropriate technologies for the different resources, by optimizing energy yields and minimizing environmental impact: thermochemical conversion processes, optimizing the use of first-generation biofuels;
public policy elements to be put in place for fair, sustainable bioenergy development.

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Publications

Fassinou W.F., Van de Steene L., Toure S., Volle G., Girard P. (2009). Pyrolysis of *Pinus pinaster* in a two-stage gasifier: Influence of processing parameters and thermal cracking of tar. *Fuel Processing Technology*, 90 (1): 75-90.

Publications

Piketty M.G., Wichert M., Fallot A., Aimola L. (2009). Assessing land availability to produce biomass for energy: The case of Brazilian charcoal for steelmaking. *Biomass and Bionergy*, 33: 180-190.

Broust F., Girard P., Van de Steene L. (2008). Biocarburants de seconde génération (Ref RE110). Techniques de l'ingénieur. Bioprocédés.

Fallot A., Girard P. (2008). Eléments d'évaluation économique des huiles-carburants. *In:* Rousset Patrick (ed.). Guide technique pour une utilisation énergétique des huiles végétales. Montpellier: CIRAD, 273-287.

Bedrossian C., Vaitilingom G. (2008). Extraction, conditionnement et utilisation des huiles végétales pures carburant. *In*: Rousset Patrick (ed.). Guide technique pour une utilisation énergétique des huiles végétales. Montpellier: CIRAD, 207-272.

Sales C. (2007). Energie, les promesses de la biomasse. *La Recherche* (406, su): 24-25.

See also

http://publications.cirad.fr

> Research projects

Analysis of global lignocellulose biomass potential for biofuel production (with Total SA, 2008-2010);
Community forest management for timber and fuelwood production in Madagascar (EU project, 2006-2010);
Fuelwood supplies to the town of Kinshasa (EU and Democratic Republic of Congo, 2009-2012);
Development of models for robust, generic estimates of fuelwood potential (ANR, 2008-2011);
Assessment and optimization of the potential for developing physic nut cultivation (Agrogénération SA and Enerbio, 2007-2010);
An alternative energy plant: sweet sorghum (EU project, 2008-2013);
Producing lipid biofuels using micro-algae (ANR, 2007-2010);
Environmental impact of replacing mineral charcoal with plant charcoal in Brazilian steelworks (EU and Arcelor-Mittal, 2004-2010);
Improving carbonization processes in Madagascar (EU project, 2006-2008);
Decentralized rural electrification in Madagascar (EU project, 2008-2011);
Preconditioning biomass by torrefaction (EU project, 2006-2009);
Preconditioning biomass by flash pyrolysis (ANR, 2006-2009);
Physicochemical characterization of pyrolysis oils (Enerbio, Tuck Foundation, 2008-2010);
Study of gasification tar cracking in fluid bed systems (Fonds unique interministériel, 2010-2013);
Characterization of different types of biomass with a view to producing biofuels using thermochemical processes (ANR-FINEP, Brazil, 2009-2011);
Building the capacity of West African countries in terms of energy (ACP-Europe energy facility, 2007-2010).

> Partners

Africa: dedicated crops and processing techniques – Institut international d'ingénierie de l'eau et de l'environnement (2IE, Burkina Faso), International Crops Research Institute for the Semi-Arid Tropics (ICRISAT, Mali); forest biomass management and use, decentralized electrification – Agence de développement de l'électrification rurale (ADER, Madagascar);

Latin America: thermochemical processes to give Amazonian communities access to energy – Franco-Brazilian cooperation (SFB), Empresa Brasileira de Pesquisa Agropecuária (EMBRAPA) and the University of Paraná (Brazil); energy and adaptation of agriculture to climate change – Centro Agronómico Tropical de Investigación y Enseñanza (CATIE);

Africa: dedicated crops and processing techniques – Institut international d'ingénierie de l'eau et de l'environnement (2IE, Burkina Faso), International Crops Research Institute for the Semi-Arid Tropics (ICRISAT, Mali); forest biomass management and use, decentralized electrification – Agence de développement de l'électrification rurale (ADER, Madagascar);

Oceania: ensuring the energy self-sufficiency of Pacific islands by developing the copra oil production chain for electrification and transport (territorial authorities);

Electricity generation from wood in a rural environment

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Europe: CIRAD is the French representative in several networks, notably with: Aston University, UK (flash pyrolysis processes); BFH, Hamburg, Germany (chemical analyses of pyrolysis oils and biomass gasification tar); University of Wageningen (Netherlands);

France: scientific partnerships with: INRA (Institut Carnot 3BCAR project, VegA/biomass of the future foresight workshop), the IFP and the CEA (thermochemical processes), the Ecole des mines in Albi and the UT Compiègne (thermochemical processes), the Institut Prisme at the University of Orléans (biofuel combustion);

Industrial partnerships in the form of research projects or study services: Total (global biofuel resource potential), EDF (state of the art in terms of gasification technologies), GDF-Suez, Véolia, Areva (energy supplies for mining activities).

> Prospects

For the poorest countries, greater access to energy could foster the development of food production, but this remains to be demonstrated in several practical cases. Improving nutrition necessarily means satisfying basic energy requirements.

The energy question is not limited to the fuel used for vehicles, which account for just a quarter of global consumption. It is static calorific energy production, and its conversion into drive force, that accounts for most of the world's energy consumption, in which coal, natural gas and oil play an equal role. It is thus not essential to produce a liquid fuel. Energies of plant origin may take various forms, notably solid or gas, that are just as useful as the liquid form, which is usually preferred because it is easy to transport and store. For instance, CIRAD is working on an agro-energy concept aimed at designing and promoting electricity generation from sugarcane, selected and grown specifically for that purpose.

For first-generation fuels, there are now no major obstacles at the processing stage, except for the ethanol esterification of vegetable oils. The main difficulties are encountered at the production stage, because of interference with other activities, in terms of management and land occupation. Based on current demand and foreseeable trends, agrofuels will only be able to cover a limited, if significant, share of requirements, even in developing countries with the right conditions for production.

Second-generation fuels seem to have greater potential, in view of the lignocellulose biomass reserve situation. What remains is to develop spatial and dynamic methods for identifying biomass and its true availability. The rules for its use also need to be set out and validated. In terms of processing, CIRAD is centring its research on developing small- and medium-capacity units for decentralized production, possibly with intermediate storage and conditioning, to promote transport of already processed, concentrated-energy products. It has opted for the thermochemical conversion method (torrefaction, pyrolysis and gasification), which makes it possible to use the whole plant without resorting to heavy chemical processes at such units.

Climate change and food security

Production instability, more frequent food crises and price volatility are bound to affect the world's most vulnerable people. Managing these instabilities is now a major challenge for the economic sciences.

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Climate change will inevitably have two types of consequences: the multiplication and exacerbation of climatic accidents (drought, flooding), and a change in land use as a result of higher temperatures. We need to be able to model these changes in order to assess their consequences for agricultural production.

The direct consequence is increasingly unstable production levels, and subsequently food availability. We can expect a multiplication of local food crises and an increase in food price volatility, which will hit the most vulnerable consumers.

This increased uncertainty will also curb investment on the part of farmers, who are reluctant to take risks, and thus limit the ability of the agricultural sector to respond to future growth in demand for food.

In view of this, managing instability is now a strategic issue for research. As far as economic sciences are concerned, the aim is to assess the different possible ways of coping with this instability.

> Research projects

On the consequences of land use changes (UMR CIRED):

- Energy-food competition for land use (Conseil français de l'Energie [CFE] project, 2006-2009);
- Autrement: adjusting land and environmental resource use by modelling manmade ecosystems (ANR, 2007-2010).
- On managing price instability (UMR MOISA and UR ARENA):
- Tools to manage agricultural price instability (Agence française de développement [AFD], 2008-2009);
- Project on the efficacy of food price stabilization policies in sub-Saharan Africa: the case of Mali (FARM Foundation, 2009);
- Characterization of price instability on food product markets in sub-Saharan Africa (FARM Foundation, 2009).

> Activities and results

On the consequences of land use changes (UMR CIRED):

Retro-foresight study of global food biomass production and use;
Hybrid modelling of the partial equilibrium of available land;
Development of an integrated agronomy-vegetation-global economy enforced by climate modelling platform enabling:
- yield simulation for the main agrosystems (crops, animal production, forestry);
- assessments of the impact of land use changes (land occupation and management parameters) on yields and climate;
-calculation of a "optimum" solution for changing land use.

Contact

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Publications

Bricas N. (2008). Nourrir le monde : retour aux fondamentaux de l'humanité. *Diplomatie : affaires stratégiques et relations internationales* 33: 58-62.

Bricas N. (2008). Attentes et responsabilité des consommateurs. *OCL. Oléagineux corps gras lipides*, 15 (2): 142-144.

Bricas N., Daviron B. (2008). De la hausse des prix au retour du "productionnisme" agricole : les enjeux du sommet sur la sécurité alimentaire de juin 2008 à Rome. *Hérodote : revue de géographie et géopolitique* (131): 31-39.

See also

http://publications.cirad.fr

On managing price instability (UMR MOISA and UR ARENA):

- Theoretical and field assessment of measures aimed at coping with price instability, either by seeking to mitigate price fluctuations through market regulation, or by attempting to mitigate the adverse consequences of fluctuations for vulnerable populations, or both.

Characterization of the factors behind price instability, making it possible to distinguish between instability linked to climate and instability linked to market functioning.

> Partners

National Resources Institute (United Kingdom), University of Wageningen (Netherlands), Institut d'Economie Rurale (Mali), Réseau des Observatoires Ruraux (Madagascar).

> Prospects

Establishment of a World Food Observatory to monitor the changes in household vulnerability and resilience in the face of the instability of their environment (climate crises, economic crises and public health crises).

Climate change and payments for environmental services

Ecosystems play a major role in mitigating climate change by sequestering carbon. However, they also have other functions, which serve to make people less vulnerable and thus foster their adaptation.

Forêts et régulation hydrologique.
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Carbon sequestration is an environmental service: it helps to reduce greenhouse gas levels in the atmosphere and this to mitigate climate change. This role has been recognized by international institutions, and carbon payment mechanisms are in place (Clean Development Mechanism, or CDM, for afforestation and reforestation projects in developing countries) or are being discussed (Reducing Emissions from Deforestation and Degradation, or REDD).

However, ecosystems do not only play a role in mitigation, they also provide services on a local or regional level that help make people less vulnerable, and thus foster their adaptation, to climate change. For instance, forests can reduce wind and wave strength in coastal areas, reduce the air temperature during heatwaves in urban areas, and regulate water quality and low-flow during droughts.

Payments for environmental services can foster the maintenance of services that are vital in the fight against climate change. PESs assume a voluntary transaction between a service provider (for instance an ecosystem manager) and a buyer (for instance a firm keen to offset its greenhouse gas emissions or a town wanting to protect its water resources). PESs are currently booming, which is raising numerous scientific questions

> Scientific questions and activities

The first group of questions concerns the characterization of environmental services: how can such services, and their contribution to human wellbeing and adaptation, be evaluated? What are the synergies or conflicts between the provision of different services?

CIRAD is working to measure and model carbon and water balances. The synergies between environmental services and mapping of those services are under study in Central America.

There is a second group of questions relating to the implementation of PESs: what are the available markets? What methods and institutions are required to involve and reward service providers in line with the local realities?

CIRAD is also looking into how to tackle PESs, for instance in Madagascar, through grouped services on a territorial level. Work is under way on the institutions required for PESs in places with few institutions and considerable poverty.

A third group of questions concerns the impacts of PESs on the environment and local development, community capacity building, and their participation in decision making. What are the risks of PESs for local communities? Can carbon payments threaten biodiversity?

CIRAD is conducting research into the impacts of PESs on local development and biodiversity, for instance in Central America. Work is also under way in the same region on the potential risks of REDD payments for local communities and the links between such payments and the adaptation of local communities.

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Publications

Vignola R., Locatelli B., Martinez C., Imbach P., 2009. Ecosystem-based adptation to climate change: what role for policy-makers, society and scientists? Mitigation and Adaptation of Strategies for Global Change. doi:10.1007/s11027-009-9193-6

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Locatelli B., Vignola R., 2009. Managing watershed services of tropical forests and plantations: Can meta-analyses help? *Forest Ecology and Managemen*t 258(9): 1864-1870.

Locatelli B., Rojas V., Salinas Z., 2008. Impacts of payments for environmental services on local development in northern Costa Rica : a fuzzy multi-criteria analysis. *Forest Policy and Economics* 10(5): 275-285.

See also

http://publications.cirad.fr

> Research projects

Tropical Forests and Climate Change Adaptation, with CATIE-CIFOR in Asia, West Africa and Central America;

Environmental services and rural land use (ANR STRA) in Costa Rica, the French overseas regions and Madagascar;

Exploring the relevance and feasibility of PES approaches for producing environmental services through changes in agricultural practices, with IRRI in the Mekong region;

Coffee agro-forestry in Central America, East Africa and India (EU project);

Environmental service indicators in Amazonia and PES conditions (EU and ANR project);

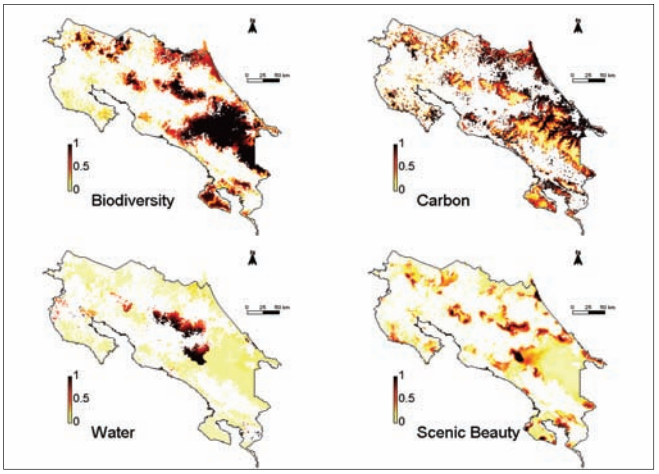
Functional diversity: an ecological framework for sustainable and adaptable agroforestry systems in landscapes of semi-arid and arid regions (EU project).

> Partners

CIRAD priority research platforms (Madagas-car, Amazonia, Costa Rica);

Scientific networks via projects;

International centres: CIFOR (Centre for International Forestry Research) in Indonesia, CATIE (Centro Agro-nómico Tropical de Investigación y En-señanza) in Costa Rica;



Mapping ecosystems of use to people in Costa Ric (Locatelli and Imbach, 2008)

> Prospects

PESs are growing in importance with the need to define multi-service payments that benefit local development and the local environment (including adaptation to climate change), and the global environment (including climate change mitigation). New agricultural, environmental or climate change policies are currently being drafted. This movement brings new, big issues for research, in interaction with politicians, NGOs, PES funding agencies and development banks. Research has to be done within international networks, such as the Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services (IPBES).

Climate change and national and local capacity building

Climate change poses new challenges for many national and local players. CIRAD supports project construction, in particular by helping build national and local capacity.

Property being paid for environmental services in Costa Rica
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Publications

Locatelli B., Pedroni L., Salinas Z. (2008). Design Issues in Clean Development Mechanism Forestry Projects. *In*: *Climate Change and Forests: Emerging Policy and Market Opportunities*. Brookings Institution Press, 107-120. ISBN 978-0-8157-8192-9.

Implementing projects linked to mitigation of or adaptation to climate change is a complex business. It is important to build national and local capacity, on three levels. Firstly, on a local or sub-national scale: forest projects covered by the Clean Development Mechanism (CDM), for instance, have to follow methodologies and project cycles that are difficult to understand. As for adaptation projects, they may receive funding provided the project developers know what funds are available and are capable of demonstrating the merits of their projects in terms of adaptation to climate change.

Secondly, on a national level, it is not easy to draw up adaptation or mitigation policies, insofar as these are new topics, which often call for an intersectorial, innovative approach. For instance, national CDM project approval rules are often defined without any clear procedures having been defined beforehand. Drafting national adaptation action plans for the least advanced countries is an important first step towards implementing adaptation projects, but it requires an overview of the issues facing the different sectors and regions in the country concerned. The available information is often too sketchy to draw up policies and assess their efficacy.

Lastly, countries have to establish national and regional positions and arguments for use in talks on international conventions. The large number of issues under discussion at any one time and the small number of negotiators from certain developing countries pose problems. Regional initiatives and dialogue between politics and science may facilitate the process of preparing for talks (see the sheet on “international talks”).

> Activities

On a local and sub-national level, CIRAD helps build capacity. For instance, it has organized many training courses in Latin America and Africa, on project design within the framework of the Clean Development Mechanism (CDM). The courses were attended by staff members from NGOs, ministries, the private sector and universities. A project to build capacity in terms of the CDM in Latin America served to support people in charge of developing projects within the CDM cycle.

On a national level, CIRAD provides technical and institutional support for the identification and building of focal points, and supports the drafting of national sheets and projects. In Central America, it has supported national CDM application rules (forest definition thresholds and impacts on local development) in several countries. In Central Africa, CIRAD has supplied the forest observatory with deforestation date of use in monitoring REDD projects.

Publications

Martínez C., Imbach P., Locatelli B. (2007). How to select a national forest definition for the Clean Development Mechanism? [¿Cómo seleccionar una definición de bosque en un país para el Mecanismo de Desarrollo Limpio?]. *Recursos Naturales y Ambiente* 51-52 : 184-190.

See also

http://publications.cirad.fr

> Research projects

Training and knowledge transfer are a major part of most of CIRAD's climate change projects, for instance:

- FORMA: Strengthening CDM capacities in Ibero-America, with CATIE;Carbon Finance for Agriculture, Silviculture, Conservation, and Action against deforestation (CASCADE), with UNEO and ONFI;
- Tropical Forest Adaptation to Climate Change (with CIFOR and CATIE);
- Observatory for the Forests of Central Africa (OFAC). EU project (with CIFOR, ICL, and FRM).

> Partners

United Nations Environment Programme (UNEP), Food and Agriculture Organization of the United Nations (FAO-UN-REDD), European Union, World Bank, Centre for International Forestry Research (CIFOR), Catholic University of Louvain (UCL).

Agricultural services, ministries, local authorities, NGOs, etc.

> Prospects

With the growing pressure to adapt to climate change, the emergence of new climate change policies (mitigation and adaptation) and the need to build local projects, it will be increasingly important to build national and local capacity. CIRAD will be contributing to this.

International talks and national climate policies

Implementing mitigation and adaptation policies in developing countries in response to international climate talks is a global challenge for which negotiators in such countries have to be prepared. CIRAD is supporting this.

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From the signature of the Rio convention on climate change in 1992, climate talks eventually led to the Kyoto Protocol in 1997. This agreement involves developing countries through the Clean Development Mechanism and NAPAs (National Adaptation Programmes of Action), which can have significant effects on development, and particularly on the agricultural and forestry sectors, in those countries.

The future "post-Kyoto" or "post-2012" agreement will have major repercussions for developing countries, in particular because of the risks and opportunities it represents with respect to climate change. Negotiators from such countries are crying out for help in defining their position in negotiations

> Activities

On the topic of international climate talks and policies, CIRAD conducts research and communicates with policy makers and negotiators. For instance, CIRAD has worked with the CATIE global change group in Costa Rica to support Latin American negotiators regarding the questions under discussion. A Latin American discussion forum on the situation post-Kyoto was set up in 2006. Research work has been done in close collaboration prior to talks, for instance regarding the ways of calculating carbon credits under the CDM (in 2003) and small-scale forestry projects under the same mechanism (in 2004). This research has had direct effects: a Latin American negotiator, speaking on behalf of a dozen or so countries in the region, quoted it when arguing his position during international talks. Likewise, the results of a study on small-scale forestry projects under the CDM were used in a letter from the World Bank to the Convention on Climate Change, requesting a change in CDM application rules.

In Africa, CIRAD is supporting negotiators and helping to disseminate information within the Congo Basin, within the framework of the Congo Basin Forest Partnership. In Latin America and Africa, it is involved in training courses intended for policy makers and negotiators, on the Clean Development Mechanism or policies and instruments for adaptation to climate change.

On a global level, CIRAD, in partnership with CIFOR, has conducted research, communicated with politicians, and organized international events on forests and climate change, centring on the Copenhagen talks (December 2009). It has also organized conferences on climate policy in association with IDDRI.

> Research projects

CIRAD is involved, either directly or through its researchers assigned to international centres, in numerous projects relating to climate policy. International talks and national policies are not necessarily the main topic of these projects, but are a major component. Numerous projects have been designed to support policies and include them in their research, primarily:

- Hydroclimate and Society in La Plata Basin (CLARIS, EU project);
- Tropical Forest and Climate Change Adaptation (TroFCCA, EU project with CIFOR and CATIE);

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Publications

Karsenty A. (2009). Régime international, déforestation évitée et évolution des politiques publiques et privées affectant les forêts dans les pays du Sud. *Natures sciences societies* 17: 209-212.

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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.

Pirard R., Karsenty A. (2009). Climate change mitigation: Should "Avoided Deforestation" be rewarded? *Journal of sustainable forestry* 28: 3-5

See also

http://publications.cirad.fr

- Strengthening Capacities for the Clean Development Mechanism in Latin America (FORMA, EU project with CIFOR).

And also

- Energy-food competition for land use: prospects for and viability of biofuels;
- ECOCLIM, which is aimed at developing a model that integrates economics, land use and climate;
- GICC-PED, looking at climate policies that could encourage developing countries to commit to reducing greenhouse gas emissions.

> Partners

International: Centro Agronómico Tropical de Investigación y Enseñanza (CATIE, Costa Rica), Centre for International Forestry Research (CIFOR, Indonesia), Institut du développement durable et des relations internationales (IDDRI, France).

Ministries, NGOs, decision makers and delegates.

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> Prospects

After the Copenhagen summit, talks on international climate policy are continuing, and the support of researchers is required. If an agreement is signed, its details will be negotiated over the following years and national policies will be introduced. Researchers will have an important role to play. As regards REDD (Reducing Emissions from Deforestation and Degradation), an agreement would be just the start of a series of challenges surrounding its implementation, which will call for scientific support. CIRAD will be continuing research, communication, technical support and training on these topics.

Notes

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