CIRAD

Images of Research

Images of Research

The Centre de coopération internationale en recherche agronomique pour le développement (CIRAD) is a French research organization that specializes on agriculture in the tropics and subtropics. It is a state-owned body and it was established in 1984 following the consolidation of French agricultural, veterinary, forestry, and food technology research organizations for the tropics and subtropics.

CIRAD's mission is to contribute to the economic development of these regions through research, experiments, training, and dissemination of scientific and technical information.

The Center employs 1800 persons, including 900 senior staff, who work in about 50 countries. Its budget amounts to approximately 1 billion French francs, more than half of which is derived from public funds.

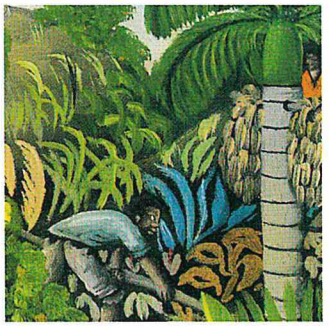
CIRAD is made up of seven departments: CIRAD-CA (annual crops), CIRAD-CP (tree crops), CIRAD-FLHOR (fruit and horticultural crops), CIRAD-EMVT (livestock production and veterinary medicine), CIRAD-Forêt (forestry), CIRAD-SAR (food technology and rural systems), and CIRAD-GERDAT (management, common services and laboratories, documentation). CIRAD operates through its own research centres, national agricultural research systems, or development projects.

ISBN 2-87614-175-2

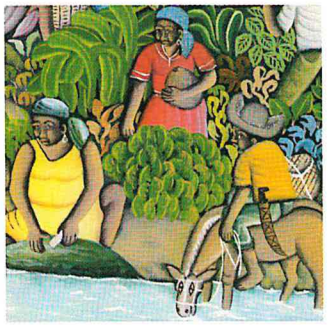
Images of Research

Images of Research

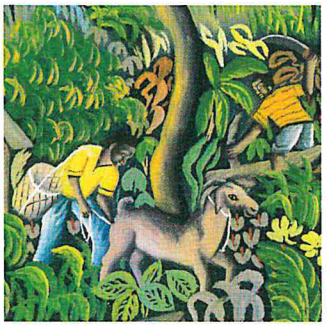
More productive agriculture



Towards ecological development



THE WEALTH OF LIVING ORGANISMS



BIRTH OF AGRO-INDUSTRIES

AGRICULTURAL POLICIES AND CHANGES

This new edition of *Images of Research* bears witness to the assistance provided by CIRAD to developing countries. Of course, it is impossible to describe or show all the work that has been performed, as the fields of activity are vast and the cooperative projects are so numerous. But, as the pages are turned, the reader will find the purpose and realities of the battles we are fighting and will discover the main directions that our research centre is taking.

It is occasionally forgotten that more productive agriculture in tropical countries must provide for rapidly increasing populations. However, this intensification should be achieved with minimal disruption to conserve natural resources and encourage their renewal. This is the focus adopted for projects in ecological development. Furthermore, the wealth of living organisms is far from being fully utilized: research on the genome and on plant and animal physiology is progressing by leaps and bounds and will doubtless provide us with more productive material of higher quality. CIRAD is also participating in the improvement of rural community life by supporting the creation of agro-industries capable of retaining populations in the rural environment and of supplying the cities with food. Finally, political and agricultural changes are analysed to provide decision-makers with the factors at play in dynamic evolution.

Each of these major themes is illustrated by articles whose sole aim is to bring into sharp focus the variety of the studies undertaken and CIRAD's capacity to tackle numerous scientific and technical problems, and explore new fields of research. The project teams are motivated by two major forces: the desire to perform quality research work, tending towards excellence, but also the wish to see the results obtained transferred and applied to the rural environment. The social usefulness of our organization must be manifest by the progress made in a science devoted to helping mankind, a science that cares for the well-being of peoples.

Images of Research is replete with examples of work and interactions with farmers and organized rural groups, now recognized as being the true agents of development. Their aims and their needs, analysed on a regional basis in liaison with politicians and with financial backers, formed the foundations of the research efforts made by our teams. These teams collaborate with numerous partners in the North, and in the South, particularly with national agricultural research institutes whose researchers have contributed greatly to the work presented here. The impressive diversity of cooperative efforts and their intensity mean that we can henceforth speak of truly international networks. At the heart of these networks, CIRAD continues to work in research that is ever closer to development.

Michel de Nucé de Lamothe
Director General

MORE PRODUCTIVE

The main challenge confronting countries of the Southern hemisphere is to nourish and find work for their fast-growing populations. They must produce more. To maintain sustainable development, they must put their land to better use, diversify production and protect their crops.

AGRICULTURE

Better use of lowlands

Throughout the world's tropical regions, the numerous lowlands — small zones of water convergence — are particularly well suited for agriculture. In Africa, where they are minimally or badly exploited, development planners would do well to pay them more attention. Diversified cropping and water management installations, modest when compared to their efficacy, are the means of their development.

Rice output from improved cropping can reach 3 t/ha.

Lowlands in the Sikasso region of southern Mali during the rainy season: rice and fruit trees on the micro-relief.

In intertropical regions, a lowland is a small flat-bottomed valley which, although it does not generally have a permanent body of water, entraps water from the surrounding watershed. The water table lies just below the surface. Compared with other types of agricultural land, lowlands have a special water regime which, if properly harnessed, can render them very productive.

There is a growing concern to improve the development of these vast areas — there being approximately 1 million km² in Africa. But when speaking of lowlands, one touches on a multitude of diverse aspects: climate, hydrological processes, morphopedology, planning, agricultural use, human activities — all are elements which contribute to the specificity of each lowland.

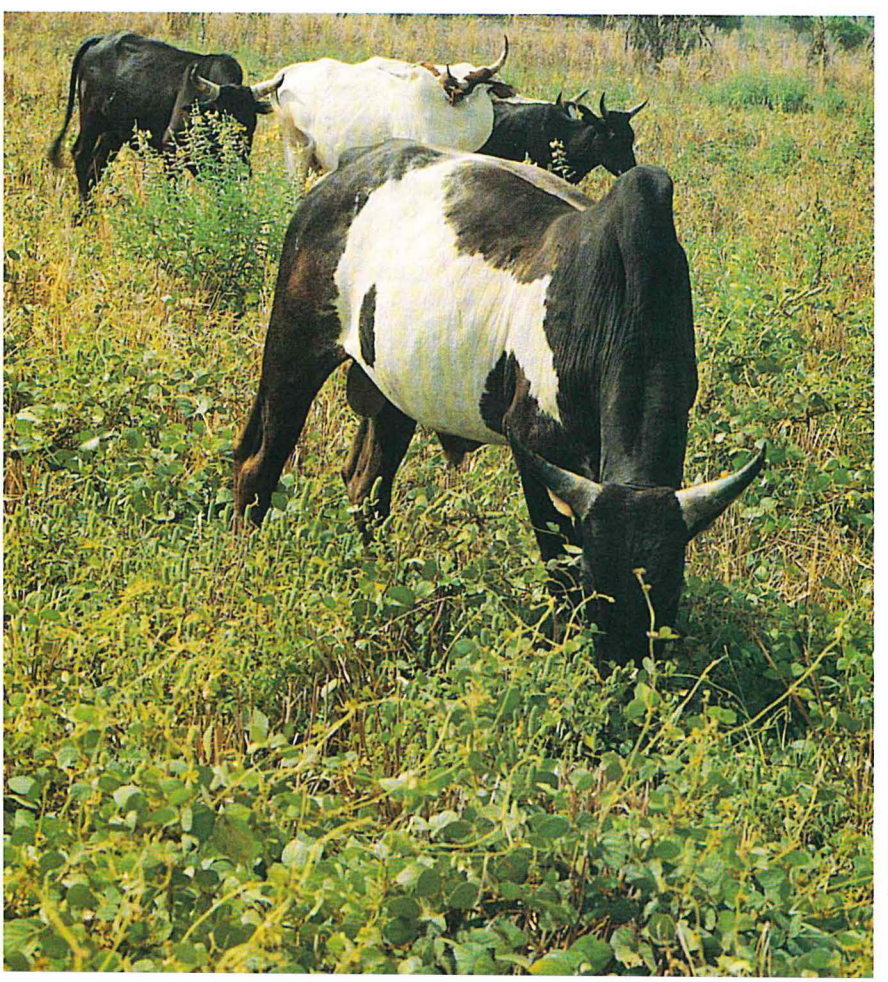
The lessons learned by past experience can be summed up in four main points: traditional growing systems are often characterized by low yield and a very low productivity/labour ratio; attempts to intensify them are hampered by a lack of water management; whatever success there has been has resulted from broadly-based land-use and productive systems specifically adapted to the zone; lastly, any action undertaken must be preceded by a thorough understanding of the water supply and how it functions.

With the Sénoufo farmers

One of the sites under study at present, where much can be learned, is in the region of Sikasso, in southern Mali, where lowlands cover almost 200,000 hectares. Here, l'Institut d'économie rurale (IER) and CIRAD are working with the Malian Compagnie pour le développement des textiles (CMDT) on a project financed by the French Ministry of Cooperation to increase productivity at low cost through careful planning and improved multiple cropping. Rice, traditionally grown by the women, is far from being the main production and other crops are also grown: potatoes, sweet potatoes, cassava, maize, bananas, mango and citrus trees, all of which exploit the gentle slopes and water fluctuations.

The first step is to analyze the ways in which water behaves in the different types of lowlands found in the region. In their studies of the small Kambo lowland and a conventional cultivation area at Samagossoni, water management engineers demonstrated that ground permeability was 10 times greater, horizontally as well as vertically, than in a traditional paddy field. This could explain to a large extent why sizable installations meet with operational difficulties. Water-retaining walls, 1.5 m deep in the ground, built by the farmers with help from an NGO are better suited to stabilize the water regime.

Rice is far from being the only crop. After its harvest, potatoes can be planted as irrigation is possible from the high water table via bore-holes.



In order to improve crop-production systems and in co-operation with the Sénoufo farmers, the researchers chose three sites corresponding to three different water regimes — uncontrolled flooding, flooding controlled by conventional methods and rainfed cropping supplemented with groundwater.

N'Tenebougou is situated in an undeveloped lowland consisting of a 10-km plain, whose natural outlet is the Lotio river. The many villages farming the land have no technical support. In the flooding zone farmers produced, on average, 1 t of rice per hectare. Use of an improved variety increased the yield to 1.5 t/ha, manuring increased it to 2.5 t/ha and tilling the soil, to 3 t/ha. Thanks to these three improvements a day's work brings in twice that of the cotton fields on upland areas. When, in 1993, the CMDT launched a credit campaign for rice growing, almost one family out of four invested in improved rice cropping on plots from 0.3 to 1 ha. During the dry season, potatoes are a good choice on well drained soils: the yield of the rice planted afterwards can be as high as 5 t/ha without tilling. And cowpea cropping after the rice harvest makes use of the residual

Another off-season crop, **Macroptilium atropurpureum,** *a fodder crop, could become a valuable source of animal feed.*

moisture in the soil to produce 0.5 t/ha.

PHOSPHATE FROM MALI

The experimental site for controlled flooding is in the Kléla region. It is part of a zone developed in a conventional manner — with a dam and primary and secondary irrigation networks — managed by the CMDT. Some of the farmers who cultivate its sole crop of rice come from villages far away. Training and campaign credits have enabled farmers to make use of improved varieties and mineral fertilizers. Yields are around 2 to 2.5 t/ha. By tilling at the end of the growing season and again before sowing, these can be increased to 3 t/ha. Use of a phosphate-containing fertilizer from Tilemsi does not increase yields further, but saves up to 11,000 francs CFA per hectare over conventional fertilizers. Since it is of Malian origin its use reduces imports. Applied to more than 1,000 ha at Kléla, the CMDT is testing the development package on other sites.

Another objective has been to reduce working time; this has been achieved to a great extent by perfecting a three-row rice seeder with the farmers and the CMDT. Now the women only need 30 days for manual weeding compared with 60 days after traditional broadcast seeding.

Regulation of the lowlands' water supply by simple, cost-effective methods.

Also in the Kléla region, the third experimental site is typical of the more elevated areas of lowlands, especially the fringes of the flooding zone. The underground water level is only about 2 m below the surface in the dry season and sometimes rises to the surface in the rainy season. The rice roots can then reach it: this is called groundwater cultivation. A variety of rice half way between rainfed rice and aquatic rice, IRAT 216 (IDSA 6), can be grown in this type of situation. With proper fertilizing and tillage, it yields about 3 t/ha, as much as in flooded paddy fields. After the rice, a leguminous fodder *Macroptilium atropurpureum* can be grown to take advantage of the residual moisture at a time of year when there is little for animals to eat.

SIMPLE UNDERTAKINGS

Thus water management and agronomic studies have already produced many results. As we can see, it would be possible for productivity in the undeveloped lowlands to compete with that of the developed lowlands. Greater food security could be obtained simply by regulating the water regime.

This is where new planning concepts come in. Action should be taken with the entire development area in mind; e.g. planning of the watershed basins (planting contour hedges among other things) is necessary to halt erosion and stabilize the water flow; and, as for the lowlands themselves, simple and inexpensive work can be undertaken to reinforce their natural functioning, such as building cofferdams and stream-flow barriers to retain surface water. During the rainy season, these constructions modify the regime of the various hydrological elements in the

lowlands. Later, they facilitate cultivation in the off-season by slowing the lowering of the groundwater.

Planning of this kind is being carried out in the Kobani lowland, on the lands surrounding the village of M'Pegnesso. The villagers themselves will be entirely responsible for the labour and have agreed to finance it through a local investment fund supplied by the FAC. The CMDT hopes to use the M'Pegnesso project as a blueprint for 20 or so other lowland planning schemes which will be financed by the African Development Bank.

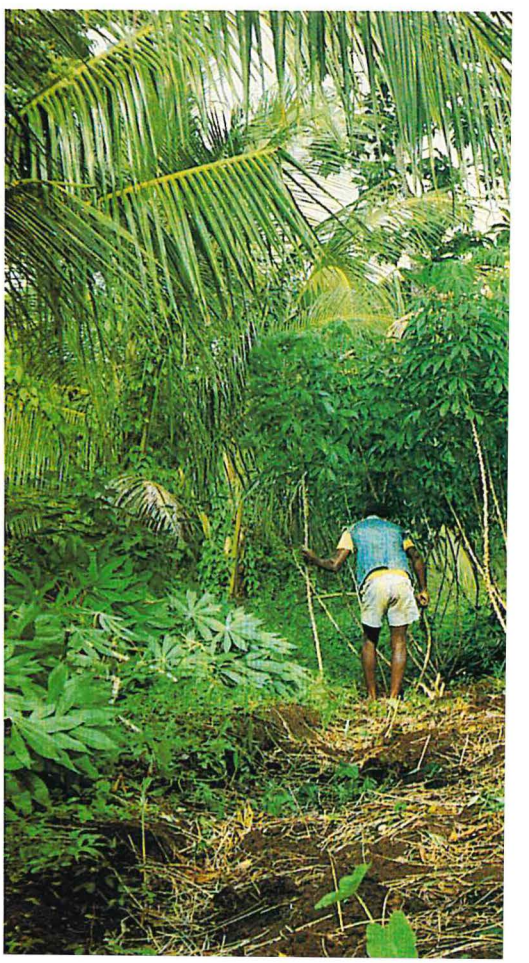
All this enriches CIRAD's experience. With what it learned in Ghana, in the south of Burkina Faso, in Senegal, Côte d'Ivoire, Burundi and Madagascar, it is now in a position to offer these findings for application in other regions on the basis of a technology transfer package with satellite data which can be used to rapidly further the development of lowlands in Africa and elsewhere.

For further information:

CIRAD
Programme cultures
vivrières paysannes
BP 5035
34032 Montpellier Cedex 1, France

Projet bas-fonds
IER-CIRAD
BP 183
Sikasso, Mali

Coconut growers habitually practise intercropping to protect themselves from fluctuations in copra prices. But what are the best crop mixtures in a young grove, or an adult grove? Annual food crops? Perennial crops? Light penetration below the plant cover plays an important role. To complement agronomic research, architecture modelling of the coconut tree should help growers reach a decision.



Temporary intercropping: coconut-cassava (right). Permanent intercropping: coconut-cocoa (above).

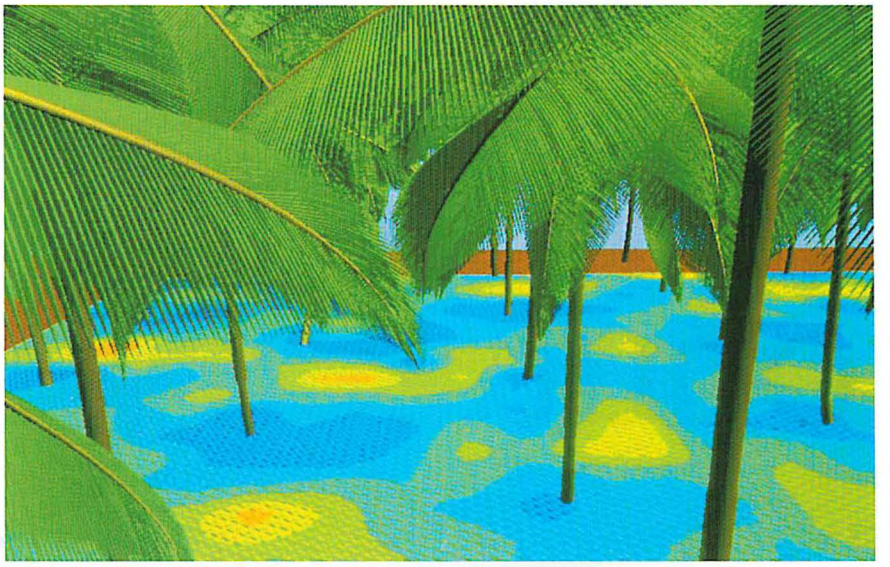
Intercropping in coconut groves

Copra prices vary so considerably that coconut planters never have peace of mind. Crop diversification is one of the strategies they adopt for protection, often growing crops in the groves. The rarer the available land, the more intercropping is practised: in South-east Asia it is estimated that about half the small planters have recourse to intercropping in one form or another.

Researchers in many countries are studying intercropping to discover which mixture is the most appropriate. CIRAD is working with several organizations in Philippines, Indonesia, Vanuatu, Côte d'Ivoire and Tanzania. We hope to progress beyond traditional agronomic studies which rarely make it possible for the results of one experiment to be used under other conditions.

Immediate income

In the 3 or 4 years following the plantation of a coconut grove, intercropping annual food crops works well because there is sufficient light between the young trees. The situation changes when the canopy is too thick to allow much light to filter through to the ground. What is needed, therefore, is to intercrop with a crop that likes shade, or else alter the spatial arrangement of the coconut trees at the time of planting.



Modelling light penetration within a coconut grove: used to reduce in-field testing.

Temporary intercropping in young groves is doubly beneficial: from an economic standpoint, since it generates income at a time when the young trees are still unproductive, and from the standpoint of the coconut trees themselves, which appear to benefit from the intercropping.

In the Gagnoa region of the Côte d'Ivoire, the best agronomic and economic results were obtained from the following successive plantings: in year 1 following planting of the coconut grove, yams, or mixed cropping of maize and groundnut or maize and sweet potatoes; maize and *Pueraria* (a leguminous cover-crop) the second year; *Pueraria* by itself in the third year. Leaving aside home consumption, the annual food crops earned an estimated 45,000 francs CFA per hectare. This income helps pay for establishing the grove. Moreover, it was evident that the young coconut trees which were intercropped with annuals grew faster than those which were planted in pure stands. In the third year, their collar-girth was up to 50% more than the others. The coconut trees must have benefited from the careful husbandry of the annual crops.

This care for intrarow crops probably accounts for the positive effect on the growth and flowering of young coconut trees intercropped with annuals in southern Sumatra. Cassava and bananas are among the most well-adapted and best revenue-producing crops in this region.

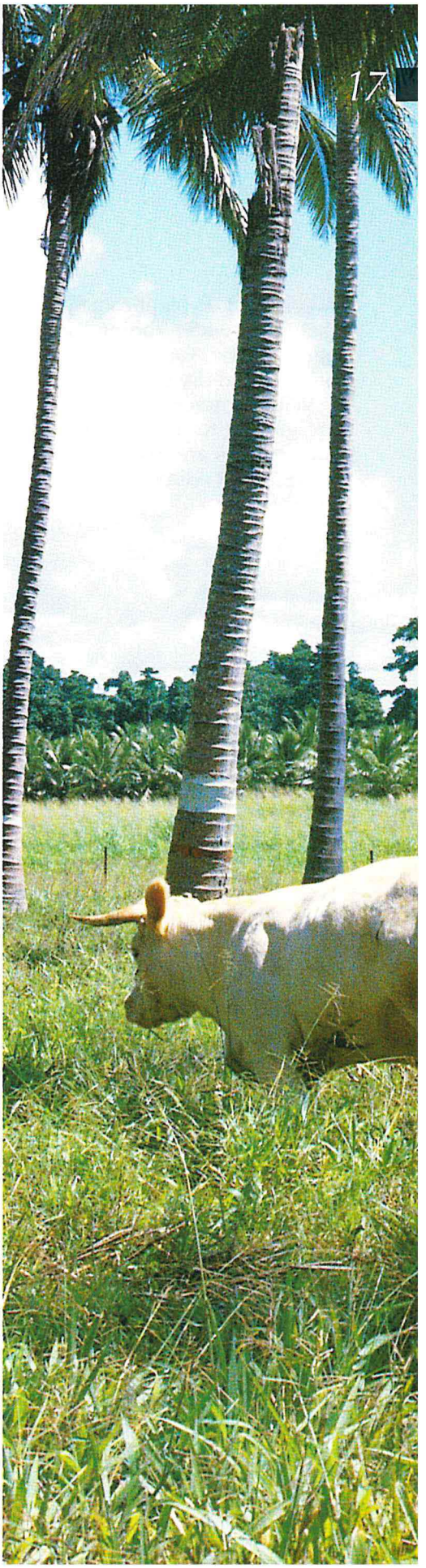
Yield and light

In Vanuatu, intercropping trials in young groves were set up with sweet potato and groundnut, cocoyam, yam or cassava, either alone or in combination. Since the coconut trees are planted at an optimal density for sole cropping, the photosynthetically useful light which filters through the canopy is maximum at the start of the intercropping, but progressively diminishes as the grove matures; at age 3 years (fourth cropping season), only 30 to 40% reaches the ground. Sweet potato and groundnut need a lot of light and can therefore be planted only for the first 2 cropping seasons. As the canopy spreads, cocyam, yam and especially cassava stand up better to less light, and their root systems probably compete better for water and nutrients in the soil. According to the preliminary observations, it appears that the coconut tree's vegetative and sexual development is not disturbed by intercropping. Of all the systems tested, intercropping with cassava alone between the rows of young coconut trees is the most productive: the first two cropping seasons produce about 58 t/ha of tubers, and the fourth, nearly 30 t/ha. Within the framework of a family farm, it means that, on average, over 4 cropping seasons, a day's work is worth 55 francs.

In Philippines, research was carried out under the aegis of PCARRD in adult groves of varying density. The sweet potato, which produces only 6 t/ha under 156 trees, produces 9.6 t/ha under 98 trees and 15.6 t/ha under 40 trees. Measurement of the light filtering through the plant cover should result in a quantitative ratio of yield to light. Such data, gathered from different situations, are being used for an initial approach to modelling crop systems beneath coconut trees in order to help researchers and, of course, growers in their choices.

Computer models

The security which intercropping coconut with permanent food crops means to the grower is enough to justify more fundamental research in this field. The project consists of setting up a model which takes into account the yield growth of the coconut grove, the yield growth of the inter-row crop, and for the whole system, integrating data concerning competition for light, water and nutrients. This model would limit the number of long and costly experiments which take up needed ground space. The Commission of the European



Cattle rearing: another method of diversifying agricultural income.

Union is helping to finance this research.

At first we studied light penetration through a coconut grove. The architecture of the trees in an experimental plantation consisting of five different tree densities was measured in cooperation with l'Institut des forêts de Côte d'Ivoire. With these measurements, CIRAD's plant modelling unit is creating computer models of coconut trees using the Amap software created by the unit.

The coconut tree has a simple architectural form: continuous growth from a single apical bud and inflorescences at the axil of each leaf. The principal difficulty resides in creating a model of the curve and twist of the palms, which play an important role in light transmission. With this model it will be possible to simulate coconut trees of different ages and planted at different densities. It will then be possible to deploy three other programs created by the unit to simulate radiation transfer: Shadow simulates the spread of light over the ground; Transrad calculates radiation exchanges between plant canopies; and finally, Ray tracing, which simulates directional radiation flows.

Radiation measurements derived from the coconut groves of Côte d'Ivoire will help to validate these simulations. Similar methodology has already been successfully tested in an oil palm plantation.

A 30-YEAR OUTLOOK

Research into perennial crops beneath coconut trees is progressing rapidly in several countries: Vanuatu, Indonesia, Philippines, Tanzania. Part of the research is based on cooperation with institutes such as the NRI, which is contributing to the study of socioeconomic aspects of intercropping.

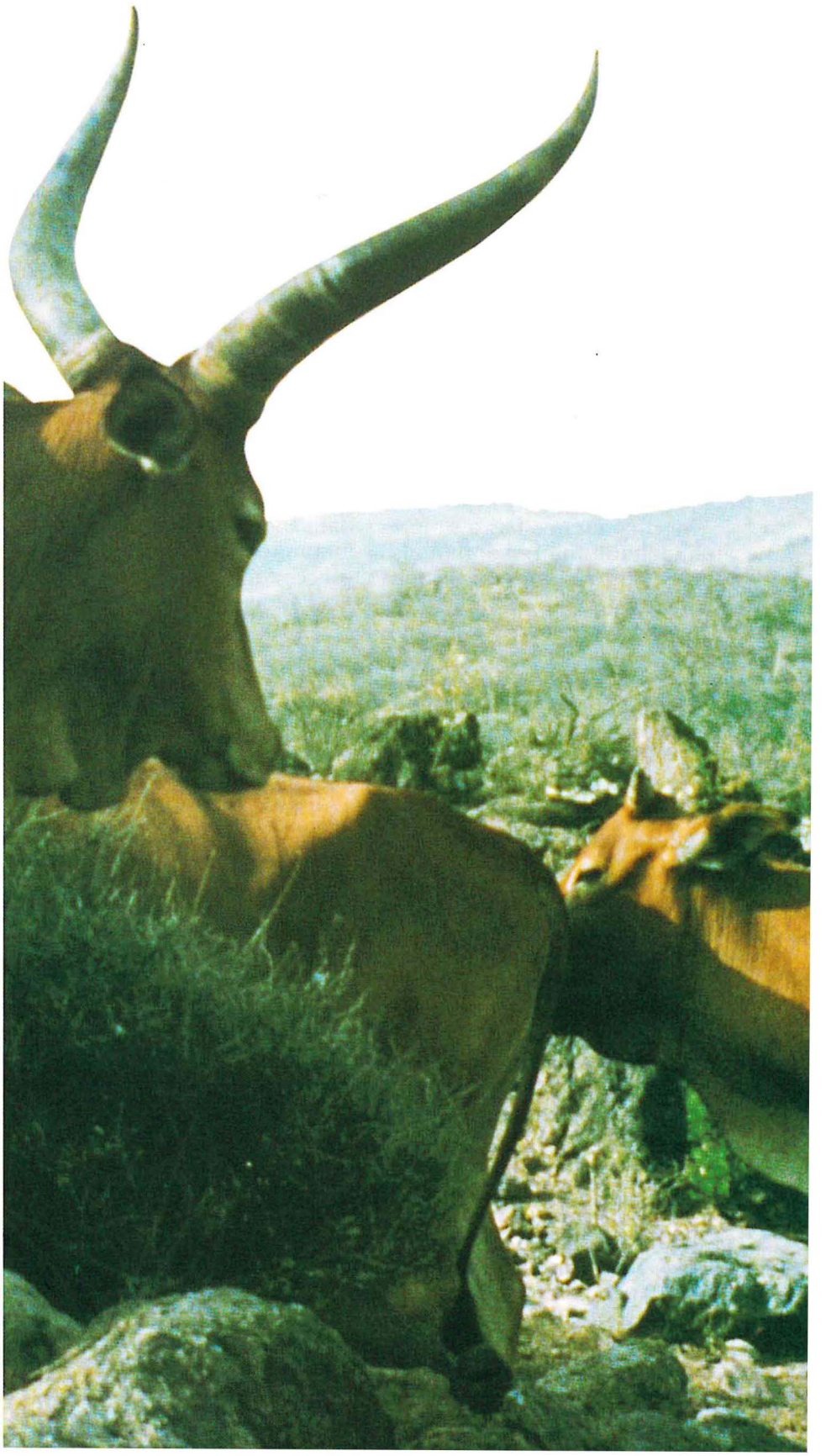
One of the most attractive perennial intercroppings in coconut groves is with cocoa, a plant which is traditionally grown in shade. Field research is being carried out mainly in Vanuatu and Indonesia. Young cocoa trees planted in a coconut grove of normal density (160 trees per hectare) had no harmful effect on the latter and produced pods in their second year. By studying the architecture of the cocoa tree, we can begin to model its growth beneath a coconut grove. Research will be carried out as to the nature of competition be-

Cattle husbandry with coconuts?

Vanuatu's agriculture is dominated by coconut groves which make it the world's foremost producer of the nut per inhabitant. But the growers are seeking new sources of revenue, given the low price of copra on the world market and the aging of their plantations. Some of them keep cattle under the palms. CIRAD's Département d'élévage et de médecine vétérinaire has shown that the system is not very productive: grazing areas in perpetual shade are poor and animal development limited. But diversification should be encouraged. For some of the smaller growers, one solution might be to keep part of their coconut grove, maintaining and replanting it, and turn the other part into improved grazing for raising quality livestock. ■

tween the two plant root systems, that for water being studied particularly for regions with pronounced dry seasons.

When intercropping commits the grower to 30 years of work, such studies are justified. And all of Southeast Asia is concerned.



For further information:

CIRAD-CP
Unité de recherche d'agronomie
BP 5035
34032 Montpellier Cedex 1, France

CIRAD-GERDAT
Unité de modélisation des plantes
BP 5035
34032 Montpellier Cedex 1, France

Field diagnosis kits

It is not always possible for developing countries to meet international meat standards, as they often lack the necessary networks of veterinary staff and laboratories. In Africa, where the lack of communication further worsens the situation, the state of health of a herd is often unknown. As a response to this, the Office International des Epizooties (O.I.E.) asked CIRAD to develop a kit for diagnosis in the field.

Zimbabwe is the only sub-Saharan African country that exports meat to Europe, although many countries have extensive herds. Export markets are closed to them as they are unable to guarantee the health of their livestock. How can diseases be diagnosed if the only efficient veterinary laboratories are in the capital, usually several hundred kilometres from the grazing regions? Added to this, the lack of trained personnel and veterinary equipment and the all-too-frequent disruptions in cold-transport services — where these exist — which alter the samples, make diagnosis difficult.

Virulent diseases

Under such conditions, national authorities have only a vague idea as to the condition of the livestock, the geographic extent of the diseases and their relative impact. Therefore, their official statements to international bodies, such as O.I.E., which publishes information about outbreaks of infectious diseases throughout the world, or FAO, which

Peste des petits ruminants and mycoplasmosis decimate goat and sheep herds in the southern Sahara.

Various definitions

Competitive ELISA

An antigen (purified virus or virus protein) is fixed onto a polystyrene plate. The animal serum to be analyzed and a monoclonal antibody are placed on this support simultaneously. The monoclonal antibody and the serum antibodies then compete to fix the coated viral antigens (the monoclonal antibody will target only one site, thereby providing the diagnosis with considerable specificity).

The monoclonal antibody's presence in the antigen-antibody complex is revealed by an enzyme conjugate, which transforms a colourless substrate into a coloured product whose intensity is read by spectrophotometry. In this type of test, colour intensity is inversely proportional to the quantity of antivirus antibody in the serum. No colour means that the animal is positive.

Immunocapture test

The principle of immunocapture is to sandwich a pathogen (virus or bacteria) between two monoclonal antibodies, each of which recognizes a different site on the antigen. The capture antibody (lower "slice" of the sandwich), which is linked to a solid phase, increases test specificity. The developer antibody (upper "slice") is labelled with biotin to increase the signal of the coloured enzyme reaction.

Agglutination test

This test can be used to screen for antibodies in a serum as well as for a virus in a sample.

In the first case latex microbeads are used to fix the antigen. If the serum contains antibodies, the latter react with the antigen and the microbeads agglutinate to form a network which is visible to the naked eye or under a microscope.

In the second case monoclonal antibodies (or serum containing high levels of antibodies from a hyperimmunized animal) are fixed onto microbeads .

If the sample contains the virus, the latter is captured by the antibodies and the microbeads agglutinate. ■

publishes an annual report on animal health, are also imprecise. European meat importers are all the more wary in that, through lack of reliable information, eradication or disease control programmes have little effect.

Since it is difficult to send samples from infected animals to the laboratory, why not carry the material needed for diagnoses to the diseased animal? Progress in molecular biology has made it possible to think in realistic terms of devising diagnosis kits usable on-site. In 1991, O.I.E. named Pathotrop, CIRAD's laboratory of tropical animal diseases, as the first Centre d'application de méthodologies pour le diagnostique des maladies animales (CAMDA) (Centre of applied methodology for diagnosing animal diseases). Its mission: to devise field kits for rinderpest, peste des petits ruminants (goat plague), contagious bovine pleuropneumonia, caprine (goat) contagious pleuropneumonia and other mycoplasmosis and train technicians how to use them. They are cooperating with the National Veterinary Institute in Ethiopia, the Farcha laboratory in Chad, the Bingerville laboratory in Côte d'Ivoire, Utrecht University in the Netherlands, and Uppsala University in Sweden.

Rinderpest is the deadliest of the diseases which affect cattle (oxen, zebus, domesticated buffalo) as well as wild artiodactyla. It is caused by a morbillivirus, an RNA virus related to measles virus. The animals develop ocular discharge, mouth lesions, severe diarrhoea and they lose

weight rapidly. The more virulent strains cause death in 90% of cases. Rinderpest is found in sub-Saharan Africa, Egypt, the Middle East, India and Sri Lanka and started to make inroads into Turkey in 1991.

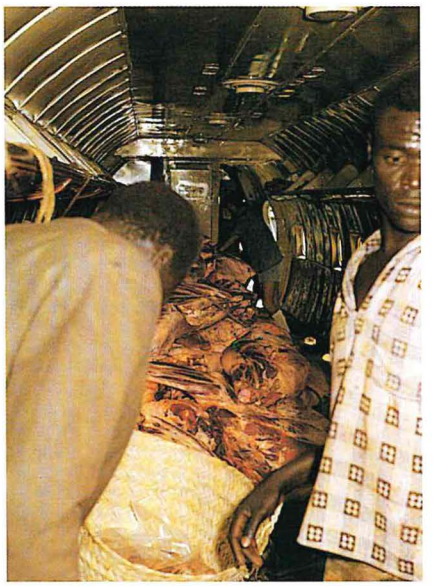
The symptoms of peste des petits ruminants, which is also due to a morbillivirus, are very similar to those of rinderpest. This disease is decimating goat and sheep herds in the southern Sahara (Senegal and Ethiopia), the Middle East and the Arabian peninsula. It is suspected in India.

NOT DANGEROUS

Diagnostic techniques are available for these two diseases, but they are slow and require laboratory equipment. To isolate the virus in cell culture, for example, takes from 3 to 15 days in an absolutely sterile environment.

Recent advances in the study of genomes have created new possibilities for the diagnosis of viral diseases. Characterization of the virus genomes of rinderpest and peste des petits ruminants have led to the development of two specific probes. These radioactive probes are formed from fragments of the gene coding for the nucleoprotein N and are labelled with phosphorous 32; they are very sensitive and have no "background noise", i.e. no interfering reaction that can alter diagnosis.

But there is no question of using these probes in the field. Manipulating them is dangerous. Besides, they must be used quickly since phosphorous 32 has a very short half-life (losing half its radioactivity every 14 days). So the researchers have come up with two specific "cold" probes, one for rinderpest, the other for peste des petits ruminants. These are oligonucleotides labelled with biotin or digoxigenin. They are not dangerous to use but have several disadvantages: reduced specificity and sensitivity, considerable background noise, plus the fact that they must be kept at a temperature of 4°C, which is difficult outside a laboratory.



How can meat be exported when the health of the herd cannot be guaranteed?

VISIBLE TO THE NAKED EYE

Researchers therefore began work on another technique based on monoclonal antibodies while continuing to improve the cold markers. An ELISA immunocapture test using monoclonal antibodies specific to each virus is in development. It enables diagnosis within about 2 hours and its specificity is excellent. However, it will have to be made more heat-resistant and simple to use by replacing the microplates used now with ready-to-use strips. Field testing will be carried out in Chad.

Markers and immunocapture tests reveal the presence of virus in samples. But it is also possible to screen for antibodies which show that the animal has been infected previously. Detection of antibodies establishes identification of the disease which affected the herd, as well as the efficacy of a vaccination campaign.

The competitive ELISA now available and used widely in Africa can be used only in a laboratory. So researchers are also working on a latex agglutination test. Genes coding for the N protein in the viruses that cause rinderpest and peste des petits ruminants are inserted into the baculovirus (insect virus) genome. The baculovirus then manufactures large quantities of N protein which is then fixed onto latex microbeads. These microbeads agglutinate in the presence of anti-rinderpest or anti-peste des petits ruminants antibodies. This test qualifies as a field test since it can be done quickly at the location of the diseased animal and the result is visible to the naked eye. Although it is hardly as sensitive as an ELISA test, it can still be very useful in ascertaining whether or not an animal has been vaccinated in a country where there is no systematic

branding and therefore no follow-up of individual animals.

RAPID, SIMPLE, FLEXIBLE

Similar research has been conducted into diagnosing mycoplasma infections — contagious bovine pleuropneumonia, caprine pleuropneumonia, contagious agalactia. Markers are available and the ELISA test for contagious bovine pleuropneumonia is being certified in countries adhering to O.I.E. and the International Atomic Energy Agency.

Whereas marker diagnosis techniques are reserved for the laboratory, monoclonal antibody tests present certain advantages for field use — rapid diagnosis, simple equipment, and they are robust and flexible to use. It is true that they will probably never be as specific nor as sensitive as laboratory techniques, but they were not meant to replace the latter. They are an extra tool to be used in the case of severe epidemics to confirm clinical observations.

At the very least, given a network of minimally equipped laboratories and one or two technicians trained to use these tests, or mobile teams equipped with four-wheel drive vehicles, it would be possible to improve health supervision of livestock in developing countries.

For further information:
CIRAD-EMVT
Programme de pathologie infectieuse et parasitaire
10, rue Pierre Curie
94704 Maisons-Alfort Cedex, France

A strategy to control the fruit fly

In Réunion several hundred hectares of orchards have been protected against fruit fly thanks to recent research methods whose priorities were to respect the environment and save on chemical products.

The fruit fly

The common name of "fruit fly" is given to several species of the Tephritidae family, three of which have an economic impact in Réunion: Ceratitis rosa *called "Natal", is present throughout the island and to an altitude of 1500 metres;* C. capitata *is found in the low-lying zones of the northwest;* C. catoirii *in the south and east. The Natal fly causes the most extensive damage and tends to dominate the two other species. It attacks almost all Réunion fruit, except pineapple and banana. The fly oviposits a string of eggs in the fruit. The hatched larvae feed on the fruit for about 12 days. At the end of the third larval stage, the larvae fall from the fruit, bury themselves into the ground and pupate, in turn to become flies. The entire cycle lasts about 3 weeks.* ■

The fruit fly is the main pest in Réunion orchards and market gardens. The cost of chemical treatment, added to that of lost sales because of damaged fruit, has been estimated to be US$ 1.2 million each year, more than enough to justify the Réunion authorities' decision in 1990 to make the fight against this pest one of their research priorities.

The arduous task of improving methods for contolling fruit flies, especially the Natal fruit fly, began more than 15 years ago. The main concern is to avoid using high doses of conventional chemicals, for both economic and environmental reasons. Almost all avenues have been or are being explored, and the very concepts of control methods had to evolve to produce today's achievement.

ATTRACTIVE TO MALES

Although biological control using the pests' natural parasites was used successfully against other insects in Réunion to keep their populations below the harmful threshold, these methods appeared to have little effect against the fruit fly. Ten parasitoids, whose efficacy had been proven elsewhere in the world, were laboratory-bred in massive quantities in the 1970s. Forty million insects were released in the orchards, but only one species survived and had no effect on the fruit fly population.

But work along this avenue continues with the possible introduction of two parasitoids from Hawaii, where their parasitism reaches levels of 80%: *Biosteres arisanus*, a minute wasp, parasitizes the egg of the fly and develops rapidly to kill the pupa; *Biosteres vandenboschi*, a closely related species,

The Natal fly's preferences

What, for the fly, are the attractivity factors of a fruit, especially for a female? Insect behavioural studies are attempting to answer this question, and work in insectariums with false fruit permits study of each factor — size, colour, odour — separately. The biggest fruit and yellow, red and dark-coloured fruit attract the flies especially. But the Natal fly, unlike most other species, is most attracted by odour, particularly that of citrus fruit and guava. Analysis of the volatile substances produced by fruit at different stages of maturity should lead to preparation of synthetic substances to attract and trap the females. Another aspect of this research could be to select varieties which are relatively less attacked. ■

The sexual trap: a method used to monitor the insects.

attacks the young maggots. These parasitoids will have to multiply before being released in the field, and factors favouring their mating and a good sex-ratio are now under study.

With the intention of reducing chemical treatments to only when the economic harmful threshold has been reached, as opposed to systematic spraying each week, an insect population monitoring technique has been devised. It is based on a sexual trap with a parapheromone (trimedlure), a substance which attracts males. Counting the trapped insects gives a precise idea of the population growth and, therefore, of when it is necessary to apply insecticide. This indicator makes it possible to considerably reduce the number of treatments and monitor their efficacy. Research into types of traps and recipes for trimedlure and associated insecticides was sufficiently advanced in 1991 for trapping to be standardized and made available to farmers. Four traps per hectare are recommended.

Although they were devised for monitoring, traps could also be used to control the pests. Present research is combining various lures to attract females as well as more males.

THE FARMERS' CHOICE

"Spot" treatment is another way of using fewer chemicals. This method consists of treating a small surface of the foliage (about a square metre) with a solution of insecticide and protein hydrolysate, an edible lure which diffuses over a radius of 10 m. This poisoned lure attracts mostly sexually maturing females in need of protein. It is not a new method, but to date there has been no precise reference for its use against the Natal fruit fly. After defining the proportions of insecticide to lure, we experimented with spot treatment on citrus fruit and mango trees. Less than 2% of the fruit was attacked, which puts this treatment in the same class as conventional total chemical spraying. It has many advantages: saving on materials and time and respecting useful fauna and the environment in general. However, as in the case of the peach, some fruit are more attractive than the lures, and in these cases spot treatment is not very efficient.

Pheromone traps or spot treatment? Which method should the farmers choose, since each can be used separately and effectively? But they are also complementary and can be combined in a form of "strategic control": traps signal the need for spot treatment, on the basis of type of fruit, variety and location. Thus, at low altitude, spot spraying of citrus trees would begin when 20 flies per trap are counted in a week. At middle altitude, total spraying of peach trees is still necessary, but would begin only as soon as flies have been trapped. At higher altitudes as many as seven sprayings have been avoided, and in certain cases no spraying at all has been necessary.

When the costs of "strategic control" and conventional chemical treatment are compared for similar protection, the former wins. Basing calculations

Spot treatment: only small leaf areas receive the insecticide that contains a product attractive to flies.

on an orchard of 1 ha planted with 300 trees where one out of two trees are sprayed, the farmer using traps and spot treatment will spend 400 francs compared with 950 francs for conventional chemical control. The reduction in work hours from 6.5 to 1.5 per hectare is another advantage to be taken into consideration.

Major information campaigns

CIRAD prepared and sold 4000 traps in 3 years, which on the basis of four traps per hectare means 1000 ha of land are being monitored. The amount of food lure sold for spot treatment shows that about 200 ha have been treated in this way. This method not only presents a considerable challenge for Creole farmers, but many growers remain erroneously convinced that conventional spraying offers better protection.

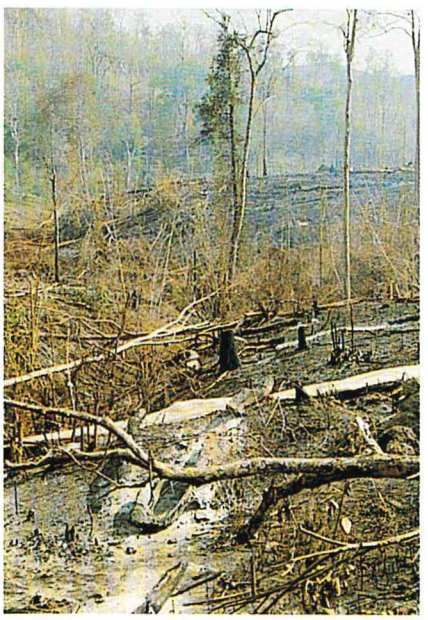
In an attempt to promote "strategic control" of the fruit fly, the Conseil Général of Réunion is covering half the cost of the traps and lures. The Chamber of Agriculture, the office for plant protection and the cooperatives have launched major information campaigns: distribution of technical data cards, radio, television and press announcements, billboard advertising — everything is being done to encourage Réunion farmers to adopt this efficient, economic and environment-friendly methodology.

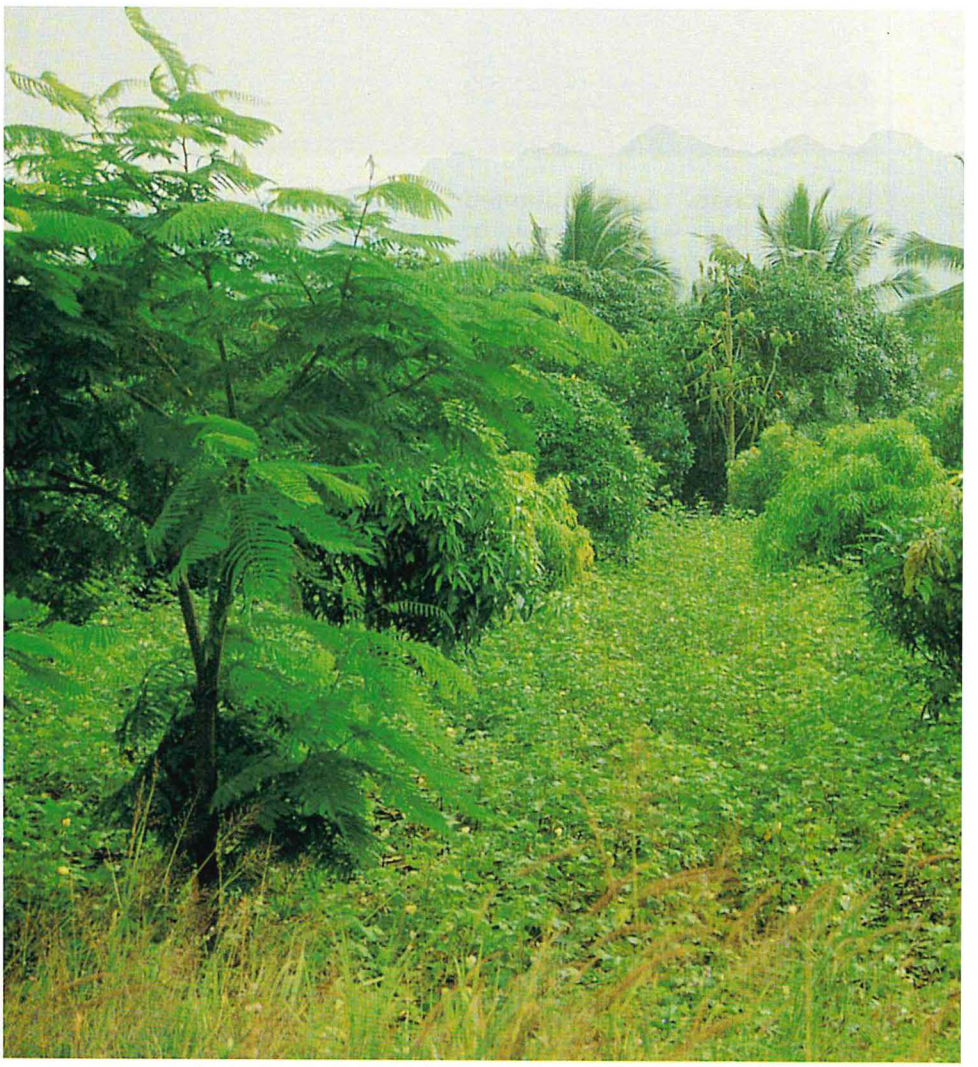
▶ For further information:

CIRAD-FLHOR
Programme agrumes
et arboriculture fruitière
BP 5035
34032 Montpellier Cedex 1, France

CIRAD
Station de Bassin-Martin
BP 180
97455 Saint-Pierre Cedex, France

Before modifying farming systems it is necessary to understand their past and current dynamics. In western Thailand it was essential to identify the factors which had influenced the move away from a maize-cotton cropping sequence towards a more stable system integrating perennial crops. It was then possible to orient farmers toward sustainable agriculture.





Although deforestation in the Kanjanaburi region continues, despite being banned, fruit-tree cultivation is progressing, suggesting that the system is evolving towards permanent agriculture. Opposite, a young orchard comprising mangoes intercropped with cotton.

Agricultural dynamics on a pioneer front

We are in the Thailand province of Kanjanaburi, bordering the Kwae noi river which flows through the Tenasserim mountains. This mountainous region, about the size of a French *région*, has been a pioneer front for the last 30 years, peopled by a growing number of Thais who have fled the more overpopulated western part of the central plain, and Burmese refugees. More than 6000 ha of forest land have been cleared to grow rainfed maize and cotton.

Agricultural history

The textile industry has always been vital to Thailand as it is one of the country's leading export products (more than FF 27 billion out of an overall total of FF 180 billion in 1992). Textiles — spinning, weaving and clothing manufacturing — account for some 400,000 tonnes of cotton fibre per annum.

Only 10 to 15% of this fibre is produced domestically and seed cotton (unginned cotton) production halved over the 10 years leading to 1990, when barely 100,000 tonnes were harvested. Many farmers are discontinuing cotton in favour of other crops,

Roller ginning cotton in a mill on the outskirts of Bangkok.

such as sugarcane, soybean or cassava. Can they be persuaded to return to cotton growing? In 1991, the Development-Oriented Research on Farming Systems project was set up by CIRAD in conjunction with Kasetsart University in response to a request by the Thai authorities concerning the above questions. The following objectives were established: identify the factors that lead to a decrease in cotton production on a regional, farm and plot level with a view to proposing ways of reversing the trend.

At a regional level, research into the agricultural history of the area and the changes that ensued — supported by satellite imaging and ground surveying — made it possible to chronicle the history of this pioneer zone. A Kasetsart University team interviewed the oldest villagers. Researchers from the Asian Institute of Technology compared their answers with aerial photographs and satellite images taken from 1972 onwards and were able to trace the region's history back to 1945, the year when the first road was built and migrant populations began to move in the area (following logging companies) and to farm.

Maize-cotton cropping system: the cotton is planted between the rows of maize when the cereal is about to be harvested.

Reinstating trees

The region's evolution can be seen as circular: although deforestation continues even today, despite the official banning of forest exploitation, trees, albeit fruit trees, are being replanted. The annual maize-cotton cropping system which was so successful in the 1970s has gradually given way to fruit tree crops, sometimes mulberry, or teak and rubber plantations, rainfall permitting. This return to tree cover is often accompanied by labour and input-intensive farming such as market gardening or improved cattle breeding, or other high-value-added activities. The maize-cotton system (that becomes an inter-cropping system for several years after the plantation of perennials) appears to offer a sequence-based approach to sustainable agriculture based on a diversification of farming activities.

It was necessary to understand how this sequence functions, how long it takes, and why some farmers do not follow it through.

We were able to establish a typology of farmers by studying their history of farming systems

Diversified agricultural activities: silkworm breeding (above), teak plantation (right).

and their decision-making processes in the light of their strategies and objectives. At the top of the ladder figure the well-off farmers, who have accumulated enough capital to diversify into long-term investment farming. At the bottom is a minority of smallholding farmers, émigrés who have no land-owning rights and who will soon join the ranks of the farm workers.

Between these two poles figure the majority of the region's farmers. The maize-cotton system they have used year in, year out, good year, bad year, should, under optimum conditions, enable them to accumulate the capital necessary for diversification. Research is being undertaken to identify those optimum conditions.

Pest and disease control

Exploratory experiments were compared with farm surveys at the small-farmer level to determine and grade limiting factors and to assess which improvements would be readily applicable. Weekly follow-ups on several small farms gave an insight into farming methods and their rationale. Tests served to clarify what happens in farmers' fields and verify the best technology to adopt.

Surveys and experiments were carried out under three contrasting soil and climatic conditions, covering two types of soil and three rainfall regimes (1000, 1500 and 2000 mm per annum). They showed that the main obstacles to system profitability concerned the type of cotton plant itself and its cropping methods.

The varieties grown are smooth-leafed and are highly vulnerable to very early sucking insects which attack most virulently at the start of the growing season. Spraying, often done 15 days after emergence, also destroys useful predators — ladybirds, spiders, chrysopas, etc. — leaving the pests free to multiply.

Types and doses of fertilizers and pesticides are used somewhat indiscriminately, constituting a health hazard for the farmer. Some of the worst pests have developed resistance to the pesticides used, and the price of the latter figures in production costs, thus reducing profit margin.

And, lastly, plant heterogeneity shows that poorly organized seed production has resulted in varieties that are no longer pure and in poor quality cotton lint.

Once the diagnosis had been made, it was necessary to remedy the obstacles: find more resistant and productive varieties, control diseases and pests and develop an appropriate technology for growing cotton in the region.

Profitable and harmless

Varieties selected by CIRAD for production on other continents were field-tested. The quality of their fibre is superior to that of the varieties grown in Thailand and

their ginning yield is excellent. Among them, the glandless cottons present another advantage: their seeds, which have no gossypol, can be made into a cottonseed cake for consumption by single-stomach mammals. Thailand imports 200,000 tonnes of plant protein per annum to feed its pigs and chickens, so this advantage is far from negligible.

Attacks by the main pest, *Amrasca biguttula,* a sucking insect of the Jassid family which causes immeasurable harm, have been halved by the introduction of hairy varieties.

A seed multiplication plan has been set up and aims to produce delintered seeds (without fine down-like fibre covering the seed) treated with a systemic insecticide and a fungicide. This treatment protects the young cotton plant for 45 days, particularly from *Aphis gossypii,* an insect vector of blue disease. It also avoids destabilizing insect populations at the beginning of the season and reduces the handling and use of toxic products.

The underlying aim of this research is to limit the costs and danger associated with chemical treatments: choose resistant varieties; use target-specific active ingredients; reduce the volume of pesticides with ultra low-volume spraying, a CIRAD technique adaptable to the degree of infestation; combine insecticides with biological control. If the measures taken are guaranteed profitable and harmless, then, and only then, will Thai farmers return to cotton.

Technology-transfer aspects of this project and its regional impact are of the utmost importance. Two researcher-lecturer teams have been trained in the context of this programme, one at the Prince of Songkla University in the south, the other at Kasetsart University in the centre of the country. They are responsible for training others in the use of French research concepts, methods and tools for farming systems research and development. Moreover, Kasetsart University is at the heart of a regional network which covers Laos and Vietnam, and will soon include Cambodia, with a view to coordinating research concerning cotton in Southeast Asia.

For further information:
CIRAD-CA
Programme cultures
cotonnières paysannes
BP 5035
34032 Montpellier Cedex 1, France

Other Highlights

■ **IRAT 204 SORGHUM IN AFRICA AND BRAZIL.** Some of the characteristics which contribute to the success of this sorghum variety, a caudatum derivative, are its rapid growth, its low water consumption, its soil fertilizing capacity and its high yield, as much as 7 t/ha in tropical zones. This explains why the variety is grown widely along the irrigated perimeters of the Sahel: several hundred hectares in Senegal, Mauritania, Burkina Faso and Niger. In Brazil, where it was introduced 3 years ago, it is already cropped over 2000 ha in extensive plots sown from the air.

■ **HIGH-ALTITUDE RICE.** The cold temperatures of higher altitudes cause rice to become sterile and prone to disease. CIRAD is encouraging Malagasy farmers to use new rice varieties which are cold-tolerant and resistant

to the principal bacterial disease caused by *Pseudomonas fuscovaginae,* for aquatic cropping between 1500 and 1900 m. These varieties were selected from among the hybrid progeny of local rice and consistently produce higher yields than traditional varieties. Hybridizing rainfed and high-altitude aquatic varieties has led to the development of some very productive varieties for rainfed cropping in the uplands. Apart from in Madagascar, these new cold-tolerant varieties should interest other countries where altitude or latitude make rice cropping problematic because of low temperatures as in the Mediterranean region, for example.

■ **Cotton improvement in Cameroon.** A summary of the sizable pool of information available on cotton selection in Cameroon has been drawn up. The study shows the plant's genetic evolution and the impact this has had on improving the country's cotton activities. Creation of new varieties is dictated by developments in modern spinning techniques and fluctuations in the world cotton market. Eleven varieties have been widely adopted in the last 40 years. Average ginning output has increased from 26 to 41.5%. Over the same period, fibre production per hectare has been multiplied by 4.8 and that of cottonseed by 3.5. Technological parameters of the fibre have also improved. Because of Cameroon's particular climatic conditions, researchers selected a variety for the north and another for the south. In addition to improving the selection, research and development staff have been working on the development of a seed multiplication system for this growing agricultural sector and the improved availability of two regional varieties.

■ **Vineyards in the tropics.** Although of Indo-European origin, vines can be grown in the tropics. If irrigated, they adapt well to the dry, hot climate of Réunion's western coast, as proven by a few vinegrowers — new to the activity — working with the Chamber of Agriculture and CIRAD. All available technical knowledge was used to minimize the growers' risk: in the choice of varieties and vinestocks, location of the vineyards, crop maintenance and protection. It is possible to harvest twice a year, and prices on the local market are high, given the growing tourist demand for table grapes and quality wines. At Cilaos, inland, a vine-growers' association and a cooperative have been created and a wine cellar and commercial outlet have been built, as part of the effort to promote quality wine. A programme has been launched to create a vineyard of noble stock. All this work will soon be rewarded by official recognition of the island's viticulture and attribution of the label "vin de pays de Cilaos". Grapevines might also be grown in the leeward western regions of Guadeloupe. Some experimental plots have been planted in Basse-Terre for table grapes.

■ **Forage trees and bushes.** Several types of wood forage grow well in humid tropical zones as nitrogen-containing feed supplements for livestock. But better species management is necessary, especially in arid zones. The European Commision financed a project to study the nutritional value of about 100 species prevalent in Central and West Africa and preferred by livestock. Animal measurements and numerous laboratory analyses were used to assess the livestock appetite for the species and nutrient availability — which is strongly influenced by their indigestible lignin and tannin contents. In the future, the nutritional contribution of woody fodders can be taken into account when appraising forage resources. The variability of the more useful species according to environment, stage of development or genetic origin will be determined more precisely.

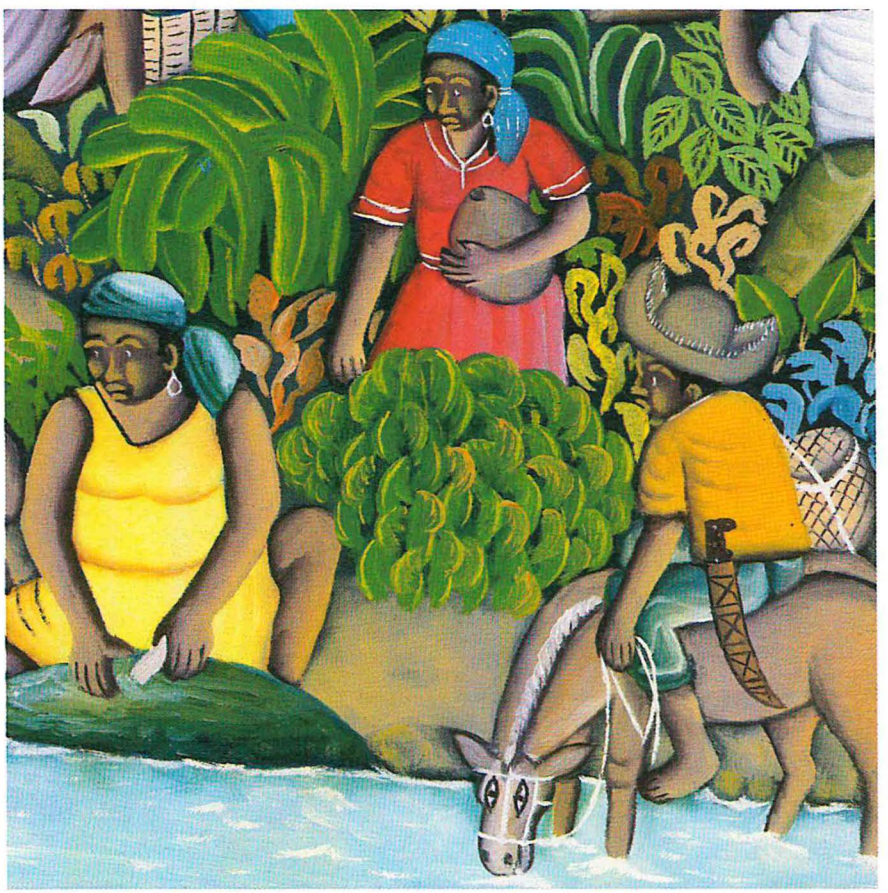
■ **Rural fish farming in Côte d'Ivoire.** Twenty years of extension work have proven that fish farming in the Côte d'Ivoire lagoons must be done without expensive inputs. Consequently, inputs of low food and fertilizer value are being optimized by the creation of artificial reefs (acadjas), adjustment of fish stocking densities, and treatment combinations. Also concerned by this experimental approach are the complex mechanisms which link productivity and production in the lagoon ecosystem.

■ **Adoption of agricultural innovation.** Why do farmers accept or reject technology that stems from research work? CIRAD attempts to answer this question in a synthesis entitled *Développement et recherche agricole dans les pays saheliens et soudaniens d'Afrique.* First, the research knowledge gained in the agricultural zone under study is succinctly expounded. Then, five development activities derived from that research are analyzed — animal-drawn equipment, varietal improvement, mineral fertilizers, maintaining or restoring soil fertility — in order to understand and interpret why they were adopted or rejected. Suggestions aimed at improving transfer of research ideas to the farming community are made in three fields: research, development, and agricultural policies.

TOWARDS ECOLOGICAL

Increase agricultural production, yes, but at what price? Water, soil and forests are our capital, to nurture, not to squander. Be it in the South or the North, we may still have time to learn to live in harmony with our planet.

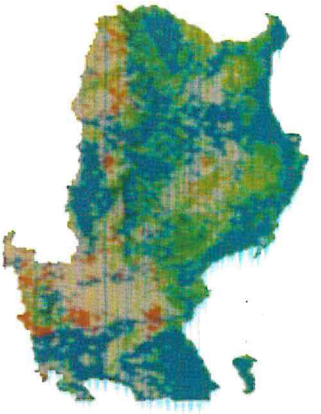
DEVELOPMENT

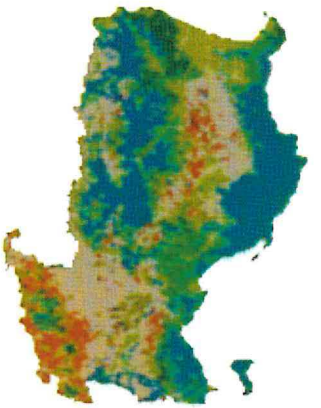


Monitoring the forests

Deforestation in Asia has accelerated at an alarming rate since the 1960s, and the consequences for the environment, the economy and society in general threaten regional growth in the near future. To draw up effective plans for protection and development, these countries need a reliable tool they can use to determine forest resources and map their evolution. The method based on satellite data devised by CIRAD with the collaboration of these countries should help them preserve their forests and make better use of forest resources.

In east Kalimantan, the destroyed mangrove forest is replaced by a single-species growth of dwarf palms, the nipah.





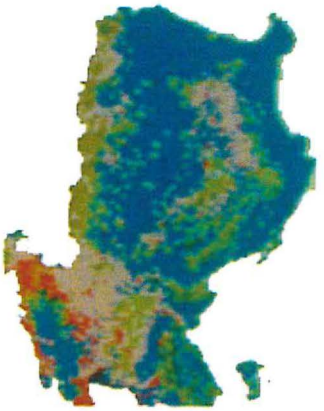
Is the tropical forest disappearing? According to FAO, the average rate of deforestation between 1980 and 1990 in insular Southeast Asia was 1.2% per year, i.e., 1.8 million hectares of forest destroyed each year. The Philippines, for example, have lost half their trees in a few decades. We are all aware of the devastating effects of deforestation on the environment: deeper erosion damages crops and, as the forest can no longer regulate water flow, floods and severe droughts increase the damage to arable land. The disappearance of tropical forests means a loss for the national economies which are based to a great extent on the sale of timber for hard currencies.

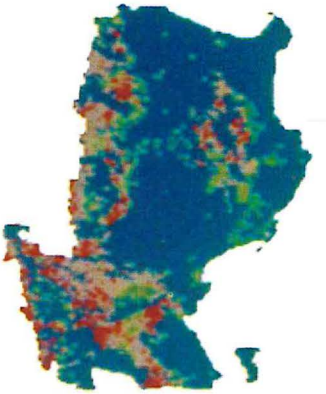
Deforestation is due to many causes. As much as 50% could be caused by Southeast Asia's rapid population growth coupled with traditional slash-and-burn farming methods. Roads for logging lead to spontaneous settlement of hitherto inaccessible zones. Added to that is large-scale planting and, in Indonesia, population transmigration towards as yet uninhabited regions, all of which eat away at natural forest lands.

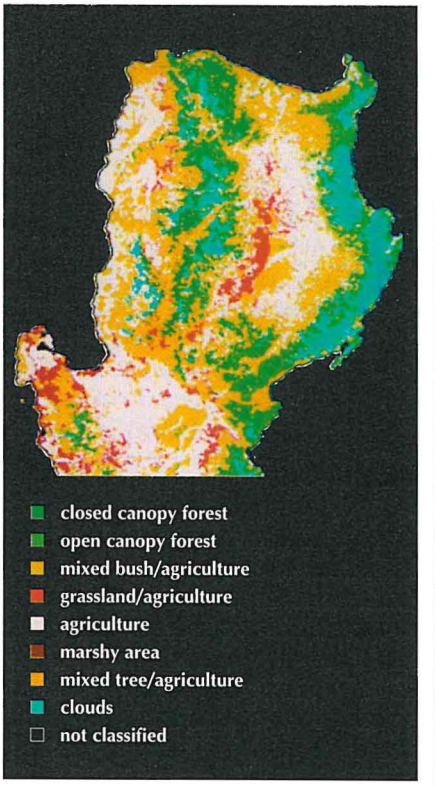
PROCEEDING MORE RATIONALLY

Although national and regional authorities are aware of the situation, they have not to date had available reliable means of rapidly assessing existing forest cover and monitoring its alteration on a regional scale. SEAMEO (Southeast Asian Ministers of Education Organization) asked France, in the context of a project financed mainly by the Ministry of Foreign Affairs, to develop a method using remote sensing from space. The project was entrusted to CIRAD and the French consultants Scot Conseil with both a technical and pedagogic objective: map the forest cover in 1990-1991 and provide these countries with the equipment and human-resource means of monitoring forest alteration themselves. To enable them to manage their forests in a consistent and sustainable fashion: place under conservation untouched areas, exploit their natural forests more rationally and

North Philippines: interpretation of four NOAA images and synthesis of these interpretations (previous page and below).







replant species for timber and pulp wherever possible.

Unlike field inventories, remote sensing from space makes it possible to locate forest resources quickly, relatively cheaply and on a large scale, even in inaccessible regions.

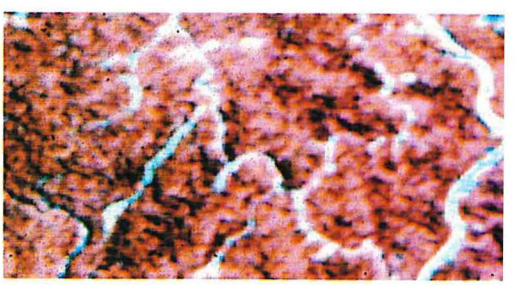
To begin with, a global study was carried out using images taken by the NOAA satellite, to assess the forest cover of the region: Philippines, Sabah, peninsular Malaysia, Kalimantan, Brunei and Sarawak. The NOAA satellite, used mainly in meteorology, provides one or two images a day of the same zone. The information contained in each image is available on reception. In LAC (local area coverage) mode it gives resolution of 1 kilometre; i.e., each point (pixel) represents a square with sides of 1 kilometre.

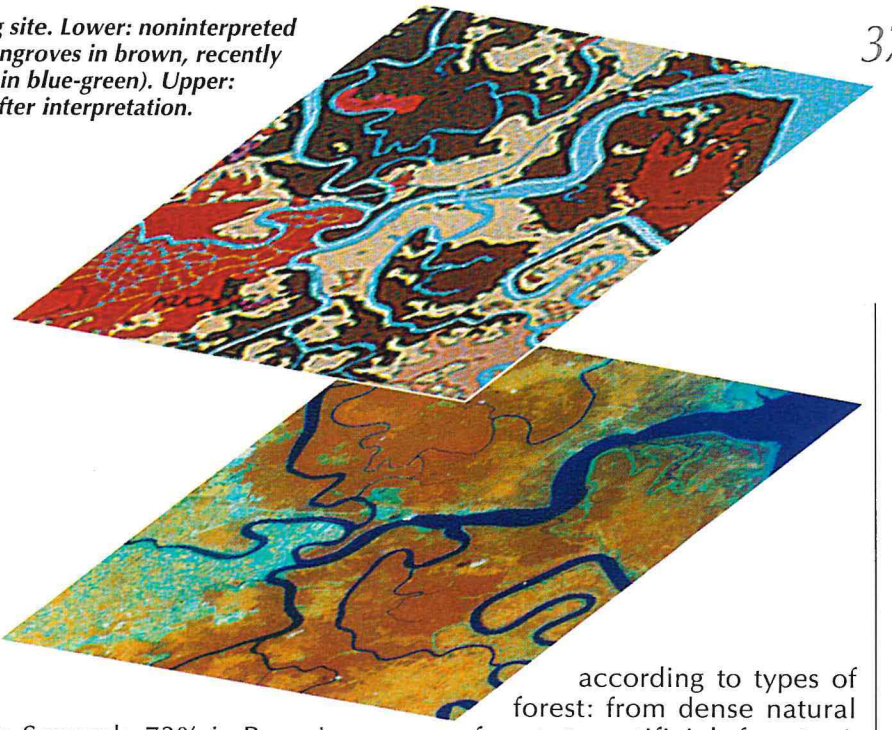
Five or six images in LAC mode were obtained from the NOAA satellite for each of the six geographic zones. Cloud cover is particularly dense in this part of the world and several images of the same zone were necessary to construct one clear image. The images were pre-treated in France by the Centre National d'Etudes Spatiales in Toulouse. First they underwent a geometric correction to eliminate distortions due, among other things, to the Earth's curvature, then radiometric treatment.

By opening new tracks, forestry work encourages colonization of hitherto inaccessible areas.

MASKING THE CLOUDS

The images were then put through a computerized image processor so they could be displayed on a screen and interpreted one by one. To





Sarawak, Kuching site. Lower: noninterpreted Lansat image (mangroves in brown, recently deforested zones in blue-green). Upper: the same image after interpretation.

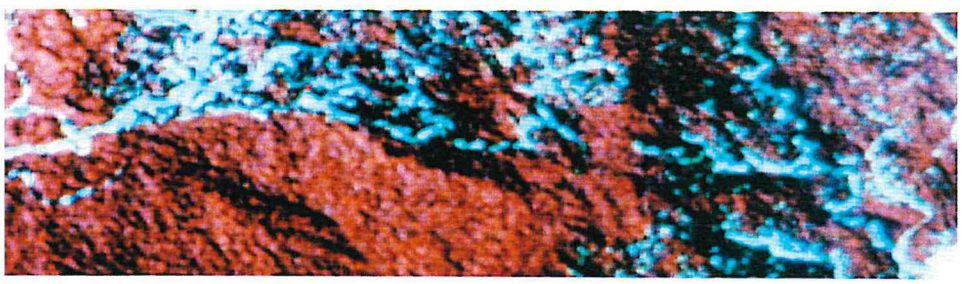
do this, "training areas" were designated on the computer. These were based on land inventories representing vegetation cover: closed structure (dense natural forests, where crown closure is more than 40%), mixed structure (shrubs and cultivated areas), open structure (low vegetation, urban and agricultural zones), clouds, water and swamps. Five to ten "training zones" were designated per class. The computer determined their parameters, then classified each pixel into a particular class after calculating the highest probability. Classes were identified by different colours on the screen. The image-processing software also makes it possible to enhance contrasts and mask clouds and oceans. Five or six images are interpreted per geographic zone, then superimposed to obtain the most complete and clearest image possible. The final images were juxtaposed to form a map on a 1:2,000,000 scale of the forest cover in that region in 1990. Using this map, and taking into consideration uncertainties due to cloud, each country could calculate the percentage of forest covering its territory: 17% in the Philippines, 38% in peninsular Malaysia, 45% in Sabah, 57% in Kalimantan, 67% in Sarawak, 73% in Brunei.

However, this global vision was not sufficient to analyse alterations in the forest; there was nothing to compare it with, since NOAA images in LAC mode dated back only to 1989. Thus, detailed studies based on high-resolution (20-metre) SPOT satellite images were instigated. Each country chose two sites, test zones corresponding to a SPOT image of a 60 kilometre-sided square. A preliminary set of images recorded between 1986 and 1990 was acquired both in digital tape form and hard copy on a 1:100,000 scale. Engineers and forestry technicians from each country learned to interpret these images visually in four training sessions. Field observations enabled them to identify each colour, then to draw up land distribution maps according to types of forest: from dense natural forest to artificial forest. A second set of SPOT and Landsat TM (thematic mapper) images of each site was then acquired — these images had been taken at least 2 years later — and compared with the first to analyse modifications in the forest cover.

Training for 25 foresters

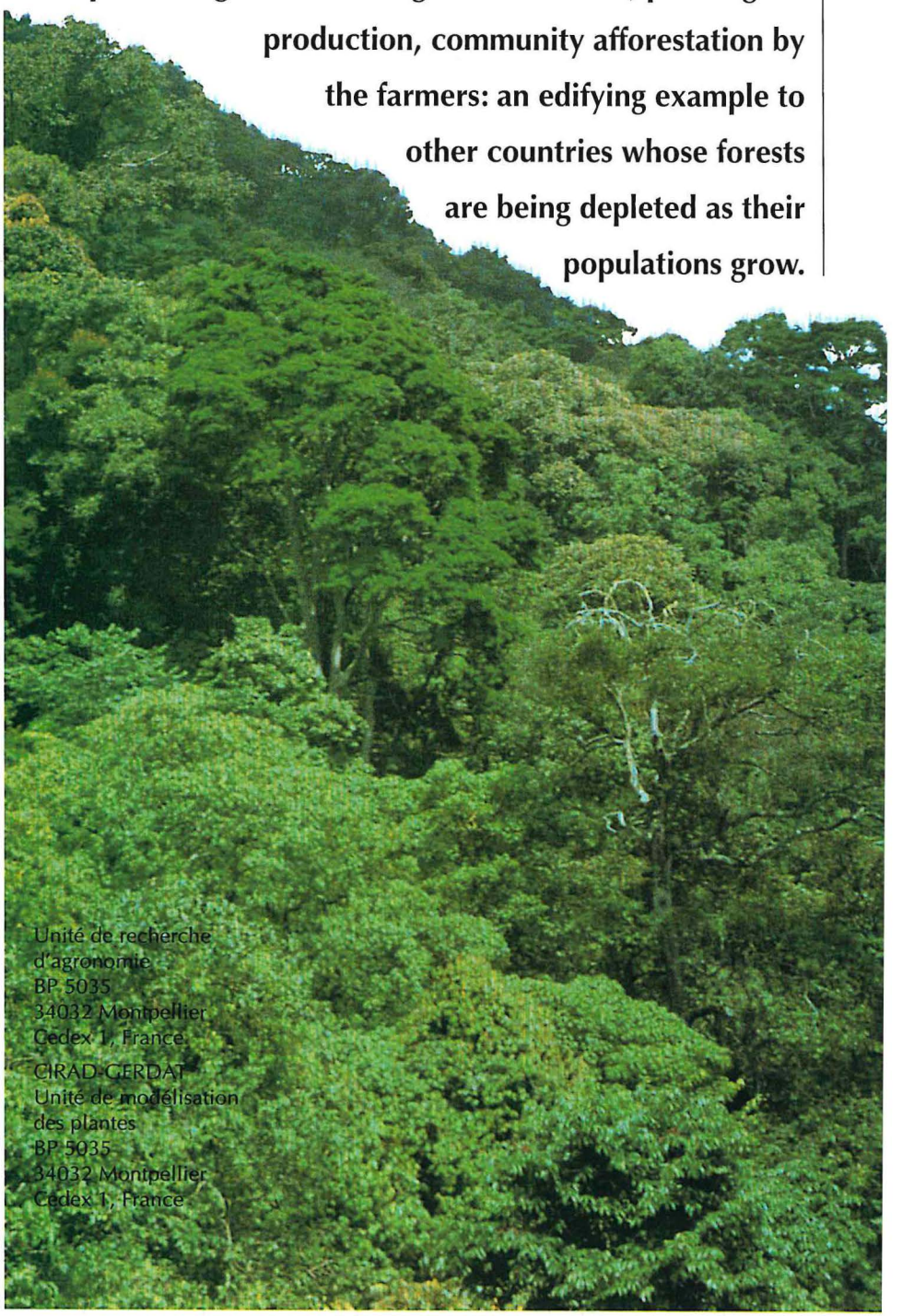
These detailed studies validated the results of the global study and contributed to a better understanding of the process of deforestation, since the images specify transitory stages of vegetation cover.

The outcome of this cooperation project between France and SEAMEO was that the Southeast Asian countries mastered a tool enabling them to monitor their forest and to decide what policies to adopt in the matter of protection, management and development of their natural resources. Twenty-five foresters were trained in the techniques of mapping by remote sensing. But an obstacle remains: satellite data are not readily available. In the densely cloud-covered region, numerous images are needed to obtain one complete



view. One solution is to install receiving stations on the spot to capture data from the satellite as it passes overhead, as Indonesia is in the process of doing. Other countries, such as Thailand, are equipping their present stations to receive data from new satellites, particularly the radar satellites which can study the Earth through clouds.

Burundi, a country which had been denuded of trees, is becoming an agroforestry garden. Fifty million trees have been planted over the last 10 years. Everything has been done to meet the country's timber requirements and protect the mountainous regions from erosion — protecting the remaining natural forests, planting for production, community afforestation by the farmers: an edifying example to other countries whose forests are being depleted as their populations grow.



Unité de recherche d'agronomie
BP 5035
34032 Montpellier Cedex 1, France.
CIRAD-GERDAT
Unité de modélisation des plantes
BP 5035
34032 Montpellier Cedex 1, France

For further information:

CIRAD-Forêt
Programme forêt naturelle
45 bis, avenue de la Belle Gabrielle
94736 Nogent-sur-Marne Cedex, France

Burundi, a model for afforestation

Fifteen years ago, with only 2% of its surface covered in forest, Burundi was one of the most deforested countries of Central Africa. There was not even enough wood for essential needs, such as cooking and building. In the 1980s, faced with the urgent necessity to intervene on a large scale, the international community — in this case, the European Development Fund, the French Fonds d'Aide et de Coopération (FAC) and the World Bank — began to set up forestry development projects supported by research all over the country. CIRAD participated with the Institut des Sciences Agronomiques du Burundi (ISABU) in all three types of project launched — to protect the natural forests, to replant trees and to introduce agroforestry.

The natural forest has now acquired the status of a national park (opposite). Assisted by an effective policy to create tree nurseries, farmers have taken it upon themselves to re-forest the country.

Symbolic value

When measures to protect the natural forests were set in motion, only strips of these remained on the ridge between the Nile and Zaire watersheds. These 50,000 hectares were the last refuge for forest species threatened with extinction — e.g. the high-altitude mahogany and *Podocarpus usambarensis,* one of the only conifers indigenous to Africa. The chimpanzee and many other animals are sheltered there, as are springs which provide water for towns and villages and irrigation of the Imbo plain to the west. The growing population on the outskirts worked these forests in an unrestrained manner, hacking away at them to cultivate in a more or less slash-and-burn fashion.

CIRAD was entrusted with planning and technically managing the first operation sched-

The right to use the forest has been restricted, but compensation has been offered to the rural population.

uled to build a 200-kilometre track on the edge of the protected area. Several thousand workers were employed to build this track, which permitted replanting of deforested areas and better acquaintance with plant and animal biodiversity. But it also had symbolic value: for the surrounding populations, it clearly marked the limits to their right of use of the forest. And indeed, haphazard clearing of the forest ceased almost immediately. Contributing greatly to this success were the compensations offered to the villagers, especially the rural nurseries set up around the protected zone. From then on, the farmers produced on their land what they could no longer take out of the forest: trees for fuel and fruit, bamboo for Pygmy handicrafts.

Today this region is a national park. The environmental department responsible for its protection would now like to develop an ecological tourist industry, with Pygmies abandoning chimpanzee hunting to become guides.

Under research guidance

The state-sponsored afforestation has a different objective: to plant for production. Ten thousand hectares of pine and eucalyptus were planted over 10 years in still uninhabited regions on the western slope of the Zaire-Nile ridge. This provides timber and fuelwood for population centres such as Bujumbura.

This technically successful afforestation was carried out under research guidance. Researchers recommended management methods — planting, weeding, thinning, pruning. They advised on species adapted to the ecological conditions and to meet different needs, with increased productivity in mind. For example, *Eucalyptus grandis,* a tall tree which produces on good soils 320 m^3 when 9 years old, replaced *E. maidenii,* which produces only 50 m^3 at the same age. Several Central American species of pine were productively substituted for cypresses. *Pinus caribaea* is a good example, increasing yield per hectare from 15 to 42 m^3 in 10 years on poor soils. Researchers also improved methods for working and using wood.

Today, state afforestation accounts for most of the country's needs. However, so as not to exacerbate social tensions which could arise from extended afforestation of community pasture lands, replanting was pursued in different ways.

Taking charge of production

Most Burundi farmers live in the banana and coffee-growing regions on very small farms (the national average is 0.7 hectare for a family of eight). For decades they have been used to planting trees in hedgerows or on fallow land. The foresters believed that the farmers, with their experience, could play an increasingly important role in the production of timber for the country and earn a better living by doing so.

Under the technical direction of CIRAD and in cooperation with the Association Française

Satisfying the country's timber requirements by national reforestation.

A rural nursery.

des Volontaires du Progrès, a policy was drawn up to create rural nurseries to make this possible. Between 1980 and 1985, 20 nurseries producing 50,000 saplings each were set up in the west of the country. In other words, farmers planted a million trees each year. From 1985 onwards, 120 rural nurseries were set up all over the country; each nursery had a capacity of 40,000 saplings, 5 million trees in all. Other, smaller nurseries have continued to be created nearer the users. At present, the trend is for farmers to set up sapling production in privately owned nurseries which produce from 5,000 to 10,000 saplings a year and whose range of operation permits transportation on foot.

Today the nurseries propagate about 20 species. Two examples illustrate the various uses made of these trees. The Australian silver oak *(Grevillea robusta),* which is not competitive with crops, is used for timber and firewood. The calliandra, a leguminous fodder shrub planted in contour hedgerows is a living supply of nitrogen-rich fodder, much appreciated by livestock. These are illustrations of two uses for trees: production and soil conservation in mountainous areas.

FARMERS PLANT 28 MILLION TREES

Researchers worked alongside the farmers, simplifying methods for them to use in their nurseries and supplying them with seeds of species tested in the state afforestation programme.

The results of these 10 years of tree research and development are impressive: 50 million trees were planted, 28 million of these by the farmers themselves. The forest cover of the country has increased from 2% to 6%. Widespread research counselling and training at grass-root level has been one of the keys to success. One hundred and fifty extension agents work with farmers in 90 of the country's 114 village communes. But CIRAD's mission in Burundi is not finished. It intervenes on a regular basis, keeping an eye on the projects which, 3 years after the researchers' departure, continue to function satisfactorily, despite serious social difficulties in the country. Proof of an effective transfer.

▶ For further information:

CIRAD-Forêt
Programme agroforesterie,
conservation des eaux et du sol
45 bis, avenue de la Belle Gabrielle
94736 Nogent-sur-Marne Cedex,
France

How can we combat soil degradation in the heavily populated African savanna? At a time when more land is needed, available farming and grazing areas are disappearing, overworked to the point of sterility. Two techniques can help to partially conserve or restore soil fertility: prohibiting for a time the use of exhausted fallow land and establishing permanent grasslands. Together they answer some of the needs of both farmers and herders.

Conserving soil fertility

In the humid savanna of Sudano-Guinean Africa, farming activity has increased in parallel with the population over the past 20 years. Poor methods and incessant cropping have exhausted the land.

In zones where population density has remained below 10 people per square kilometre, the traditional system of extensive land cultivation does not seem to have caused severe damage to the soil; after clearing, the farmer crops his plot of land 4 or 5 years running, then leaves it fallow for 20 to 30 years, the time necessary to restore the savanna. The system is balanced and crop production is stable, even if the yields are relatively low (500 kg of cereal crops per hectare).

Grazing land made up of **Panicum maximum** *and* **Stylosanthes hamata,** *ready for grazing.*

Lack of forage

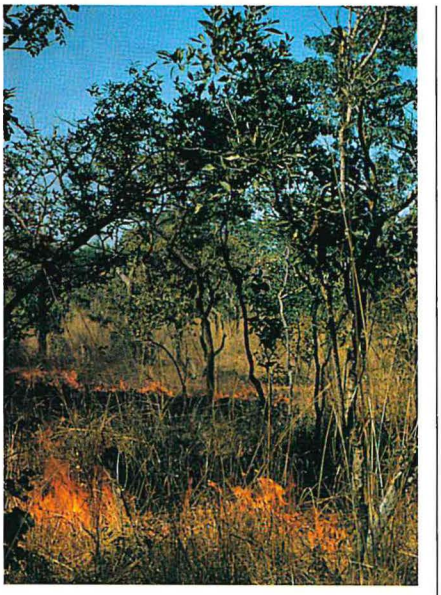
In heavily populated regions, on the other hand, the needs are so great that the farmers are under pressure to recultivate fallow land before its fertility has been restored. Consequently, yields drop and the farmer abandons his plot of land after 2 or 3 years of cropping, which accelerates the rotation cycle. Moreover, an increase in population usually entails an increase in the number of grazing stock. Since pasture land has been taken over for farming, the little natural fallow land left has become overgrazed, accelerating soil degradation and the disappearance of forage.

Research conducted to date has shown that animal manure maintains soil fertility and helps restructure the soil. Ways must therefore be found to increase forage production, so that herders can feed their stock.

Research on this problem has led in two complementary directions: restoration of fallow land through rational management

Overgrazing accelerates soil degradation.

Land under fallow.



Plant fodder species that resist fire.

and the creation of permanent grazing land. Experiments have been carried out in the Korhogo region, in the north of Côte d'Ivoire, which, with more than 900 mm of rain per annum, is representative of the Sudano-Guinean region. CIRAD worked with the Institut des savanes (IDESSA) and two Côte d'Ivoire development agencies, SODEPRA and CIDT.

How to increase forage production on fallow land? Natural fallow land evolves through three stages: from year 1 to year 4, the plot of land is invaded by poorly productive annual Graminaceae and adventitious weeds of little nutritional value; from year 5 to year 20, the high-yield and nutritious perennial graminaceous *Andropogon gayanus* takes over; this in turn is replaced by savanna Graminaceae (*Hyparrhenia* spp., *Andropogon* spp.) of similar quality; at the same time the tree layer has reformed, and the land assumes an aspect of tree-covered savanna. The savanna is considered restored when *A. gayanus* has disappeared from the herbaceous layer.

FLEXIBLE

However, when fallow land is overgrazed by cattle its evolution is very different: *Andropogon gayanus* does not have a chance to develop. Vegetation remains at the early fallow stage.

Prohibiting access to degraded fallow land for 4 years results in a doubling of the above-ground biomass obtained at the end of the vegetative cycle. Forage production also doubles, measured by the cumulative production of 35-day-old fresh growth, which means more stock can be fed per hectare. The increase in root biomass is even greater. And the percentage of perennial Graminaceae (essentially *A. gayanus*) devoured by livestock increases from 15 to 60%.

Over the 4 years there is no measurable increase in organic matter or total nitrogen. However, the sum of exchangeable bases (nutritive elements present in the soil) clearly increases as far as calcium, magnesium and sodium are concerned. The soil loses its acidity (pH increases by half a unit).

The optimum cutting rhythm for maintaining *Andropogon gayanus* is around 60 days (cutting being an imperfect way of simulating grazing). The Graminacea would risk disappearing if cut at a faster rate. At 2 months, the nutritive quality of the plant is no longer at its best, but it is still acceptable. In particular nitrogen content and energy value remain constant until the 11th week, which gives the farmer a certain flexibility of cultivation.

Population growth is generally accompanied by an increase in livestock.

STABLE AND PRODUCTIVE

Setting aside fallow land in order to restore it means reducing the locality's forage potential during that time. Intensive forage cultivation must compensate for the lack of grazing land. In Côte d'Ivoire, intercropping the Graminacea *Panicum maximum* with the Leguminosa *Stylosanthes hamata* gives the best results.

These two plants are perfectly adapted to the Sudano-Guinean or humid Sudanian climate and constitute a balanced permanent grassland. The cespitose growth (in individual tufts) of *Panicum maximum* leaves room for *Stylosanthes hamata,* which is a precocious, self-seeding species. Its pods mature by the end of the rainy season and, by the time the land is burnt, there are enough seeds in the soil for reproduction. The intercropping is stable and very productive. The two plants are complementary. The *Panicum maximum*, a hardy perennial, resistant to fire and trampling, supplies most of the forage and ensures grazing over a period of at least 10 years. Its strong root system also helps restore the soil. *Stylosanthes hamata* brings nitrogen to *Panicum maximum* through symbiotic fixation and enriches the forage in protein. This type of intercropping can feed twice as many livestock as healthy natural pasture. Cultivating 1 hectare of grassland frees 2 hectares of fallow land, which can then be set aside.

WIDESPREAD USE

Permanent grasslands sown with *Panicum maximum* and *Stylosanthes hamata* tolerate errors of management because of their robustness and stability. Numerous farmers, herders, herder-farmers and traditional cotton growers in Côte d'Ivoire have successfully planted more than 1500 hectares of permanent grassland.

But the planting of such grasslands is harder work than simply restoring fallow land. They must be tilled, sown, fertilized with phospho-potassic manure. Herders are advised, therefore, to limit the size of their cultivated plots and keep the grazing land for milk and/or nursing cows, draught oxen, breeder livestock in breeding season or calves on the wean — all of which have high added value — so as to earn a return on their investment.

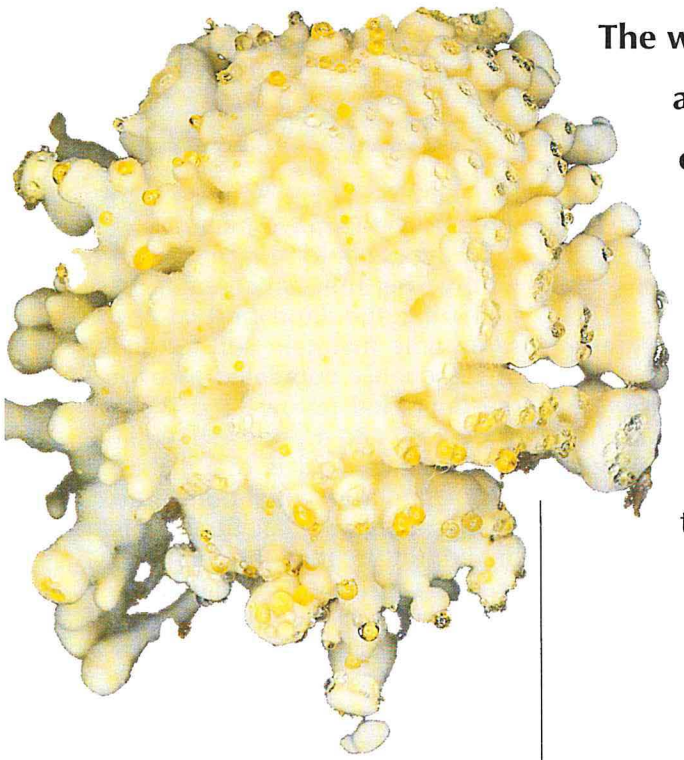
It is possible to reduce considerably the time necessary for fallowing the land and at the same time maintain soil fertility in reasonably populated areas if the degraded fallow land is set aside from 1 to 4 years and a permanent grassland is established with *Panicum maximum* and *Stylosanthes hamata*. But this is on condition that farmers and breeders succeed in managing their lands together, thus laying the basis for sustainable agriculture.

▶ For further information:

CIRAD-EMVT
Programme ressources alimentaires
10, rue Pierre Curie
94704 Maisons-Alfort Cedex, France

Projet IDESSA-CIRAD
BP 633
Bouaké, Côte d'Ivoire

Successful biological control



The fungus found in Madagascar to control the white grub does not attack any other living organisms.

The white grub, detected in Réunion in 1981, attacks all crops and can obliterate them entirely. Today, farmers are relieved: an entomopathogenic fungus discovered in Madagascar controls the proliferation of this pest to below the economic threshold. This biological treatment, as inexpensive as it is efficient and in harmony with the environment, has now been licensed.

June 1981. The Service d'utilité agricole de développement in Réunion was contacted by a planter whose sugarcane field had been devastated: canes laid flat, withered, roots severed. Each stool was found to be infested with about 20 big white worms. CIRAD, which was contacted immediately, diagnosed an attack of white grub, the larva of a cockchafer.

ROLE-SHARING

A helicopter surveillance mission revealed that 150 hectares of sugarcane had been destroyed in the region of Sainte-

A field of sugarcane devastated by the white grub.

The white grub, larva of the cockchafer, feeds on the roots. It cuts off sugarcane from its water and nutrient supplies.

Thérèse, above La Possession. There was no time to eradicate the grub which had most likely infested a much larger zone for several years. It was an undeniable catastrophe and everyone was in despair. The very survival of smallholders was at stake, and the future of sugarcane production in Réunion seriously compromised.

Everyone concerned with agriculture was immediately mobilized — Conseil General, the Chamber of Agriculture, agricultural representatives, the University, CIRAD. A combat strategy was drawn up and roles allocated: the Service de la Protection des Végétaux and the Fédération départementale des groupements de défense des cultures took charge of the only immediate measures available, i.e. chemical control; CIRAD was entrusted with the longer-term objective of researching biological control of the pest through disease or entomophagous insects.

HOPLOCHELUS MARGINALIS

Not until September 1981 was the insect identified by three natural history museums as it matured into a cockchafer, the polyphagous *Hoplochelus marginalis*. It is also found in Madagascar where it is endemic. CIRAD cooperated with INRA

Final larval stage (pre-nymph). Its pink coloration indicates that it has been fatally affected by disease.

The pest (Hoplochelus marginalis) *in its adult form, the cockchafer. Harmless in this form... but, unfortunately, it reproduces.*

and the University of Réunion as well as with the Indian Ocean research organizations, MSIRI in Mauritius and FOFIFA in Madagascar, which supplied precious help throughout.

Biological study of the insect established its cycle and correlated this with the damage done to crops. The eggs are laid in the soil in December and January. The hatched larvae become dangerous at the L3 adult stage which covers the period from April to the end of July, precisely the growth period for sugarcane. They feed on the roots and finally sever the sugarcane from its water and nutrient supplies. The plant can no longer form tissue, it withers, and topples under the wind or its own weight, since it is no longer rooted to the soil. In September, the larvae turn into pupae. About a month later they reach the adult stage. The cockchafers then wait for the first austral rains, usually at the end of November, to take flight and mate. The female then burrows into the earth to lay her eggs and the cycle resumes.

Each female lays an average of 40 eggs and the multiplication coefficient from one generation to the next is about 20. Field samples taken since 1981 show that only three to five grubs per stool cause enough damage to become an economic hazard. We also know the speed at which the pest spreads: each year the front line of attack advances by 3 or 4 kilometres.

SPECIFIC TO THE WHITE GRUB

Surveys began in Madagascar and continued over several years, essentially in May and June. Here, in the country of origin of the *Hoplochelus marginalis*, we hoped to find larvae of the species attacked by entomophagous insects, or diseases, which we could then introduce into Réunion. And indeed, in 1987, we found diseased larvae, infected with an entomopathogenic fungus, *Beauveria brongniartii.* This fungus, which is specific to the white grub, cannot develop in any other living organism.

Laboratory data rapidly showed that the pathogenic effect of *Beauveria brongniartii* on the white grub was 100 times greater than that recorded for fungi of the same type. This prompted researchers to carry out agronomic trials in the field from 1989 to 1993. These confirmed the fungus' high potency. The fungus developed rapidly in the Andosols of the island's highlands, propagating naturally year after year and reducing the white grub population to below the economically harmful level 2 years after a single treatment. This result, the best ever obtained for an entomopathogenic substance, was achieved even with the lowest inoculum dose and regardless of the formulation used. The disease progressed more slowly in the brown soils at lower altitude, reaching full efficacy in the fourth year.

In the course of these trials we noted that the fungus spread naturally to the control plots. The adult insects themselves were probably the vectors, since the cockchafers leave the ground at dusk and fly about until dawn. Hundreds of individuals leaving the treated zone acted as natural and efficient inoculants.

LICENSED

The aim of the trials was to determine the method and dosage of the entomopathogenic treatment. In the laboratory, steamed rice was used as a support for the fungus. For industrial production, INRA and the Calliope company came up with a substrate made of granulated clay. The recommended dose of 30 to 50 kg of pellets per hectare is economically acceptable. The treatment is incorporated as the sugarcane is planted, along with a quarter of the usual dose of an insecticide to protect the plants while the pathogen develops.

The Agricultural and Fishing Ministry licensed the product in 1993 and its commercialization began immediately.

There are two advantages of this biological method for controlling the white grub.

One concerns agricultural production and the environment. The white grub population drops below the economic threshold to crops as its larvae are drastically reduced. Moreover, only a low, single dose of insecticide is necessary.

The second is an economic advantage: the biological treatment (including the insecticide) costs 1,200 francs per hectare and is applied only once; traditional chemical treatment costs 2,000 francs per hectare and can be repeated every 3 years.

How will the growers receive the new treatment? Neither researchers nor extension staff need worry about that aspect. The growers were acutely conscious of the peril they faced and avidly followed the research proceedings. Even before the treatment was licensed, growers had requested the experimental treatment of 75 hectares split into plots of 500 to 1,000 m^2. In view of the rapid results obtained, they are ready to put it to general use.

For further information:

CIRAD-CA
Programme cultures intensifiées, canne à sucre
BP 5035
34032 Montpellier Cedex 1, France

CIRAD
Station de La Bretagne
97847 Saint-Denis Cedex, France

Other Highlights

■ **Safeguard of land resources and rural management.** With the support of the Malagasy Ministry of Agriculture, CIRAD hopes to involve farmer associations in the rational use of natural resources in the pioneer areas. First, simplification of registration procedures meant better control of productive land ownership and therefore of State recognition of land tenure rights. This was followed by various actions concerning environmental protection and farm development.

■ **Tree ownership.** Questions of tree ownership now include management of natural wooded areas as a result of recent studies. In Africa, trees, like other renewable resources, are tell-tale signs of numerous property rights and modes of appropriation. They are often used to alter existing social structures with a view to reorganizing land and access to its resources. South of the Sahara, user rights have always been laid down by traditions. But in some Sahelian regions, where these traditions have been "delegitimatized", exploitation has been taken over by city businessmen for short-term benefits, often causing irremediable damage.

■ **Use of Australian acacias in sustainable forest management.** In the forest zones of lower Côte d'Ivoire, land that is cropped after clearing or burning is rapidly invaded by weeds and often abandoned to fallow after 2 years. A strategy was elaborated by CIRAD and IDEFOR to reduce fallow time and produce fuelwood at the same time. In year 1 of cropping, the acacia is planted in association with yam. The trees are severely pruned before the second cropping, this time with rice or maize. The acacias then proceed to strangle weed vegetation and cover the ground with a thick carpet of dead leaves. At 8 years of age, the remarkably fast-growing *Acacia mangium* yields 70 to 140 t/ha of wood, used mainly as fuel. Other species, such as *Acacia auriculiformis*, are also promising. Several methods of recropping are under study. It already appears that yam, which uses the tree stumps for climbing, and maize, benefit from the nutritive elements resulting from slow decomposition of the leaves or their destruction by fire.

■ **Forest symbioses: a French-Australian research program.** The ORSTOM-CIRAD unit for biotechnology of tropical forest symbioses (BSFT) and the Commonwealth Scientific and Industrial Research Organization (CSIRO) in Australia are cooperating to study the biodiversity of symbiotic microorganisms in *Casuarina-Frankia* and *Acacia mangium-Bradyrhizobium* associations on the one hand, and the haemoglobin genes of the Casuarinae on the other. These studies entail joint projects, exchanges of biological material and scientific publications.

■ **Mapping the changes in grazing land by remote sensing.** Mapping land distribution and following its evolution helps more rational land management. In Burkina Faso, INERA and CIRAD used remote sensing to update the grazing land resource inventory in the Gorom-Gorom region. Comparison with SPOT images dating from 1991 and aerial photographs taken in 1975 shows that all sandy soils have been cultivated. It also shows a clear reduction of *Schoenefeldia gracilis* and *Panicum laetum* grazing land and extension of stripped surfaces on limonite-sand glacis. This common land has deteriorated partly because of successive droughts in the region, and partly because of overgrazing. On the

other hand, the bourgou *(Echinochloa stagnina)* grazing lands of Ménégou floodplain have held up, despite heavy grazing.

■ **An atlas of grazing potential in the Sahel.** The atlas *Elevage et potentialités pastorales sahéliennes*, published by CIRAD with financial support from CTA, covers six Sahel countries, Chad, Niger, Burkina Faso, Mali, Senegal, Mauritania, i.e. more than 1,300,000 km^2. It summarizes 40 years of research in the field of plant resources — botany, farm-grazing, plant nutrients, use of common land, water resources — as well as in the field of animal resources and health — zootechnics, parasitology and veterinary infrastructure. It contains more than 120 maps, about 30 of which are on a scale of 1:500,000 and show the grazing potential of the region, specifying distribution of the main species of Sahelian, grassy and woody plant formations.

■ **Biological control of citrus fruit greening disease.** In Réunion, the distribution of healthy stock is associated with a biological method for protecting the orchards through balancing pests which vector the disease with their parasites: the entomophagous *Tamarixia dryi* Waterson from Africa or *Tamarixia radiata* Waterson from Asia attack the citrus psylla which transmit the disease.

■ **Cotton protection in Cameroon.** Since 1990, Cameroon has been involved in a new programme for cotton crop protection. Called staged and targeted control of pests, it is a compromise between traditional methods — systematic applications of pesticides — and threshold intervention — treating according to the degree of infestation. The results are evident in the savings that have been made in applied pesticides, somewhere between 30 and 50%, for a yield at least equivalent to that of the previous years. Planters are obviously pleased with the method: 3,500 ha treated in 1991, 35,000 ha in 1993, i.e. almost 40% of all cotton plantations.

■ **Wildlife management in Cameroon.** What role is played by wildlife in the diet and revenue of rural households in humid tropical Africa? Do fluctuations in cocoa, coffee and food crop prices and devaluation of the national currency have any influence on hunting? What are the traditional methods for wildlife management, and are they in line with national laws? To answer these questions, CIRAD decided to carry out a study on wildlife in the Dimako forest, in Western Cameroon. A comparison will be made between management in Dimako, a non-protected area, and that in the Dja reserve, with its similar ecology. The study will be used to analyse their respective economic efficacies, integrating revenue from hunting on the one hand and conservation costs on the other. This economic evaluation of hunting resources outside a protected zone will be followed by a more global economic evaluation and viable management study of an ecosystem in the humid tropical forest.

■ **Wildlife protection and development.** Despite the extension of protected zones, the number of animal species threatened with extinction continues to grow. Wildlife conservation can be achieved only through rational exploitation on the part of the populations that live in contact with the animals. This is the conclusion of an African wildlife study in which CIRAD participated. As sources of foreign currency, activities connected with wildlife — tourism, game breeding, commerce and hunting — weigh considerably in national economies. Wild animals are essential both as food for man, especially between harvests or in times of penury, and for ecosystem balance. A renewable natural resource, like the forest, wildlife could be used sustainably. It is a question of survival: not taking care of wildlife, like not tending the farm, will lead to its demise.

■ **Depollution and use of slaughterhouse waste in Africa.** The Transpaille fermentor, which was developed by CIRAD and installed at Thiès, in Senegal, can treat 480 tonnes of slaughterhouse waste annually, while producing biogas equivalent to 13,000 electric kilowatt hours and 55 tonnes of compost. As well as enhancing organic matter, the compost is used for potted seedlings which facilitate the planting out of market garden crops. A lagoon unit, an ecological filtering technique which is simple and inexpensive, recuperates liquid effluents. Organic matter is disintegrated by bacteria, then absorbed by algae. This treatment of solid and liquid waste separately saves water and energy and is also an original depolluting technique. And through sales of the compost, it is also a new way of bringing in income.

THE WEALTH OF

The tropical plant and animal world is still relatively unknown. However, knowledge of plant genomes and physiology is at the root of all improvement. New technologies are helping researchers to explore the vast wealth of living organisms, to make the most of what we have.

LIVING ORGANISMS

Hevea rubber: progress in in-vitro cultivation

In the days when Hevea was grown from seed, the crop yielded not more than 1 tonne of latex per hectare. At present the yield is closer to 2 tonnes, due to multiplication by grafting of selected clones. And if the yield were to increase to 3 tonnes? This would imply rigorously homogeneous plantations of trees embodying all the characteristics of the selected clones. Microcutting and somatic embryogenesis are two in-vitro techniques making undeniable progress in producing true-to-type saplings.

The in-vitro Hevea cultivation programme: to obtain homogeneous trees and plan for the genetic transformation of the plant.

For a long time, Hevea was multiplied by sowing the seeds found beneath the trees. Now, clones derived from a varietal improvement programme, which yield about 2 tonnes of dry rubber per hectare, are multiplied by grafting. But this technique results in a two-tiered tree: the bottom, whose root system, developed from rootstock produced from a seed, is young, unselected material; the top, or trunk and crown, which has been grafted from a selected tree at maturity. It is a composite tree, whose top benefits from selection and whose rootstock contains unknown diversity. This is why the grafted tree produces less than the tree from which the graft was taken and why two à priori identical clones produce different quantities of rubber.

THE TAPPING YIELD

Today the tapping yield, i.e. what each tree produces at each tapping, is what a planter looks at when extending or renewing his plantation. Yield should be the same if possible from one tree to the next so as not to waste the time of increas-

Propagating Hevea microcuttings.

ingly expensive labourers. The homogeneity of the trees on a given plantation becomes an economic consideration and can heavily influence latex production.

Uniform reproduction of entire trees by in-vitro cultivation is the only method envisaged for progressing along these lines, but it has not yet been achieved.

The Institut français de caoutchouc launched a programme of cultivating Hevea in-vitro 15 years ago with this objective. CIRAD and the Côte d'Ivoire Institut des forêts (IDEFOR) are partners in the programme, which makes full use of the Laboratoire de biotechnologies appliquées à l'amélioration des plantes tropicales (biotechnology applied to tropical plant improvement) and of the contamination-free greenhouses in Montpellier. The Institut des forêts supplies the plant material and carries out field trials. The programme has now entered the crucial preindustrial stage.

Microcutting and somatic embryogenesis were both explored simultaneously to keep as many doors as possible open in what promised to be arduous research work.

Well-rooted trees

In 1987, a basic technique of microcutting stem fragments resulted in the production of saplings from seedlings. The enormous potential of this led several private firms to join with CIRAD in setting up the SMH, Société de microbouturage de l'hévéa, whose objective was to perfect and micropropagate selected material. SMH did not reach the development stage and had to close down in the unfavourable economic environment of 1993. But what of the method itself?

There are several stages involved in microcutting. For first growth, stem fragments with latent axillary buds are cut from the plant that is to be reproduced. These fragments are disinfected, then placed on a gel medium containing growth hormones, cytokinine and auxin. Small-leafed stems emerge from the buds after a month. For multiplication, the new stems are

These Hevea, planted in Côte d'Ivoire, are derived from microcuttings. They show excellent growth and rooting.

fragmented and planted out on a new medium. At the stabilized stage, the unselected material has a multiplication coefficient of 2 to 2.5 every 3 weeks, while that of clones such as IRCA 18 and PB 235 is between 1.5 and 2. In the conditioning stage, stem tissue matures and leaves thicken before roots are induced. Roots develop in compost in an acclimatization cell. Seventy per cent of 25,000 seedling-produced saplings and of several hundred clone-produced saplings were successful.

In 1992, the SMH used this method to produce 23,000 plantlets, 18,000 of which were from selected material: 15,000 plantlets came from the IRCA 18 clone, 2,000 from the IRCA 111 clone and a few hundred from the PB 235 and PR 107 clones. However, once in the greenhouse acclimatization stage, their growth was very slow.

This setback could not be foreseen prior to tests under real conditions and naturally meant taking up research again. It did not, however, discredit microcutting. In fact, the first microcuttings obtained in the laboratory and planted in Côte d'Ivoire in 1983, as well as the microcuttings from nonselected material which have been planted in field trials since 1988, cover 10 hectares at present and consistently produce well-rooted trees with normal above-ground development. They grow as quickly as trees produced from seed. Tapping trials will begin on 2 hectares. And, as a world première in 1993, microcuttings of selected clones were planted in the open, with a new series to follow soon. The

Plantlets ready for shipment.

trees will be compared with those produced by conventional grafting.

Embryogenic suspensions

Somatic embryogenesis was the second method we explored to reproduce entire Hevea trees. A tissue fragment is taken from a tree selected for its traits. Other laboratories use anthers, but CIRAD chose to use the inner seed coat because this mother tissue retains the selected genotype. Six or seven successive cultures lasting about 3 weeks each are necessary to obtain a plantlet. The preparation goes through the following stages: callogenesis initiation and embryogenic induction; appearance of proembryos; development of embryo (becomes visible to the naked eye); embryo maturation, during which it stocks reserves and develops its germinating faculty; germination; growth of the plantlet to the two-leaf stage. The plantlet is then acclimatized in compost, either in a greenhouse or in a protected germ-free nursery, and after 4 months is planted in the field.

Several hundred plantlets have already been obtained from four clones of industrial interest — PR 107, RRIM 600, PB 235 and PB 260. The first three of these clones were used in field trials in 1992. They started well and developed normally. Other samples will be planted each year.

The biotechnologies laboratory has been encouraged by these results to develop somatic embryogenesis for large-scale production. But two problems must be solved before plantlets can be produced at acceptable cost. First, the tissue culture has to go through a stage of intense multiplication of the embryogenic calluses; embryogenic suspensions capable of regeneration were obtained for the first time in 1992. Second, only 10 to 15 out of 100 embryos germinate and develop into a plantlet. This yield — the best obtained so far by any laboratory — must be increased.

Large-scale performance

The Hevea in-vitro cultivation programme is at present concentrating its energies on somatic embryogenesis with the aim of adapting the technique to a large number of clones already planted or in final selection and setting up field trials in several Hevea-growing countries. Microcutting is still a possible solution for those clones that do not respond to somatic embryogenesis.

How high are the stakes in this in-vitro cultivation? The demand for natural rubber for specialized use is growing. In 10 years, the supply of latex may become insufficient, since the number of hectares given over to Hevea has reached a standstill and the existing plantations are aging. The need for quality plant material will be urgent. Before then, CIRAD hopes to develop techniques for implementing its in-vitro cultivation programme on a large scale. Moreover, genetic transformation of Hevea necessitates in-vitro cultivation. These improvements to "the rubber factory" could lead to 3 tonnes of rubber per hectare, a revolution in Hevea growing.

For further information:

CIRAD-CP
Programme hévéa
BP 5035
34032 Montpellier Cedex 1, France

Projet IDEFOR-CIRAD
Station de Bimbresso
BP 1536
01 Abidjan, Côte d'Ivoire

Discovery of the genome

Molecular biology has provided access to plant genomes and, consequently, to almost unlimited prospects of variety improvement. Genome mapping of banana, cocoa and sugarcane is progressing well and could become extremely useful to breeders.

Taking advantage of biodiversity. Wild banana trees, which provide seed-bearing fruit, are used in the selection process.

Although genome mapping of the human species and several breeding animals is already at an advanced stage, that of plants, particularly tropical plants, has been slower. And yet the need is urgent; according to FAO, we must continue to increase agricultural production, especially in the developing countries, if we are to feed the world population of the year 2000. To do so without further harming the environment, we will have to breed plants, in various climates and soils, that are resistant to pests and disease, more productive and less dependent on fertilizer.

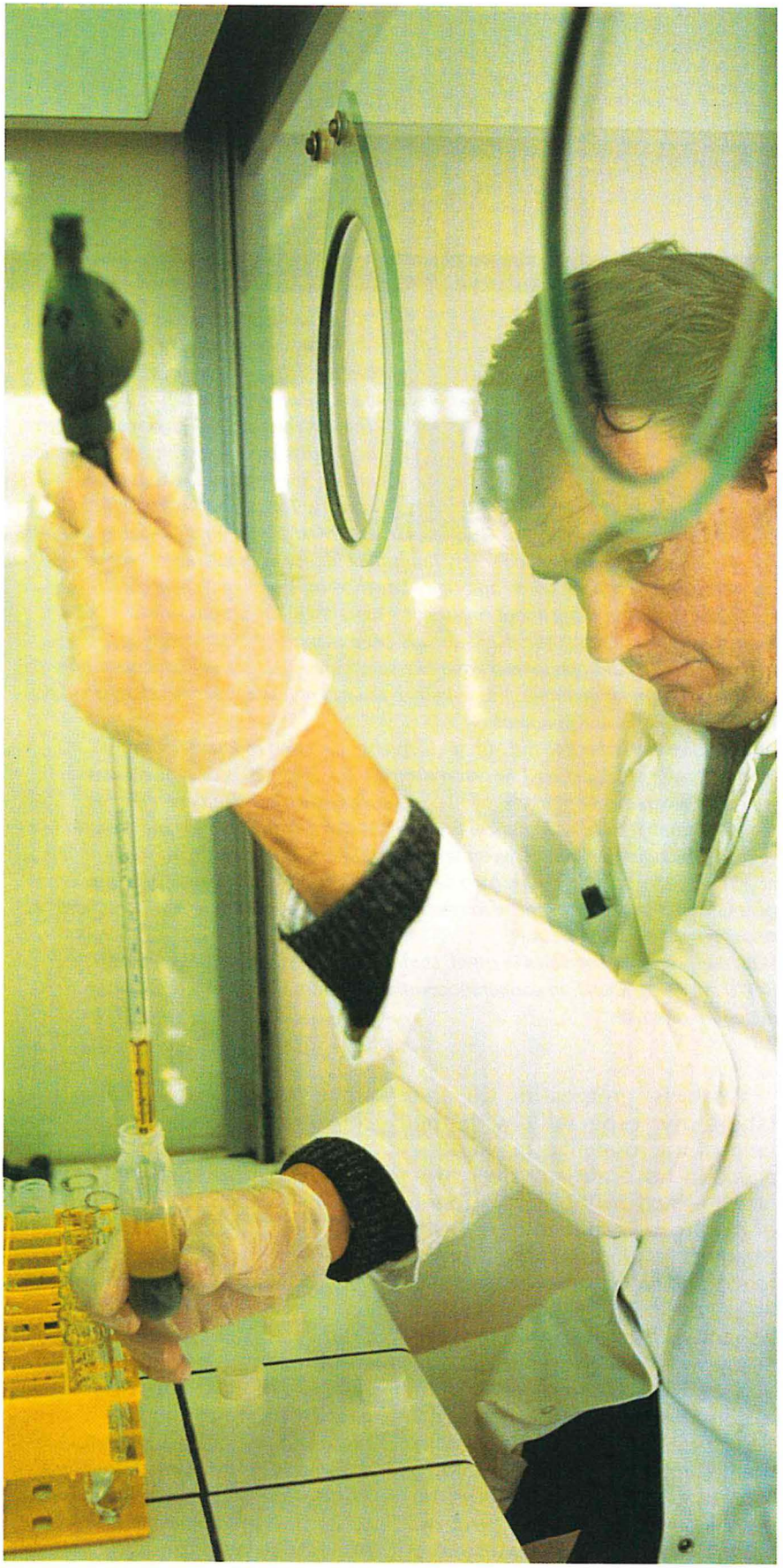
BASIC DATA

Developments in biotechnology can be of help here. Molecular labelling techniques may soon make it possible to single out the genes on the chromosome responsible for particularly interesting agronomic traits and to understand how these are transmitted to progeny. The best parents for cross-breeding could be identified more quickly and accurately, while less land would be needed for test planting. This would save space and time, which is of particular importance in view of the already long biological cycle of the plant.

What is genetic labelling? The polymorphism affecting the genes of any one species ensures that no individual progeny of sexual reproduction is exactly like another. Certain methods, such as electrophoresis, can be used to study protein variability, the expression of only a fraction of the genome, whereas techniques of molecular biology detect DNA polymorphism, i.e. the entire genome.

One of these techniques, known as restriction fragment length polymorphism (RFLP), is the most widely used and CIRAD has already adapted this technique for use with many tropical crops. More recent genome labelling methods now complement RFLP, e.g. random amplified polymorphic DNA (RAPD) and microsatellites. The development of these markers has provided biologists with new tools for genome mapping.

How is a genetic map drawn up? The principle is to tag the plant genome evenly with as



The molecular data obtained in the laboratory will then be compared with the observations made in the field.

many markers as possible. When polymorphic markers from two parental lines have been selected, we then seek to map them, i.e. tag them on chromosomes to study their segregation in the progeny. We know that, during meiosis, the closer the genes carried by one chromosome, the less likely they are to segregate independently. On the basis of this genetic law, we assemble, then arrange markers in linkage groups. The closer together the two markers, the more likely it is that they will be transferred together to the progeny. This same property then enables us, by observing the markers, to estimate the position of the genes responsible for the agronomic traits observed in the progeny.

Enemies of the banana

CIRAD began by mapping several high-priority crops, chosen because of the complexity of their genetic determinism and the economic implications of their improvement in their producing countries. These were banana, cocoa, sugarcane — the study of which we present in this document — and sorghum and Hevea rubber.

We think of the banana as an export fruit and often forget that it is a basic commodity for millions of people: the plantain

banana ranks among the world's first ten most widely consumed crops.

The banana's worst enemies are fungus disease — cercospora and fusarium — and weevils. All production zones have varieties which are more or less resistant. But all are at the mercy of attack by a virulent species or strain. Consequently, the priority of CIRAD's genetic improvement programmes is resistance to pests and disease.

The first mapping was performed for the diploid banana *Musa acuminata*. Two maps were drawn up from two progenies: an F_2-type progeny, resulting from the cross-breeding of a cultivar and a wild diploid and a progeny resulting from the self-pollination of a synthetic hybrid. The first map contains 77 markers which are assembled into 15 linkage groups; 13 other markers segregate independently. The second contains 56 markers which are allocated to 14 linkage groups. This map is used as a basis to establish the chromosomal zones responsible for variations in quantitative traits, or QTL (quantitative trait loci). We have already found 10 regions of the genome involved in the expression of those traits. At least two loci appear to control resistance to black cercosporiosis, in particular.

Field observations

According to a preliminary assessment, the banana genome is small, like that of the tomato. If this is confirmed, about 120 to 170 markers will be needed to locate one in every 10 centimorgans (cM, recombination unit).

Sugarcane, a grass among others

The astounding potential represented by the application of molecular biology to plant genomes can be seen in the case of mapping sugarcane.
The varieties of cane grown today stem from cross-breeding with a wild species in Java and India at the turn of the century. The plant's interspecific origins endowed it with a complicated and little-known genetic structure which sorely limits the efficacy of conventional breeding.
CIRAD researchers decided on an original method for studying its genome.
We know next to nothing about sugarcane's more than 100 chromosomes. But maize's 20 chromosomes have already been mapped to a large extent, and maize is an Andropogoneae grass like sugarcane. Two closely related species may have largely similar genomes (this is known as synteny). Why not use maize markers to study the sugarcane genome?
After studies carried out in the Montpellier laboratory and in Guadeloupe, 88 markers were tagged on 100 chromosomes. The hypothesis of synteny was validated when the 34 markers involved reproduced in the sugarcane genome the same arrangement as in maize. Bridging, as in this case between maize and sugarcane, could be done between the other grasses, wheat, rye, rice, sorghum, etc., according to recent work done by other laboratories. In which case, sugarcane could benefit from the advances made in research on major cereals to which considerable resources have been allocated.
With these new perspectives in mind, studies on the leading Réunion variety R 570 are going ahead, in cooperation with the Centre d'études, de recherche et de formation. ■

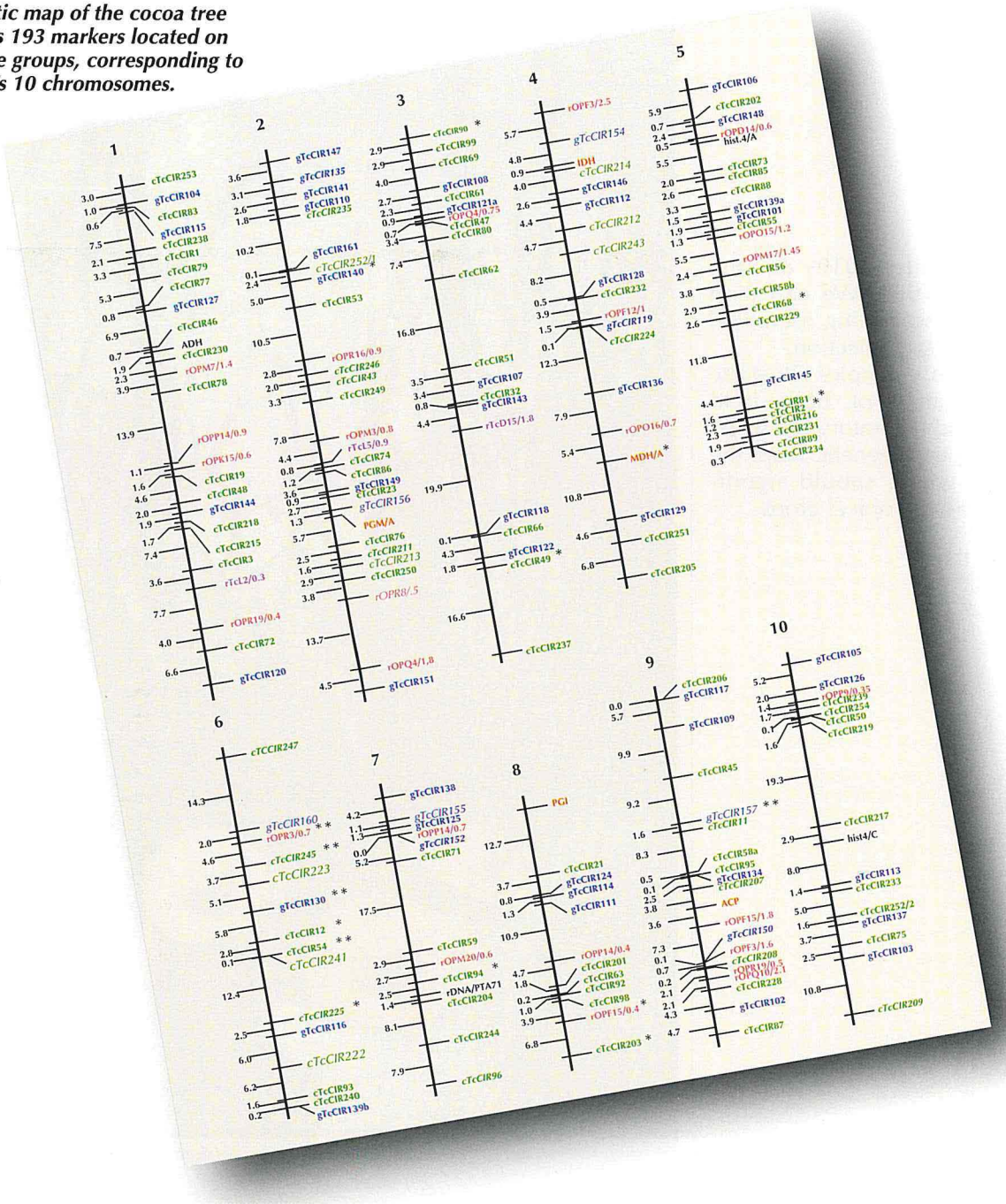
Work is progressing in the laboratory, especially with the help of microsatellite markers — a dozen have already been isolated — and in the field. Clones of the progeny studied have been planted in parallel in Guadeloupe and in Cameroon, with the help of the Centre régional bananiers et plantains. They are being analysed morphologically and agronomically. The field observations will soon be compared with molecular data, with the first results expected in 1996.

Even greater progress could be made by genome mapping of perennial crops, such as cocoa, since these crops have long selection cycles and their agronomic performance becomes evident only after several years.

Unsuspected riches

The cocoa tree, *Theobroma cacao*, is a very variable species containing mainly three genetic groups: Criollo, Forastero and Trinitario, a hybrid of the previous two. Criollo produce the finest chocolate but are disease-sensitive and not widely grown. The hardier Trinitario, and especially Forastero, are grown world-wide. A molecular marker study of their

The genetic map of the cocoa tree comprises 193 markers located on 10 linkage groups, corresponding to the plant's 10 chromosomes.



diversity, already well advanced, reveals the hitherto unsuspected genetic riches of Criollo.

In order to make use of this diversity in a classic selection scheme, it would be necessary to understand the genetic determinism for resistance to disease (mainly *Phytophthora*) and for cocoa quality (content of butter and aromatic components, size of beans, etc.). The genome map of the cocoa tree should help. On the plant's 10 chromosomes we can locate the genes, or portions of the genome, responsible for these traits.

The first map was drawn up from progeny of 100 individuals planted in Côte d'Ivoire, resulting from a cross between two heterozygotes. At present the map contains 193 markers, 160 of which are RFLP, 28 are RAPD and 5 are isozymes located on 10 linkage groups, which would correspond to the cocoa's 10 gametic chromosomes. It measures 759 cM and the average distance between two markers is 3.9 cM, which means it can already be used for trait marking and for marker-assisted selection.

The Institut des forêts is helping to collect agronomic data in Côte d'Ivoire. We hope to

locate the first QTL on the genome by 1994. We can then use the corresponding identified markers for early selection.

These two examples illustrate the importance of both field selectors and laboratory biologists in drawing up a genetic map, the results of which should significantly improve tropical crops.

For further information:

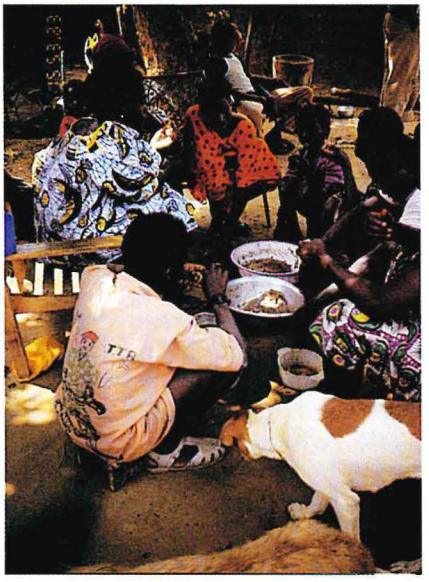
CIRAD-GERDAT
Unité de recherche
sur les biotechnologies appliquées
aux plantes tropicales
BP 5035
34032 Montpellier Cedex 1, France

The search for "quality" sorghums

In one corner, the traditional sorghums, the staple diet for millions of people in semiarid Africa; in the opposite corner, the improved sorghums, very productive but scorned by consumers because they simply do not like them. In an attempt to reconcile quality with productivity in this dietary match, breeders have sent genetics and technology into the ring.

Sorghum, which is well adapted to semiarid tropical regions, was domesticated in Sudano-Sahelian Africa and in India millenia ago, and is still the staple cereal for millions of people. Sorghum and its products are so much a part of their tradition that we can speak of "sorghum civilizations".

It is not surprising, therefore, that researchers sought to increase sorghum productivity in the face of growing food deficiency; and they succeeded: in 20 years, sorghum varieties have been created which can yield 7 tonnes per hectare.



Around a dish of tô in Mali (above). Breeders use traditional sorghums whose seeds give good tô (opposite, in Togo)

A KIND OF FIRM PORRIDGE

Why haven't farmers rushed to adopt these productive varieties, even though they recognize their agronomic qualities? Above all, because the consumers find they lack the cooking quality of their traditional sorghums.

The quality of grain is a very subjective concept. Here we are dealing with those characteristics which enable housewives to prepare their traditional dishes, the best known being tô, a kind of firm porridge which entails dehulling the grains with a

pestle, winnowing, pounding to a fine flour, then cooking with water. The dish can be found under different names throughout southern Africa and in India.

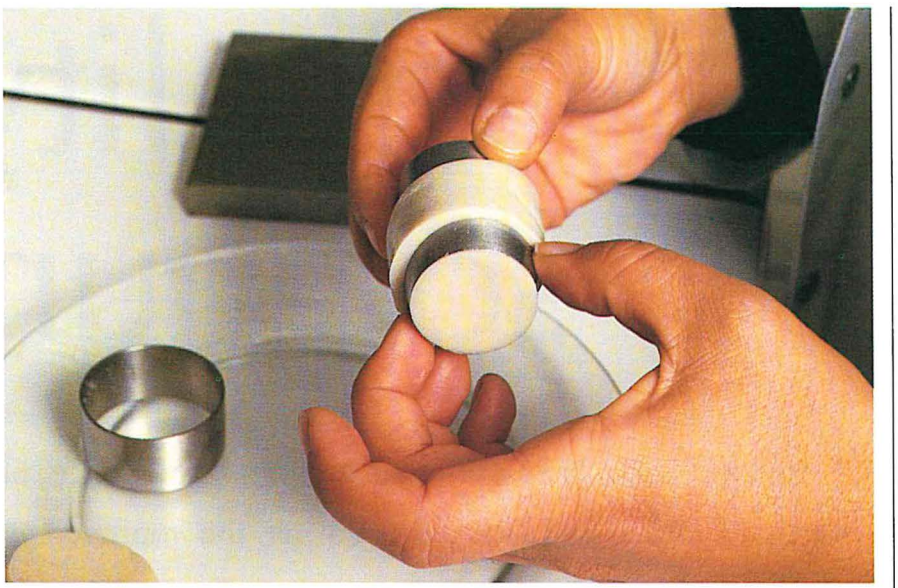
"What makes a good tô?" is therefore an essential parameter in determining which variety should be included in an improvement programme, and the choices to be made in selection.

Consumer surveys carried out with the help of the Mali Institut d'économie rurale revealed that the primary criteria are the firm consistency of the tô and its ability to be conserved overnight, since the leftovers are eaten the next morning. Far less important are colour and taste, since accompanying sauces can make up for deficiencies in these traits.

Overnight conditions in Africa

The aim, therefore, was to discover which variables contribute to the firmness of tô. Each variety of sorghum was studied on the basis of the physical properties of its grain (hardness, vitreousness, dehulling yield) and the physico-chemical properties of its flour (lipids, proteins, amylose content, swelling capacity and solubility of the starch, consistency of the tô).

Pâtons (small samples) were made in the laboratory after observation of the way housewives prepared tô. Their texture that represents tô quality was measured after about 12 hours at 35°C, simulating conditions of an African night. The pâtons are pressed between a piston and a plate until they break, and measurement of the resisting force is expressed in Newtons.



Tô samples tested for firmness.

Statistical analysis of the measurements showed that the flour's amylose content was the variable which was best correlated with tô firmness; 75% of it could be explained by this variable. Local varieties contain more than 25% amylose and produce a very firm tô which resists up to 25 Newtons. By contrast, tô made with low amylose varieties remains liquid. Consumer tasting was used to formulate a value scale, which is now available: the tô is rejected under 10 to 12 Newtons; it is considered good between 12 and 15; excellent over 15.

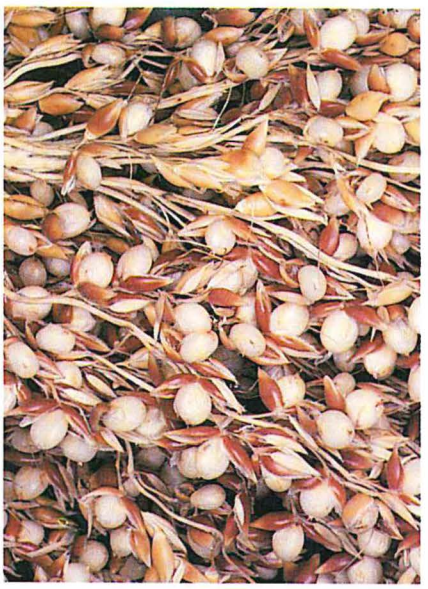
Another important characteristic, affecting dehulling, is grain hardness. Hard grain has a good dehulling ability, chafes uniformly, without breaking. It is usually vitreous, whereas soft grain is floury. Preferable to both is a semivitreous grain which has a good dehulling ability and produces fine flour. Hardness is measured, according to a "particle size index", as the percentage of ground grain passing through a 250-micron sieve. We seek an index of 16% or less.

So we now know the need to select relatively hard grain sorghums with high amylose content.

Distortions

As the *guinea* race of traditional sorghums has these properties, well appreciated by housewives, breeders want to include them in variety improvement programmes, despite their low productivity.

However, we have had to address two major difficulties. The quality sought is not retained in cross-breeding, and yield is reduced.



Sorghum of the* guinea *race,* margaritiferum *group, a source of improvement that is beginning to be used.

To obtain valid data, we undertook simultaneously a genetic study of *guinea* sorghums and investigated the distortions observed in the *guinea* progeny crossed with improved varieties. Results of practical interest are already available.

Study of the genetic diversity of *guinea* sorghums by morphological and electrophoretic methods was undertaken in the wider framework of sorghum analysis financed by the EU, to discover whether all uses of this race as improvement material had been exhausted.

Among the four races of sorghum cultivated as a cash-crop, *guinea* has the greatest diversity.

Guineas are polyphyletic. We have determined at least two centres of domestication, western and southern Africa. Other *guineas* constitute a third group with no identified geographic base. They are distinguished by their early maturity, small very vitreous grains, rather short stems and abundant sprouting. These are the *margaritifera*.

Breeders are incorporating this latter group as improvement material into the cross-breeding programmes in Mali.

No incompatibility

Simultaneously, we wanted to determine why it is so difficult to obtain progeny recombining the parent qualities when we cross the improved *guinea* with a high-yielding variety. Was this due to an abnormal trait segregation, resulting in an unbalanced reversion of the progeny to the traditional variety?

Progeny distortions revealed the dominance of certain *guinea* traits, such as height, photosensitivity, loose panicle. No marked difficulty in recombination or partial sterility of the hybrids was found. There is, therefore, no incompatibility, contrary to what we had feared.

Nevertheless, the effects of this dominance are considerable, which means it is unlikely that we will obtain interesting progeny. This considered, it would seem preferable to use methods which do not select plant material too rapidly, e.g. the bulking method, uniparous pedigree selection.

The biotechnologies laboratory in Montpellier is looking for molecular markers (RFLP) associated with those genome zones that affect high amylose content and grain hardness in order to identify the genes which express these traits. We will then be able to spot all the efficient recombinations at each stage of selection.

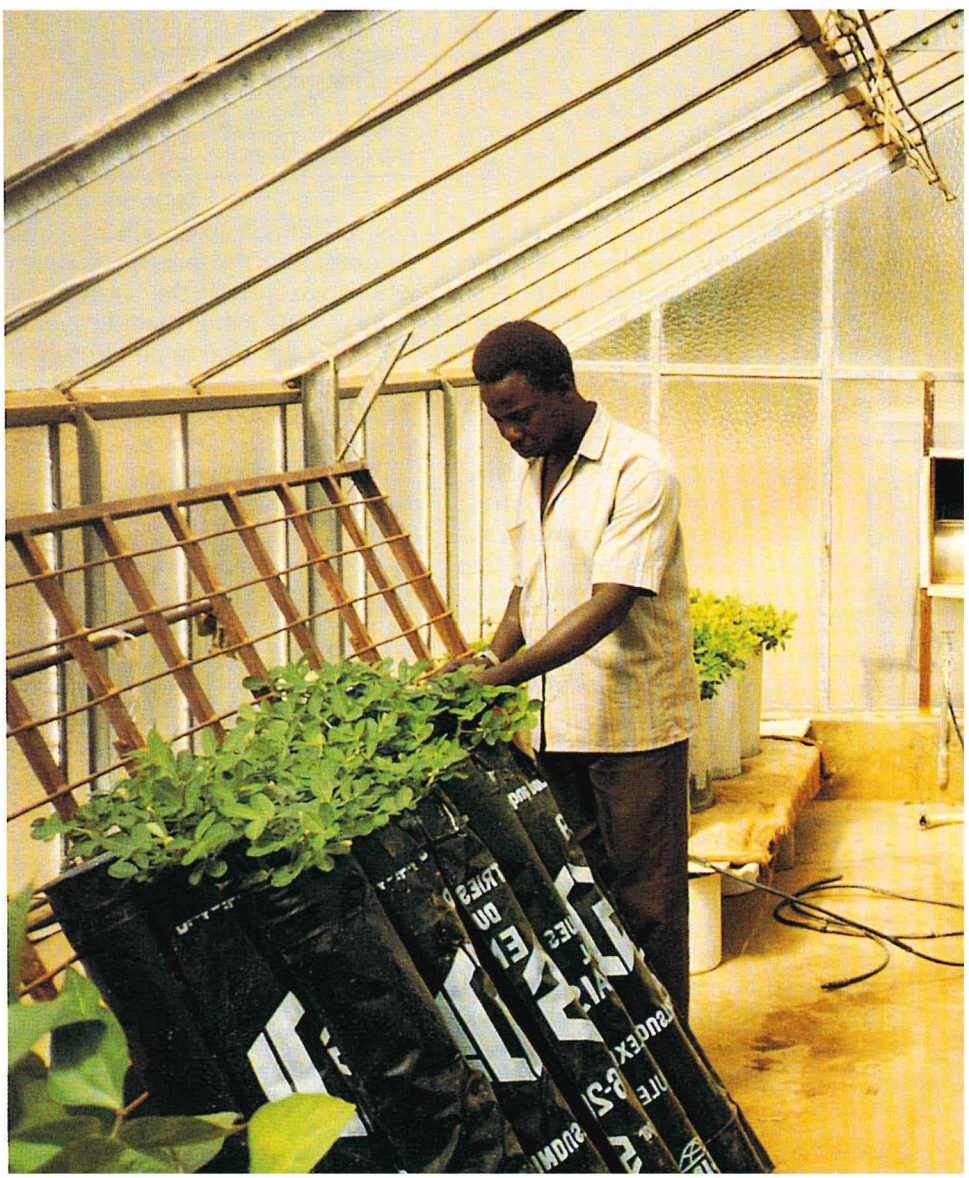
The repercussions of this work on sorghum improvement programmes have already been considerable. *Guinea* sorghum involvement in cross-breeding has increased from none to 25% in Burkina Faso and to 75% in the programme run by CIRAD and ICRISAT in Mali. They will probably be very useful in the European Union project "Diet preference of sorghum products in southern Africa", which aims to develop semi-industrial food products to stimulate production.

For further information:

CIRAD-CA
Programme cultures
vivrières paysannes
BP 5035
34032 Montpellier Cedex 1, France

Adaptation of plants to drought

Africa is still threatened by drought. Now, more than ever, it is vital to create varieties tolerant of arid conditions. Strategies for crop improvement can be pursued only if the physiological mechanisms that enable plants to survive when there is a lack of water are better understood. In a regional programme strongly backed by the EU, about 100 researchers share methods and equipment and are already working on the adaptation of 18 crop cultivars.



Greenhouses, irrigable experimental plots and laboratories are used to simulate all drought conditions.

Receiving researchers is the CERAAS vocation.

Added to the chronic lack of water in the Sahel, "natural catastrophes", or abnormally long drought periods over the past 20 years, underline the need to shape strategies for adaptation, so that farmers can recover or acquire self-sufficiency in food production. One of the responses of the international community to this need has been to set up CERAAS (Centre d'étude régional pour l'amélioration et l'adaptation à la sécheresse) (regional study centre for improvement and adaptation to drought) within ISRA. CIRAD has provided scientific support since the beginnings of this new body, whose aim is to find lasting solutions through cooperation on all fronts.

Support for the project

The creation of varieties that can withstand the present drought conditions cannot be obtained without an understanding of the mechanisms which allow plants to adapt to lack of water. The very notion of drought has to be defined according to a specific crop. CERAAS has set out to determine at what critical phases plants become sensitive to drought so as to specify the aims of variety improvement. Drought simulation during different phases of the plant cycle reveals effects on yield. The mechanisms which give rise to the observed reactions can be discovered through a physiological approach. Ideotypes for adaptation are defined and, after a study of the variability and heritability of their desirable traits, a selection programme is set up. For speedy and reliable results, this programme is structured around the physiological testing of a great many individuals with the collaboration of agroclimatologists, agronomists, physiologists and breeders who belong to member institutes of CORAF and CILSS, or to Brazilian, French, Belgian or Portuguese research establishments.

When the European Commission decided to finance CERAAS

The yam-bean (above) is one of the 18 species studied for its capacity to resist drought.

Right: observation of the groundnut's root system.

in 1989, they were convinced of the validity of its scientific project, its multidisciplinary research and its regional impact. Then, in November 1993, they backed up their support with a 4-year grant of 6 million francs to the project "Physiologie de l'adaptation à la sécheresse et création variétale pour les régions sèches". Half of this went to CERAAS, the other half, to its partners on the project: Institut du Sahel, the Lisbonne Faculty of Science, l'Université libre de Bruxelles and l'Université Paris VII. And that's not all. The European Development Fund is to grant CERAAS 12 million francs to add to its infrastructure and equipment and broaden its training programme.

What has CERAAS achieved since its foundation barely 4 years ago to merit such international renown?

100 RESEARCHERS

The main mission of CERAAS is that of a research centre. There are laboratories, a great deal of equipment, greenhouses and irrigable experimental plots where drought conditions can be simulated. It is a place of scientific methodology where researchers can compare their experiments. Fifty-five researchers have already worked on secondment at the centre, some for as long as 6 months. Moreover, two training workshops have been organized. The first, at Bambey, brought together 20 researchers on physiological aspects of adaptation to drought with relation to varietal selection. Twenty more participated in the second, in Pobé (Bénin), on tree adaptation. Today there are about 100 members of this scientific community pooling methods and tools for research on the adaptation of plants to drought.

Researchers work on different projects, and, after assignment by CERAAS, each works on his own plant material. The practical importance of what is being done can be illustrated by three examples.

In 1990, a Malian researcher brought with him a range of sorghum varieties which he had obtained by mutagenesis. Physiological studies, especially the rhizotron study of their root

system, revealed that one of them was particularly well equipped to withstand dry periods. On the other hand, it lacked anchoring roots and was liable to lodging. Back in Mali, the researcher focused his selection work on this variety and obtained a new variety which is both adapted to drought and resistant to lodging. It is now in the preliminary stages of extension. Apart from this success, the methodology clearly established a correlation between rhizotron results and field observations, i.e. the reliability of observations made in a controlled environment, which permitted faster selection.

Promotion in Africa

Cassava has to withstand dry periods of 6 to 7 months in many parts of Africa. A researcher from ISRA came in with several IITA varieties with interesting potential from more humid regions. He wanted to perfect a test to select those which could survive local drought conditions. This capacity was quantified through a measure of leaf tissue cell tolerance of dehydration. A correlation was established between the plant's cell membrane integrity percentage and its agronomic performance. From now on this test will be used in cassava selection.

The yam-bean (*Pachyrizus* sp.) is an interesting case. This legume, indigenous to Latin America, produces big, succulent tubers which are rich in protein, plentiful forage and seeds that can be used as an insecticide after fermentation. All these qualities make its promotion in Africa especially desirable, so CERAAS is studying its capacity to withstand drought. Tests revealed potential yield under irrigation to be 100 tonnes of tubers per hectare, and in the arid conditions of Bambey, 30 to 40 tonnes per hectare. This is an example of research "off the beaten track", adapting exotic species to local conditions. Crop diversification is another means of combating drought.

After research carried out on 18 crop cultivars, an inventory was drawn up of the physiological mechanisms active in adaptation to drought and the tests devised are being used for selection in several countries.

Work that interests several partners will be undertaken, thanks to the EU grant. There will be faster transfer of effective technologies to arid zone countries, thanks to cooperation among the regions and with the North. This concerns not only the Sahelian regions of Africa but 220 million hectares in a similar environment throughout the world.

The origins of CERAAS

CERAAS originated from the programme for groundnut improvement in the arid zone of Bambey, which resulted in varieties adapted to the two major climatic regions of Senegal. ISRA and CIRAD were innovative when they brought together physiologists and breeders, laying the basis for the scientific method later adopted by CERAAS. The conference organized in Dakar in 1984 on "Résistance à la sécheresse en milieu intertropical: quelles recherches pour le moyen terme?" (Resistance to drought in an intertropical environment: what policies for medium-term research?), followed by CORAF's creation of the Réseau de recherche sur la résistance à la sécheresse (research network on drought tolerance) were responses to the need to seek resources and organize research with an international dimension. ■

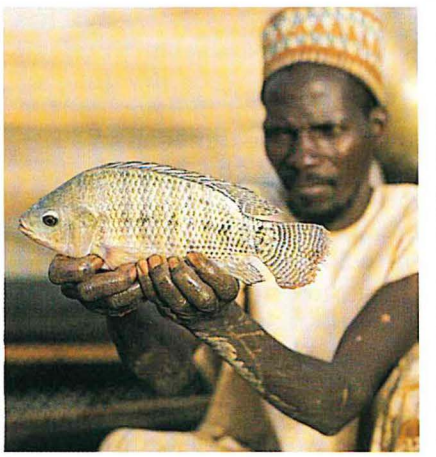
For further information:

CIRAD-CA
Programme cultures
vivrières paysannes
BP 5035
34032 Montpellier Cedex 1, France

CERAAS
CNRA
BP 59
Bambey, Senegal

Thermal treatment to replace hormones?

World-wide production of tilapia is about 500,000 tonnes per year. Tilapia costs less than meat and is the most widely consumed fresh-water fish in Africa. But fish farming of only the male tilapia is profitable. CIRAD has been experimenting with a thermal treatment which might be one of the most economical methods of obtaining male tilapia populations without endangering man's environment.



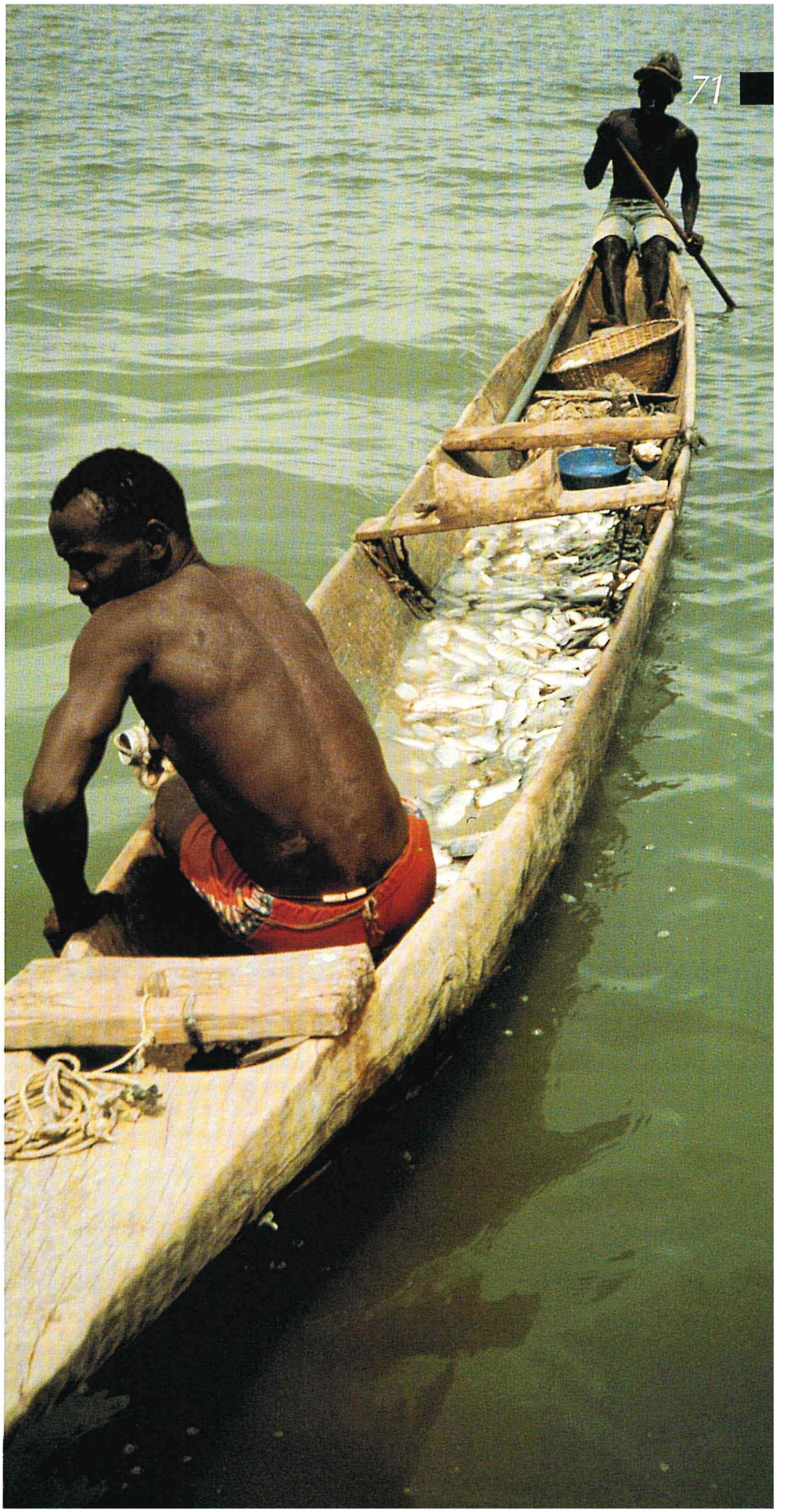
Oreochromis niloticus is the most widely bred species of tilapia; it has one of the best growth potentials and is particularly adaptable to the environment.

Tilapia's reproduction process, unlike that of other fish-breeding species, must be halted to enable the fish to develop flesh; it is so prolific that it hampers its own growth. Tilapia reproduce all year round, laying eggs up to once a month. The fry are protected by the mother and their mortality rate is low. They reach sexual maturity early (between 3 and 4 months). If males and females are left together in a pond, the fish multiply rapidly; this overpopulation induces dwarfism, especially in the female, and exacerbates reproduction which takes place more frequently.

Forced fasting

However, consumers are choosy. In Asia or in some African countries, such as Côte d'Ivoire, tilapia buyers are not interested in fish smaller than 250 grams.

Because of the period of forced fasting which she undergoes at the time of incubation and the energy she expends in reproduction, the female *Oreochromis*



Fishing in the Niger. The depletion of natural fish stock encourages fish farming development.

is always smaller than the male and uninteresting for the fish farmer. Therefore, a farmer usually separates the sexes to avoid reproduction and keeps only the males, who can then grow.

There are only two techniques available for this procedure at present. The first consists of manually sorting the males from the females when their sexual dimorphism becomes apparent, between 2 and 3 months. This is time-consuming and only possible on a small scale and, until sorting, the fish farmer feeds twice as many fish as he will actually rear. Moreover, the method is far from foolproof, since 3% to 10% of females are not sorted out. So several months after the first sexing, the females and the already hatched fry have to be fished out again. The second technique, of hormonal sex inversion, is used mainly by big producers (Israel, Taiwan, Philippines). An artificial steroid, 17-alphamethyltesterone, is added to the fry's food for a month from the time it has exhausted its vitellus, to masculinize the fry regardless of its sexual genotype. The fish farmer's infrastructure is thereby fully utilized from the very first months. This technique, however, has its detractors, including consumers who are wary of hormone-treated animals. Although used throughout Asia and Israel, it is banned in Europe because it releases into the environment about 30 derivative products whose effects are as yet unknown.

Less risk

Another sure and non-polluting method for obtaining exclusively male progeny needs to be devel-

oped. CIRAD has explored three ways of understanding sex determinism in tilapia: physiology, genetics and the influence of external factors (particularly temperature). Its partners in this research were the Institut des savanes (IDESSA) in Côte d'Ivoire and the laboratory of fish physiology at INRA.

Studies of the sexual differentiation of tilapia were performed on normal fry populations. The period of testicular differentiation was determined by histological observation: the first signs of this process appear in the 50-day-old fry, 3 weeks after ovarian differentiation. On the hypothesis that steroids, the hormones governing secondary sexual characteristics, and secreted by the gonads, could also be involved in sexual differentiation, research centred on discovering hormones specific to ontogenesis at the moment when the gonads become testes.

Two steroids were identified. They were mixed with food for the fry at the same dosage as that of 17-alphamethyltesterone, resulting in 100% males at the end of treatment. This research is undeniably of immediate interest: the natural molecules (or their true-to-type copy synthesized in a laboratory) are broken down more easily by the fish than artificial steroids; their use, instead of artificial hormones, therefore presents less risk for the consumer, the fish farmer and the environment.

MAMMALIAN SEX DETERMINISM

Genetic manipulation in fish was another possible approach. The present hypothesis is that sex determinism in the tilapia is mammalian: the females are homogametic (XX) and the males heterogametic (XY), the Y chromosome determining the male sex. If we managed to obtain viable and fertile homogametic males (YY), their breeding with a classic female (XX) would produce monosex male progeny of genotype XY.

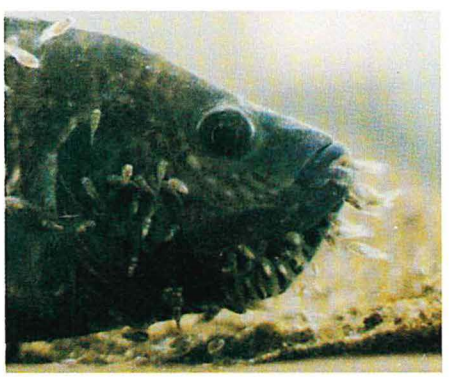
We were indeed able to obtain viable and fertile YY males by breeding genotype XY females, which had been functionally feminized by hormonal inversion with classic XY males. But, contrary to expectations, their progeny are not always exclusively male. How to explain this aberration? Several hypotheses have been put forward. The species used by the researchers might not have been pure, so the results would be biased. Sex determinism in tilapia might be more complex than supposed. And finally, sex differentiation in tilapia might be influenced by environmental factors, particularly temperature. It was this last approach that CIRAD researchers chose to follow.

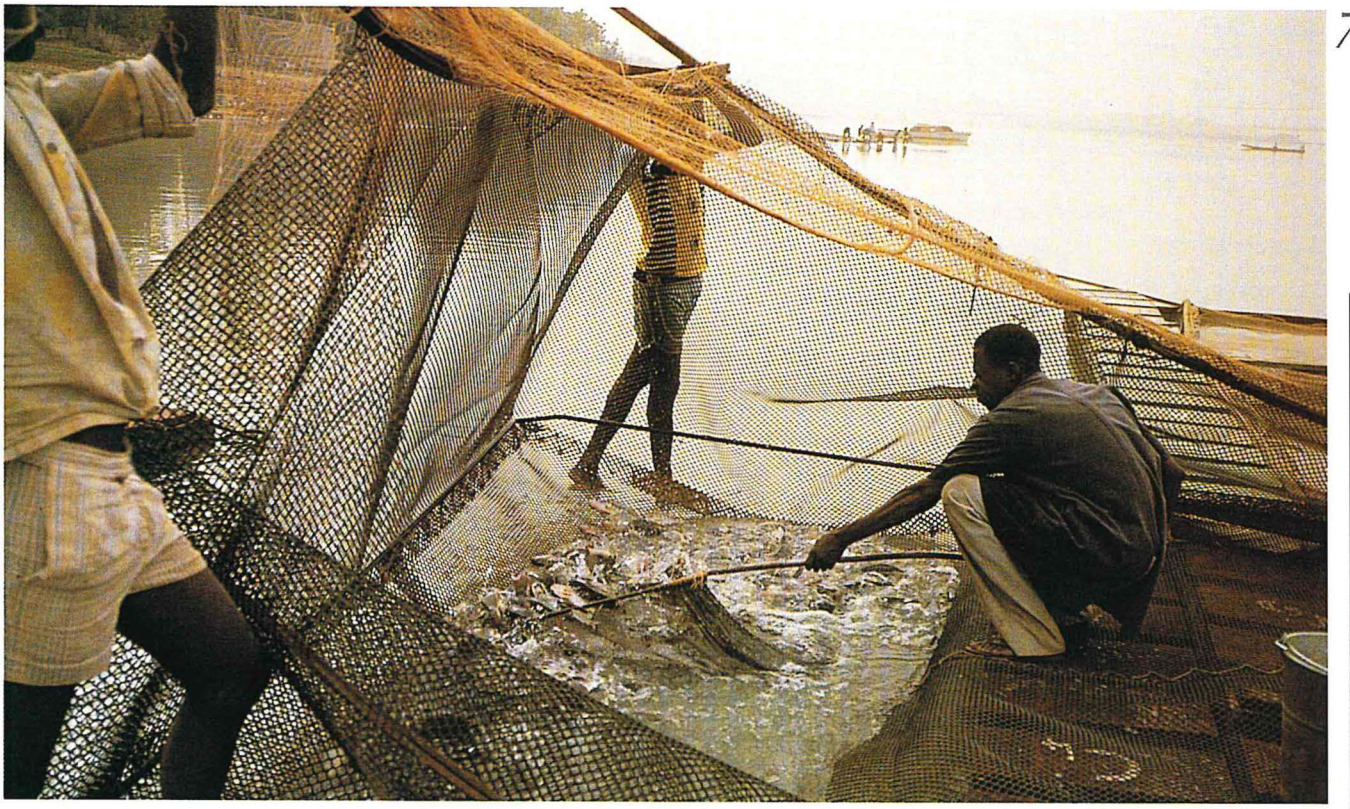
100% MALE

Why temperature? The sexual differentiation of turtles, crocodiles and some amphibians is influenced by this factor. Moreover, the researchers concluded after observations in the breeding ponds that high temperatures appeared to increase the male ratio. The researchers created parents of monosex female progeny, i.e. genotype XX males, by hormonal inversion. Their progeny was divided into two groups and reared under constant

Parental behaviour of tilapia

Tilapias are cichlids of African origin comprising about 50 species belonging to three types: Tilapia, Sarotherodon *and* Oreochromis. *The* Tilapia *scatters its eggs to protect them from parasites and to oxygenate them, whereas the* Sarotherodon *and* Oreochromis *behave in a quite different way. The female* Oreochromis *lays her eggs in a nest and, after they have been fecundated by the male, takes them in her mouth to incubate them at 27°C. They hatch 4 days later. Then for a week, several hundred to 2000 fry hustle about in her mouth until they have exhausted the vitellus, or food reserve. When it comes time for them to feed themselves, they leave their mother, shelter timidly in groups, only to dash back at the slightest sign of danger. This partial mouthbrooding behaviour gives the mother some time to eat. But only after 3 weeks, when the fry finally become independent, will she again begin to feed normally. Until the next laying....* ■





Tilapia consumers are choosy: fish smaller than 250 grams are hard to sell.

temperatures, one under 27°C, average for tilapia fish farms, the other under 36°C. Thermal treatment was applied from the 10th to 14th day after fecundation for 21 days, the period when the fry seems most sensitive to external factors.

Between 27° and 34°C there was no significant change in sex-ratio as compared with that observed at 27°C. When temperature was above 34°C, however, the percentage of males obtained at the end of treatment increased. But there was no temperature threshold above or below which the population became 100% monosex, as there is for turtles and crocodiles. Moreover, the progeny is differentially thermosensitive. According to the progeny, deviations from the norm in the sex ratio are variable — they can be as high as 91% of males under the same experimental temperature of 36°C — which suggests parental influence.

The experiments gave the same results with conventional populations. The maximum obtained to date is 98.3% of males. Research along these lines is therefore continuing. Differing thermosensitivity among individuals of the same population and among populations of the same species is now being studied to select the best fish. Thermal treatment is also being improved. It would appear that treatment can be shortened if applied at the right time. The main objective is still to obtain a 100% male population at the end of treatment, since as little as 5% of females in a pond can cause considerable economic loss.

For further information:

CIRAD-EMVT
Programme
aquaculture et pêche
Groupe aquaculture continentale
méditerranéenne et tropicale
BP 5095
34033 Montpellier Cedex 1, France

Projet IDESSA-CIRAD
BP 633
Bouaké, Côte d'Ivoire

Other Highlights

■ **Aromatic rice.** The market for naturally aromatic rice is expanding fast, especially in Europe. But development of high-yield aromatic varieties has been slow because of the lack of information about aroma-producing volatile components. CIRAD and ENSIA research has shown that the aroma component in rice is acetyl 2-pyroline, and the genes responsible for synthetizing this component have been localized. These results have led to breeding programs designed to obtain varieties that combine conventional qualities with aroma. The use of markers is accelerating the selection process which interests Vietnam, Laos and several African countries.

■ **Regeneration from rice protoplasts.** Protoplasts are cells which have been enzyme-treated to strip them of their pectocellulose wall, thus making them accessible to gene transfer and somatic fusion. A method of plant regeneration using protoplasts has been perfected and successfully applied to various tropical and Mediterranean rice varieties of agronomic interest (Miara, Ariete, Pygmalion, IRAT 177). At the French rice centre, progeny obtained from Miara showed good variation for certain agronomic characters. The technique is being extended to the Thaïbonnet, CT 53 and IRAT 308 varieties.

■ **Hevea, agroforestry and biodiversity.** In Indonesia, Hevea rubber is grown mostly by small farmers in a form of plantation called jungle rubber, a farmed forest. More than 5 million people live off this ecosystem, which covers more than 2 million hectares of fragile terrain. It has nevertheless maintained a plant cover structure and a biodiversity comparable to that of secondary forests. Ways must be found to safeguard the functions of this original system and at the same time improve farmers' incomes: high-yield Heveas, encouragement of other crops...etc.

■ **Mapping the hevea genome.** Study of the Hevea genome is based on three populations planted in Côte d'Ivoire: an F_2 created by self-fertilization with a cultivated clone, an F_1 resulting from a cross between this same clone and a wild clone resistant to the *Microcyclus ulei* mould, and finally a population obtained from back-crossing an F_1 individual with one of its parents, the cultivated clone. About 100 RFLP and RAPD markers and about 10 microsatellites have already been identified in the parents. Analyses of the progeny have begun. Measurements of resistance to *M. ulei* will be carried out in French Guiana. For this, F_1 and the population obtained by back-crossing will be duplicated by grafting in Guiana. The F_2 will be used to analyse latex production and growth.

■ **Latex diagnosis.** The production potential of the Hevea tree can be deduced by analysing four biochemical parameters of latex along with an agronomic assessment. Several drops of latex are taken from about 40 trees at a relatively stable vegetative period, not during foliation and defoliation phases. The sampling should be representative of a homogeneous area covering 15 to 100 hectares. The physiological status of the rubber-producing tissue is analysed from data concerning total solids, sucrose, inorganic phosphate and thiol content. This is a simple method of avoiding over- or underexploitation and can be used by industrial planters to rationalize production.

■ **Irrigation of clementine.** It should be possible to adapt irrigation of a clementine orchard to micrometric variations in the branches or fruit. INRA has patented a system of captors, Pepista, which takes daily measurements of the organ's diameter and amplitude of contraction, both of which are related to fluctuations in the plant's water uptake. Availability of water in the soil is not the only reason for the variations observed. The plant reacts, if only briefly, to abrupt changes in its environment: heavy rain, prolonged diminution of sunlight, low nocturnal temperatures, hygrometric variations. The geographic orientation and the nature of the branch being measured can also influence variations. All these effects must be considered when looking for signs of real water stress.

■ **Rattan plantations in Southeast Asia.** World trade in rattan — cane and other finished products — amounts to about 30 billion francs, and Southeast Asia supplies almost all of it. Demand is increasing, but natural resources are being dangerously depleted, to the point where urgent investment in vast planting programmes is required. CIRAD is associated with a Malaysian partner, ICSB, in a programme of rattan genetic improvement and planting. The genetic resources of the main species are being collected. The genetic variability of the two commercial species, *Calamus manan* and *C. subinermis* is being studied. Moreover, it would seem that the only way of multiplying certain species of rattan is by in-vitro cultivation. A joint biotechnology laboratory set up in Sabah can theoretically produce 250,000 plantlets per annum. The main species to be produced initially will be rattan — especially *Calamus manan* because of its high market value — and two ligneous forest species.

■ **A new product: decorative pineapples.** The primary aims of the pineapple genetic improvement program — currently conducted in Martinique — concern the fruit, which is intended either for export or for canning. Other ways of using the plant have been explored in the context of this program. New hybrids produced by crosses between wild forms, presenting original aesthetic qualities, could be developed for cut-flower and green plant markets, to be cultivated in pots or in a garden. These decorative pineapples would thus widen the range of horticultural products on offer.

■ **Fresh-water fish biology and physiology.** Biological and physiological study of reproduction in several species of African fresh-water fish show that three species, *Lates niloticus* (thread-fin), *Parachanna obscura* and *Heterobranchus isopterus,* can be bred. The thread-fin especially, with its remarkable growth potential, could be bred in single culture or associated with tilapia to regulate the chaotic fry proliferation of the latter. Moreover, successful hormone control of its reproduction, a first in this research, will provide year-long supplies of thread-fin fry.

BIRTH OF

Agro-industries are being set up on-farm in many parts of the world. This trend might well meet a threefold challenge in that it could supply quality foodstuffs to the cities, produce energy and materials, and encourage people to remain in rural areas.

AGRO-INDUSTRIES

Cassava sour starch, a rural agro-industrial product

Cassava decomposes as soon as it has been harvested, so the Indians of Latin America learned long ago to preserve it using different processes. One of these, used in Colombia, Ecuador, Brazil, Paraguay and as far away as northern Argentina, results in a fermented or sour starch. This product in flour form rises during cooking, and therefore can be made into several

Small loaves made from sour starch, a traditional cassava product.

Extracting starch in Ecuador: sieving operation.

When rural communities organize themselves to process their produce, they have greater bargaining power in the market. Rural agro-industry improves community living conditions by creating jobs and curtails the exodus of populations towards the cities. This is why Latin America has launched a programme to develop agro-industries in crop-growing areas. In Colombia, the example of cassava sour starch shows how research can help growers recognize the weak links in their production processes and remedy the situation with technical help.

types of bread, often with cheese, and biscuits.

FAMILY ENTERPRISES

A market for this type of product resulted from urbanization in the 1960s and numerous *rallanderias*, or small, usually family, processing units set up near cassava farms. CIRAD and CIAT set about studying the 200 or more *rallanderias* in the Cauca *département* of Colombia because they saw in them an example of the type of rural agro-industry which could keep people from leaving their land. The programme, "The Production, Processing and Marketing of Cassava in Northern Cauca", brought together the university and development and finance agencies. Two local foundations, recognized for their experience in the field and their role in community development, CETEC and SEDECOM, were responsible for coordinating the project. CIRAD studied the weak links in the process chain, improvements in the manufacturing procedures and the quality of sour starch, as well as new uses for this product.

The *rallanderias* in Cauca consume between 50,000 and 60,000 tonnes of fresh cassava

PRODAR: An eight-country experiment

The experiment in Colombia is to be allied to the development programme for rural agro-industries in Latin America and the Caribbean, PRODAR, set up in 1989 under the aegis of IICA with help from CIRAD and CRDI. This programme is based on the premise that the exodus of rural populations toward the cities can be restrained only if the quality of life can be improved and jobs created in rural communities. For small growers, the best, if not the only, way of making a real profit from their work and of penetrating the market is by managing, at least partially, the processing and marketing of their produce. It is with this in mind that PRODAR encourages the creation or development of rural agro-industries. National networks have already been set up under their aegis in eight countries: Argentina, Bolivia, Chile, Colombia, Ecuador, Guatemala, Panama and the Dominican Republic. In these countries, the relevant state authorities have been mobilized to inventory production units and evaluate the sector so as to assess projects for creating rural agro-industries. PRODAR has also piloted some interesting farmer training schemes. ■

roots per annum, usually bought as standing crop by the *rallanderos* directly from the grower. About 5000 families live off cassava cropping on small farms of 1 to 2 ha. Yields are relatively low at 8 to 10 t/ha. Nine-tenths of the production are for processing into sour starch; the remainder is for home consumption. Each *rallanderia* handles between 1 and 5 tonnes of cassava per day, i.e. a weekly starch production of 2,000 to 7,000 kg. The family aspects of the production unit are evident: in 88% of cases, the *rallanderos* own the unit and 94% of them live at the site; production costs include 72% for raw materials, 8% for labour and 2% for management. Farms and processing units are closely bound by economic and cultural ties. On an economic basis, highs and lows of cassava overproduction and dearth oblige the *rallanderos* to look elsewhere than in the region for their cassava, posing huge problems of transportation and storage.

A NOTABLE INNOVATION

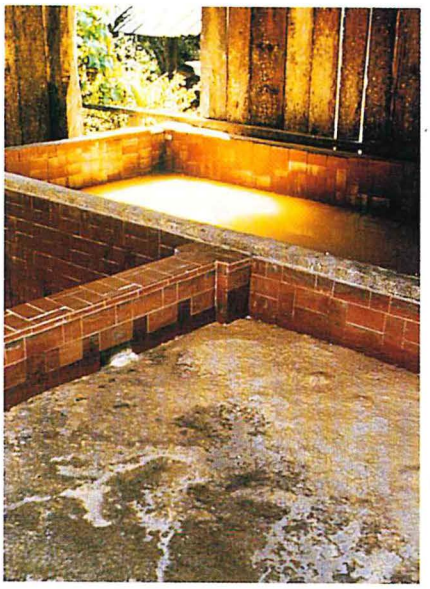
Innovation dynamics have a lot to do with the family aspect of the *rallanderias*. They have very little investment capital, so the *rallanderos* respond more readily to improvements in their processing unit than to management improvements which might lead to dismissing part of the work force.

With this in mind, researchers looked for ways of improving the starch manufacturing process in order to increase yield, rationalize labour and reduce drudgery.

The conversion of cassava into sour starch traditionally follows these steps: the roots are peeled and washed, then grated and sieved; decanting separates water from starch, which is fermented naturally under anaerobic conditions for 3 to 5 weeks, then dried in the sun and finally sieved and packaged. The production process of almost all the *rallanderias* is about the same, and it is this process which could be improved. It produces relatively little: 100 tonnes of roots yield approximately 21 kg of sour starch, with a loss of about 25%.

The most notable innovation is in decanting. In the traditional process this is done in deep vats which are difficult to manipulate. The decanted water carries off with it a fair amount of starch. Researchers proposed another system modelled on those used in Brazil and Madagascar and in potato starch works in Europe: canal decanting. A *rallanderia* volunteered to test this technique. The 50-cm deep canals serpentine over 120 m with an incline calculated to allow the water to move at the speed of 4 to 10 m/minute necessary for correct decanting. This system does not cost more than the traditional vat and yield is increased by 10%. Furthermore, the work is a great deal easier. This pilot production unit quickly caught on: in 1 year, more than 40 Colombian *rallanderias* were equipped. The technique was also tested in Ecuador and Paraguay and is making inroads there.

Drying is still done in the sun, on wattles. Experiments with artificial drying methods always resulted in starch that was devoid of the rising quality desirable for cooking. It thus appears that ultraviolet rays act as a catalyst in sour starch expansion.



Starch decantation: the canals replace the vats. The work is less arduous and losses are restricted.

INDUSTRIAL USES

The *rallanderos*, who have little marketing experience, sell 90% of their production to a few intermediaries. They have very little information as to how their produce is received or even used, and have not shown any interest in creating new markets. And yet, users and uses are many and varied. Bakeries sell hot *pan de bono* and *pan de yuca*. Small and medium businesses manufacture packaged flakes which are sold at corner stands. Multinational companies sell quantities of compound flour and ready-to-use mixes through supermarkets. One cooperative, the Coopracauca, markets 10% of the region's sour starch provided by about 15 cassava growers and *rallanderos*. They obtain higher selling prices and marketing feedback has encouraged several of the members to set up quality standards. But because of lack of capital and ready funds, the experiment has not spread, even though standardization of the market for starch would strengthen the farmers' position.

Other outlets do exist, if only the *rallanderos* looked at what is being done in other countries. In Ecuador, industrial uses have been found for nonfermented starch. One example is cartons for banana packaging. An agreement between a group of cassava growers and starch producers (UAPPY) and a carton manufacturer ensures regular provisioning and quality control, under the watchful eye of CIAT and CIRAD.

Research into the industrialization of cassava starch processing could interest countries other than Colombia, and indeed beyond Latin America. African starch-producing countries could well profit from the process that has been developed.

For further information:

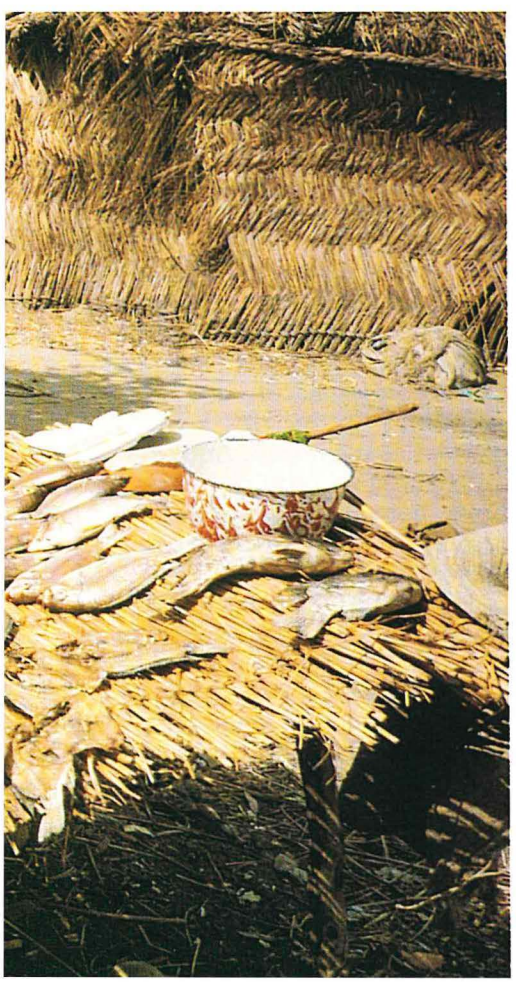
CIRAD-SAR
Programme défis alimentaires urbains et promotion des entreprises
BP 5035
34032 Montpellier Cedex 1, France

Retaining fresh-food quality in preserving processes

Man has always sought ways of preserving food for later consumption, such as sun-drying fruit or smoke-drying meat. Dehydration-impregnation by immersion, a preserving process that, on an industrial scale, is simple and economic can be used in tropical countries to add value to agricultural and fish products.

Food dehydration by immersion in a concentrated solution is one of the world's most widely used preserving techniques: saturated salt methods (brining and salting) for meat, fish, vegetables, and the sugaring of fruit.

The method consists of immersing the foodstuff in a solution rich in sugar or salt. Two exchanges of matter then take place simultaneously and in opposite directions: some of the water contained in the food is released into the solution, and salt (or sugar) penetrates into the food. Generally, this latter transfer is encouraged, while we attempt to limit food water loss. In the case of fruit sugar-preserving, the fruit is treated beforehand — by parboiling, freezing or adding sulfite — in order to partially destroy the cell membranes which could block absorption of the solution. The product is dipped several times into increasingly concentrated solutions, which takes days, sometimes weeks. This method could be used to different ends: by altering the duration of immersion or the concentration of the solution, we could obtain greater dehydration and less penetration of the solution.



Drying in the sun: a traditional process for preserving fish.

Industrial development

These processes are known as dehydration-impregnation by immersion (sometimes called osmotic dehydration). Their possible applications in the realm of food technology are innumerable. But it is necessary to control the cross-flow between the foodstuff and the solution and develop equipment which would allow the technique to be applied on an industrial scale.

With these two objectives in mind, CIRAD undertook to apply the process to the semi-sugar-preserving of tropical fruit and to procuring aromatic concentrates; then, 3 years ago, it began to apply the technique to the salting and drying of meat and fish.

Semi-sugar-preserving of fruit has developed recently in Southeast Asia in a fast-expanding market. The fruit is cut into small pieces and partially crystallized by immersion, then moderately dried.

Researchers determined the varying conditions of the process for several tropical fruits (pineapple, papaya, mango, banana): maturity, size of the pieces, type of pretreatment, composition of the solution, temperature, duration of immersion, drying method. They also tested several ways of keeping the fruit immersed without damaging it by agitating the solution. Two treatment principles have been patented.

Trap the vitamins

Experiments performed demonstrated the potentials of dehydration-impregnation by immersion, and industrialists interested in the technique have signed contracts with CIRAD. Used for pretreating in conventional processing, it improves the quality of the end product and saves energy.

The foodstuffs keep their nutritive qualities and taste. Rapid prestabilization — fruit loses 50 to 80% of its water in under 3 hours — under oxygen-free conditions, is particulary useful in tropical regions. In traditional air-drying, the long stabilization process causes fermentation and moulding of the fruit. Moreover, since the osmotic dehydration process is carried out under 20° to 50°C and in a liquid phase, most of the vitamins and aromas are trapped in the plant tissue. The superficial layer of sugar that forms on the fruit also prevents loss of very volatile aromatic components and stabilizes pig-

Optimal conditions for dehydration-impregnation by immersion are established in the laboratory.

Semi-sugar-preserved fruit conserve most of their vitamins and aroma.

ments during the drying and storing processes that follow.

Another advantage: the technique is energy-saving compared with artificial drying, mainly because water is extracted without a change in phase and because exchanges between solids and liquids are better than those between solids and gases. A comparative study revealed that drying fruit after it was pretreated by osmotic dehydration used 2 to 7 times less energy than drying fresh fruit.

This simple and rapid technique has been set up at fruit-producing locations; small semi-sugar-preserving units have been installed in Nigeria and Réunion, for example. Other projects are under development in Thailand, Vietnam, Guinea, Côte d'Ivoire and India.

Strong aromas

Alongside the research done on semi-sugar-preserving, CIRAD has developed a new application for the technique: cold manufacture of aromatic concentrates. Introducing osmotic dehydration before pressing fruit or vegetables results in exceptionally aromatic and tasty juice extracts. Researchers have come up with concentrates of lime, strawberry and mango.

Now that food-solution exchanges and the necessary technical equipment have been understood and perfected, researchers are turning their attention to syrups. In the course of the operation, the syrup in which the fruit macerates is diluted and has to be reconcentrated. ENSIA and CEMAGREF are studying syrup longevity, readaptation and possible added value as strongly scented and tasteful ingredients in pastries, jams and fruit wines.

Salted and dried simultaneously

The idea of using dehydration-impregnation by immersion in salting and drying meat and fish is more recent, but seems to be extremely promising.

Work in association with IFREMER over the past 3 years has resulted in the development of a new process, now patented, for salt-drying and cold-smoking meat and fish. It is unique, partly because salting and drying are performed at the same time.

The traditional technique consists of three successive stages: salting (dry or in brine), drying and then smoking. This presents some inconveniences. The use of dry salt or brine results in relatively rapid salting but the product loses hardly any water, so it has to be dried further before being smoked. And drying and smoking require temperatures between 15° and 20°C, favourable to the development of bacteria.

The CIRAD method of dehydration-impregnation by immersion for animal products is carried out at low temperatures (between 2° and 10°C). The foodstuff is simultaneously salted and dried through immersion in a concentrated solution of salt (NaCl) and sugar. The sugar molecule, which is larger than that of salt,

Meat and fish are salted and dried simultaneously in a solution containing sugar and salt.

remains on the surface of the foodstuff without penetrating it, controlling salt penetration and inducing water loss.

A crystallized mixture of salt and sugar can also be applied directly to the product. The instantaneous exudation of the product recreates the conditions of a concentrated solution. This dry method does not require any specific equipment. But it uses more ingredients, since the sugar and unabsorbed salt are thrown away, whereas solutions can be re-used. The treatment also takes longer.

The product is then transferred to a smoking chamber where it is smoked rapidly according to a method developed by IFREMER.

The process is now being applied to fish (salmon, sword fish, thread-fin, tuna). The salt-drying operation is being tried out on an industrial scale by a firm in Sète.

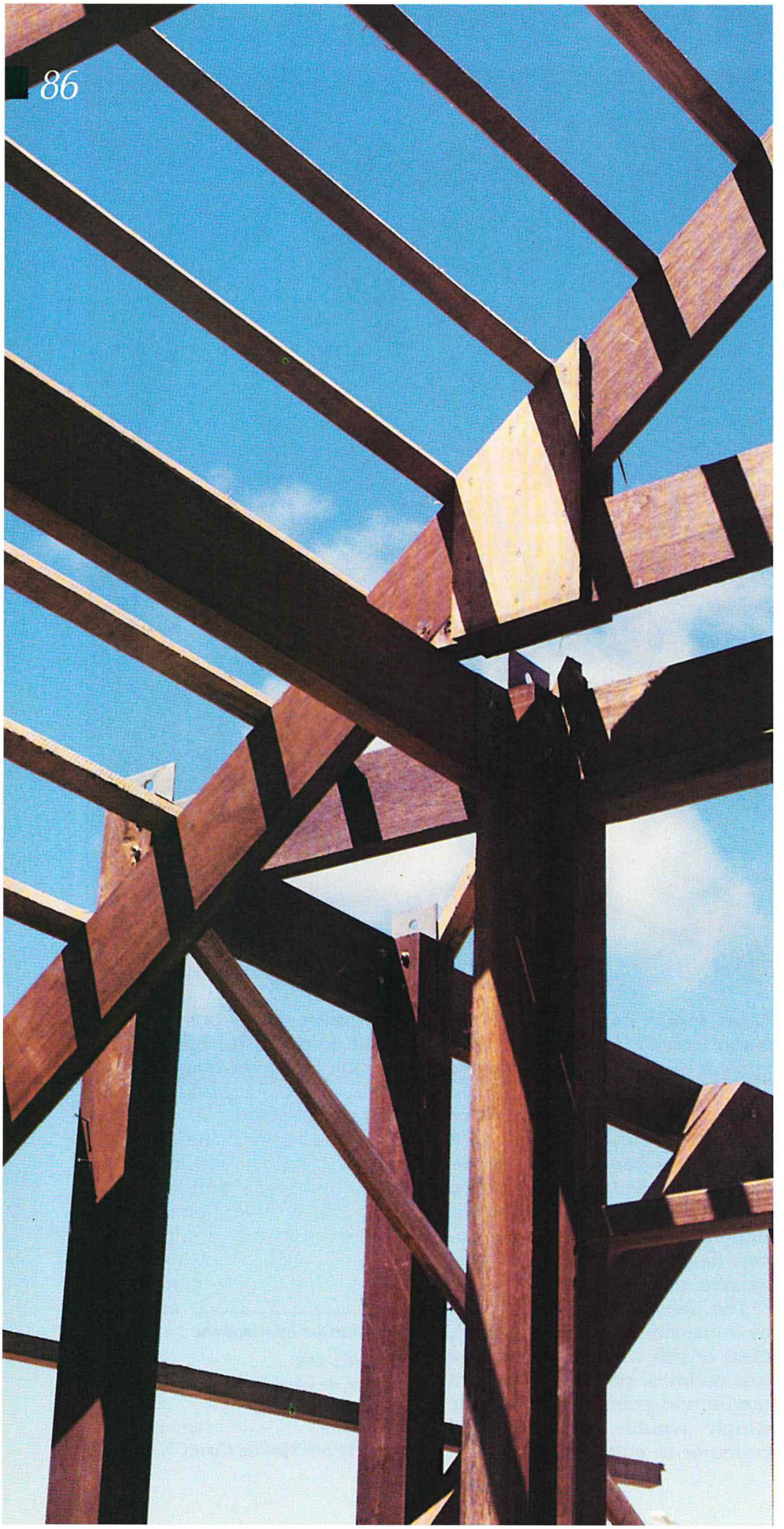
New products

Elsewhere trials are being carried out on meat. Immersion of 2 cm-thick fillets of meat into a solution containing maltodextrines and salt for 40 hours results in products whose water (55%) and salt (3-5%) content are comparable to those on the market (ham, smoked Grison beef). The product can be formulated during immersion if curing ingredients (nitrite, ascorbic acid, polyphosphates, liquid smoke aromas) are added to the solution, thus prolonging its storage time and improving its organoleptic qualities.

The dehydration-impregnation by immersion of fruit, vegetables, meat or fish can be applied to a vast realm of products. This is a simple and economic technique which would allow tropical countries to enter a fast-growing new export market of high value-added products. It is also a contribution to the development and structuring of a budding food technology sector.

For further information:

CIRAD-SAR
Unité de génie et de technologie agroalimentaires
BP 5035
34032 Montpellier Cedex 1, France



The Guianese forest, apart from being a natural laboratory of key importance, especially for research into tree diseases and pests and wood deterioration, is also one of the country's principal resources. Production has remained low, like the country's population, so Guiana has decided to invest in quality and is offering top-grade products guaranteed by the label "Bois guyanais classé".

Timber for building: the need for norms.

Wood products in French Guiana

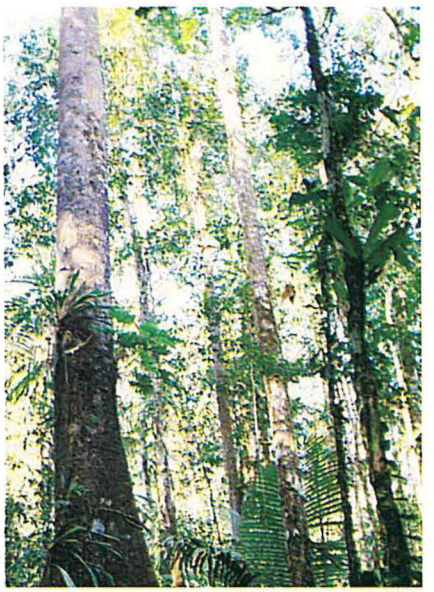
Nine million hectares, of which 8 million are dense forest: Guiana's economic future would seem to be bound to its forest. Indeed, it is the third most exploited natural resource in this French overseas *département*, after the sea — for fish and shrimps — and gold mines.

Rich in flora

The northern part of the Guianese forest, which is accessible, is now well explored. CIRAD was given the responsibility 20 years ago by the Office national des forêts of inventorying tree types, their relative prevalence and trunk diameters.

The Guianese forest, like many primary intertropical forests, is rich in flora, with several hundreds of tree species per km^2. CIRAD has inventoried data concerning the physical and mechanical properties of their wood, their resistance to termites and mould, and their manufacturing qualities.

But yearly timber exports have rarely risen above 100,000 m^3, or the equivalent of the output of one African lumber company. Why? Is higher output possible? Or different output?



More use should be made of the wide diversity of species present in the Guianese forest.

Many tree varieties are present, but they are widely dispersed. No single variety is dominant, like the okoumé in Gabon, or the sipo was in Côte d'Ivoire. Four or five species at most could be considered sufficiently prevalent to be exploited industrially by today's standards. Moreover, the wapa, which covers 23% of the inventoried area, has discouraging technical characteristics: it splinters at felling and exudes a resin which prevents correct finishing.

Small-scale use

The quality of uncut wood is generally not excellent. It is as if the forest were aging badly: many trees are hollow or small. Contrary to the dense African forests, there are few trees with trunk diameters in excess of 70 cm. Also, access to the Guianese forest is extremely difficult. Only about 150,000 ha along the coast are exploited. Construction of roads into the forests is hampered by swamps, flooded zones — annual rainfall is from 2 to 6 m — and bad erosion.

If, in addition to these natural obstacles, we take into consideration the scarcity and high cost of labour, the small home market and the absence of a deep-water harbour, which makes exporting lumber difficult, we can understand why exploitation of forests in Guiana has remained on such a small scale.

Woodworking businesses are also on a small scale. There are fewer than 30 lumberers, most of whom also run sawmills. Out of

A few Guianese wood species

For a long time, Guiana's forests were exploited solely for rosewood, for essential oils, and for balata and its gum; today, other more productive species are forested. Dicorynia guianensis *is a beautiful, hard and heavy wood which can be used, like the oak of temperate climates, for flooring, staircases, banisters... Salmon-coloured* Ocotea rubra *can be substituted for mahogany. The violet* Peltogyne venosa *and the red or yellow* Andira coriacea *are used in cabinet making.* Qualea *sp., although devoid of any aesthetic qualities, is a sound wood for building, and accounts for 25% of production.* Goupia glabra *is used mainly for construction frames. Finally, the most abundant wood of the Guianese forest,* Eperua falcata, *is used mainly for the manufacture of shingle-boards for the home market.* ■

Classifying and marking sawn timber.

25 sawmills in the *département,* 5 handle 80% of total output. The biggest of them handles 10,000 m^3 of raw wood per year. These small enterprises hardly ever employ more than 25 people. Only 2 joineries could be said to work on a semi-industrial scale. Small-scale craftsmen, carpenters, joiners, and cabinet makers make up an industrial production system which is far from organized. Their workshops are usually well equipped, sometimes even overequipped. They number anywhere from 30 to 300 — it is difficult to tell — wood-working being a sideline activity for many of them.

A QUALITY LABEL

Under such conditions, how can a profit be made from wood? First, by renouncing competition with African and Asian types of commerce: large-scale operations in Guiana are out of the question because of the scarcity and cost of labour and the species composition of the forest. On the other hand, it should be possible to benefit from the rich variety of wood and the competence of Guianese craftsmen to market top-quality products.

With leadership from CIRAD, and with its technical support, the timber industry in Guiana has begun to get organized. Standards were defined for raw and semi-raw products (planed planks, construction timber...), as well as for luxury products such as flooring and panelling. The "Bois guyanais classé" label was created. Standardizing wood dimensions and quality has several advantages, e.g. being able to group supplies in order to meet bigger orders and to export under a quality label which attracts customers.

Timber processing, especially drying and treating against termites and mould, has also advanced under CIRAD research guidance.

So Guiana is now offering a range of top-quality products: solid wood panels made from chips of the most beautiful varieties, improved flooring and panelling, wooden houses, sawn shingle-board. These new products make far better use of the many varieties present and increase the forest's usefulness.

NEW IMPETUS

Until recently, annual production was 40,000 m^3 of sawn timber per year (equivalent to 100,000 m^3 of raw timber), 30% of which was exported mainly to the West Indies. But since 1988, the Guianese industries have met with tough and growing compe-

tition from Brazil. The arrival of Brazilian wood in the West Indies caused Guianese exports to tumble to 2000 m^3 of sawn timber. At first, the local market grew, with construction of the hydroelectric dam at Petit-Saut and the development of the space station in Kourou, thus compensating for the fall in exports. But these major projects were completed in 1992. Guiana has also been hit by the recession. Today the timber industries are in a disastrous state: production in 1993 was only about 60,000 m^3 of raw timber; many businesses have closed down.

Faced with this crisis, the lumberers' unions, real estate companies (initiators of building projects in the department) and the Government have set up a regional economic commission on construction and public works, with CIRAD as their adviser. The commission has been charged with finding ways to save the timber industries. First objectives: improve construction quality, clearly define the rules governing construction and see to it that they are adhered to, and, especially, give new impetus to exports. In order to do this the *département* will have to be fitted with harbour structures specific to the timber trade — storage systems, a terminal for wood containers. The abnormally high freight tariffs will then have to be renegotiated with the shipping companies. Then perhaps wood will regain its rightful place in Guiana's economic development.

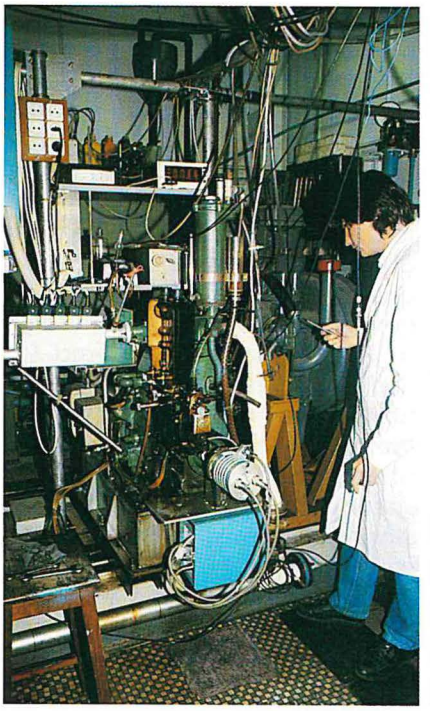
Fixing shingle-boards.

For further information:

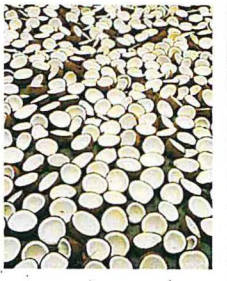
CIRAD-Forêt
Programme bois
45 bis, avenue de la Belle Gabrielle
94736 Nogent-sur-Marne, France

CIRAD
BP 701
97387 Kourou Cedex, France

Plant oils for diesel engines



Run diesel engines on plant oil? The idea isn't new. Before World War II tests had already been successfully conducted with plant oils, which resemble hydrocarbons. But petroleum has retained its supremacy as the most economic fuel. Is this situation changing? Biofuels are exciting new interest in the North as well as in the South, and in some rural regions plant oils could well supplant diesel oil which has become too expensive.



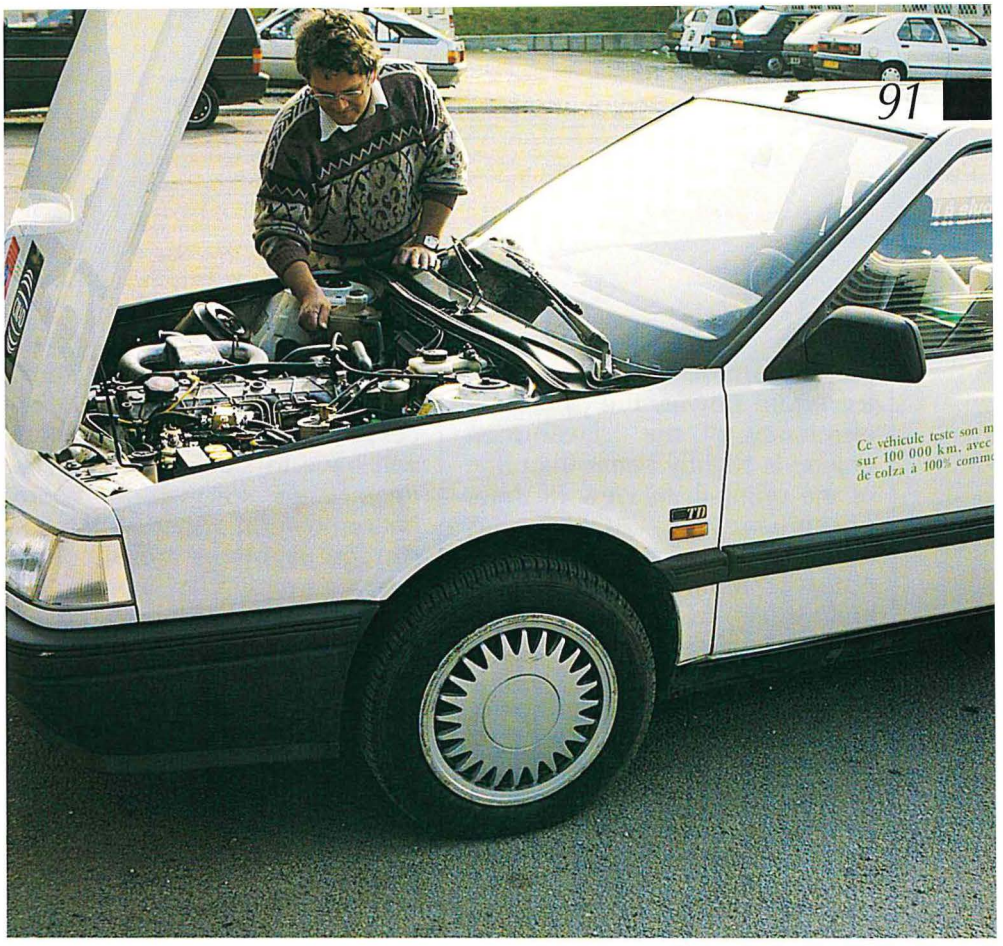
In France today, as well as in Southern countries, oil is used as the only fuel for many vehicles, oil presses, pumps, and power units supplying factories or villages and diesel engines which run on plant oils are being sold industrially. CIRAD has been active in this research field for about 10 years.

COMPETITIVE

A rise in barrel price or currency devaluation — whatever the cause — the developing countries which have no petroleum are paying higher and higher prices. How can we help them find cheaper energy?

These countries may not have petroleum, but they do have huge agricultural potential. Oil-yielding plants such as oil palm, coconut, groundnut or cotton — whose seed is rich in oil — can now be grown with ease and their oils extracted by simple processing at cultivation locations. Plant oils are both renewable and easily accessible.

And yet, until recently, manufacturers of diesel engines — exclusively Northern corpora-



The engine of this Renault 21 Nevada has been adapted by CIRAD researchers to run on colza oil.

tions — have been slow to finance research into adapting their products to biofuels. Why? Because as long as the industrialized countries continued to use petroleum, the market for bioenergies remained too limited.

Today, profitability is not based on such arguments because it also takes account of environmental costs. Under the recent European legislation concerning pollution, plant oil, which is renewable and cleaner than petroleum, can hope to compete against the latter. And subsidies for oil-yielding crops, which are part of the European agricultural policy, have created new interest in biofuels.

Mixed-fuel engine

CIRAD has taken advantage of the new impetus in Europe given to research on energy substitutes to contact companies about marketing plant-oil engines with the usual manufacturers' guarantees.

Engines today hardly resemble the first diesels, which could be run on either oil or diesel fuel. Only indirect injection engines, such as those found in automobiles, can use oil as fuel without too much alteration. Plant oils congeal at higher temperatures and are more viscous than diesel fuel, so it is enough to reinforce the fuel preheating system and add a pump to obtain a mixed engine which can run on either diesel fuel or oil. This alteration should not cost more than 2000 francs when the necessary research is finished.

As a result of CIRAD's cooperation, Hatz France now offers a range of diesel engines which run on all plant oils. Made especially for retail in developing countries, these 5 to 8 kW engines can be mounted on small agricultural machinery: motor pumps, oil presses, grain mills, etc. Deutz, for their part, offer two tractors under 100 horsepower which run on oil.

Endurance tests

More powerful diesel engines — over 100 horsepower — are direct-injection engines which, if run on oil, gum up entirely in a few hours. But trucks, tractors and most farm machinery are equipped with this type of engine. So the stakes are high. CIRAD has collaborated with John Deere to adapt the direct-injection engine to plant oil, since the manufacturer wants to add this model to its tractor range. Research began about 4 years ago, in cooperation with the Orléans University mechanics and energy laboratory. The engine is ready, and John Deere is carrying out endurance tests and checks.

The contract with John Deere authorizes CIRAD to apply the research results obtained to the manufacture of other equipment. The researchers decided to adapt a Massey Ferguson tractor, the most widely sold tractor in Africa, to a fuel composed of 50% fuel oil and 50% plant oil. Work is being financed by the Agence de l'environnement et de la maîtrise de l'énergie (ADEME). Only the pistons, combustion chamber and injector were modified. The prototype is being tried out by a

French farmer. Tests show that, for equal power, the operating efficiency of the transformed engine is slightly better than that of the original. In view of these positive results, ADEME has asked CIRAD to study the possibility of adapting burners for grain driers, to benefit the many rice and maize driers in Southern countries.

In each of these experiments, the researchers carried out tests with oils in different states, from crude to refined, and found that treatment may have an effect on their quality as a fuel. But some elementary precautions are necessary. Agro-industries, which will have to stock fuel, will use degummed oil which keeps better. In rural zones, where no storage problems are encountered as supply can immediately meet demand, filtering the oil thoroughly could well suffice.

IRRIGATE CROPS

The use of plant oils as a substitute for diesel fuel is interesting on more than an energy plane. It could help some countries solve problems caused by overproduction. Big oil palm producers such as Malaysia and Indonesia monopolize the world market to the detriment of smaller, uncompetitive producers, such as Nigeria and Côte d'Ivoire, who have to sell their products on their nonexpandable home markets. Reconverting palm oil to fuel to be used on the spot would be a welcome new opening for this product. The same would be true for cottonseed oil, which is produced in increasing quantity with increased fibre production, and for copra, whose market price has fallen drastically.

The opening of this new market for plant oils could inspire farmers to grow new crops, e.g. curcus oil. This perennial oleaginous euphorbia grows spontaneously in humid or semiarid tropical zones. It is also planted in hedges to protect crops from animal herds. It requires little attention and furnishes up to 600 litres of oil per hectare.

The importance of this research is obvious for developing countries whose economy is based on agriculture. The use of plant oils as fuel means that rural zones which are far from the main supply routes, or even cut off from the rest of the country

Catalytic cracking of oil

When petroleum is in short supply, adapting engines to run on plant oils is not the only possible response. It is also possible to transform oils chemically so they can be ignited in ordinary engines.

One of these processes is the conversion into esters. With good-quality oil, the operation is easy and the results obtained are excellent. However, the biofuel obtained by this process is suitable only for diesel engines. Moreover, the chemical reaction requires alcohol, which is difficult to find except in sugarcane-growing regions, and produces glycerol, which in turn has to be marketed.

Catalytic cracking has none of these disadvantages. When this process, which is used for refining crude petroleum, is applied to plant oils, it produces combustible gases and two types of hydrocarbons, one of which is close to gasoline, the other to fuel oil. There are two stages to this extremely simple operation: the oil is brought into contact with a catalyst at an average temperature of 450°C to break down the oil's long hydrocarbon chains into simpler hydrocarbons; the mixture thus obtained is fractionated either in the course of condensation or by later distillation. The catalyst is a solid mineral — an industrially made silico-aluminate or a soil-extracted mineral (sand, bauxite) — which regenerates through simple heating in air. Other advantages: the process is self-sufficient since the gases from the reaction can provide the energy necessary for the cracking; it is semi continuous, which means that the size of the installation can be reduced; lastly, it is non polluting.

Catalytic cracking has been tested with palm concrete and copra oil, but is still at the experimental stage. The researchers hope to graduate rapidly to trials in a pilot unit to test it on the scale of an agro-industrial plantation or for an isolated region. ■

This Massey Ferguson tractor, adapted to run on a mixture of fuel oil and colza oil, is tested by a French farmer.

Agricultural machinery (here a rice de-huller) can now be fitted with engines that run on plant oils.

during the rainy season, can be self-sufficient as far as irrigating their crops, supplying villages with electricity, installing a small flour mill, etc.,

are concerned. This is a first step toward energy autonomy with its accompanying revival of economic activity — the source of progress.

For further information:

CIRAD-SAR
Unité de recherche conception des équipements, énergie et informatique
BP 5035
34032 Montpellier Cedex 1, France

CIRAD-CP
Unité de recherche chimie et technologie
BP 5035
34032 Montpellier Cedex 1, France

Other Highlights

Mechanical de-hulling of millet and sorghum. Traditional de-hulling of millet and sorghum with a mortar and pestle is a tiring daily job for women. CIRAD has developed a mechanical de-huller which does the job much faster by dry abrasion; its ground product is stable and keeps well. Its 50 to 100 kg/h capacity and continuous function make it suitable for villages and small city workshops. The mechanical de-huller is simple to make and can be built locally.

Semi-industrial rice mill. A semi-industrial unit for milling rice, processing 700 to 1500 kg/h of paddy was invented in cooperation with the Gauthier company. Farmer organizations and rural entrepreneurs adopt it for its capacity and processing can therefore be done in the field. It is made up of various modules — precleaner, de-huller-whitener, grader — which can be purchased progressively. The rice produced by this mini mill is as white as that from industrial mills. The bran is retrieved for animal food. It might be possible to use the chaff as fuel.

Clementine calibre. Leaf spraying with dichlorprop or 2.4 DP, a synthetic auxin, after the physiological fall of immature fruit, clearly stimulates clementine growth. The technique was developed in Corsica on the common clementine. Because fruit treated in this way is bigger and better when received by the buyer, growers' incomes improve considerably.

Semi-industrial fruit juice production. In Zaire, Cameroon, Ghana, Togo and Burundi, small fruit processing plants have joined the ranks of economy-diversifying novelties. They were developed and installed by CIRAD in cooperation with a French firm. At present, these complete mini production-lines, which handle fruit from reception to final packaging, process passion fruit in Burundi and guava, mango and pineapple in Cameroon, Zaire and Ghana.

Mango aroma concentrates. Many hot-climate countries produce more mangoes than can be consumed by the local population. New mango-based products could use up some of the surplus and encourage the development of small conversion industries. CIRAD with INRA, Nottingham University and technological research institutes in Thailand (IFRPD) and India (CFTRI), have begun research on the production of mango aromatic concentrates. They can be used in the producing countries for making fruit juice and in other food processing sectors and could also be exported. This work is being financed by the European Commission. First, a small pulp extraction unit was devised. At present, enzyme and structural biochemical studies of the pulp are under way with a view to improving technological processing: liquefaction, separation by tangential flow micro-filtration, concentration. Thai and Indian technologists are acquiring experience at CIRAD which they will then be able to put to use in their own countries.

Ridding dates of insects. Microwaves might well soon be used to rid dates of insect larvae without altering fruit quality. The new process developed by CIRAD could replace methyl bromide treatment, which is efficient against insects, but harmful for man and the environment (destructive of the ozone layer). Methyl bromide has already been banned in the United States, and a law concerning its use in producer and consumer countries is at hand. CIRAD has applied for a patent and should soon offer the manufacture of a pilot device to a company.

■ **Fried tropical food.** Immersion frying consists of plunging small pieces of food (slices, strips, gratings) into hot fat between 110 and 180°C. Three things happen simultaneously during immersion: cooking, dehydration and fat impregnation of the product. Research is being carried out into improving the process and its application in two fields: the drying phase preceding oil extraction from oleaginous fruits, such as coconut; production of stabilized food morsels "for nibbling" (fruit, vegetables, meat), or for addition to prepared dishes.

■ **Packaging in leaves.** To improve the quality, the diversity and the availability of packaging materials in developing countries, their cost must be reduced. With this objective in mind, studies conducted in Congo, Côte d'Ivoire and Cameroon showed the advantages of natural packaging materials manufactured and used on an artisanal basis. Thus, leaves from banana, papaw or biloria trees are used to protect numerous food products. Leaf packaging has many interesting aspects: packaging and presentation of the product (food-holding during cooking, shipment, and appearance for marketing purposes), protection from microbial contamination and insects, heat insulation. In certain cases it also interacts with the product, endowing it with specific properties. In Benin and Congo, a program intends to improve the functional properties of leaf packaging and develop its production.

■ **Rapid detection of sticky cottons.** Sticky cotton harvests are systematically devalued. The H2SD was devised to limit devaluation to only that part of the output which is indeed sticky. It analyzes each sample in 20 to 30 seconds and can be integrated into high-capacity measuring lines (HVI) used to classify commercial cottons. The Scanera firm is participating in this project supported by ANVAR, the French national agency for the promotion of research. Two patents are pending.

■ **Controlled fermentation and cocoa drying.** New knowledge concerning fermentation stages and transfers during drying has gone into devising a modular fermentor-dryer assembly designed to rationalize initial cocoa processing operations. With this equipment it will be possible to produce cocoas of consistent quality in compliance with chocolate makers' selection standards while reducing energy costs.

■ **Cocoa aroma.** About 85% of cocoa aroma results from fermentation and roasting. The fermenting stage is decisive, most likely because of the Maillard reactions that take place at low temperatures. These reactions were thought to occur only during roasting. This was revealed by statistical analysis of the relation between aroma precursors (sugars, amino acids, phenolic compounds, purines) and final aroma in Dominican Republic cocoa.

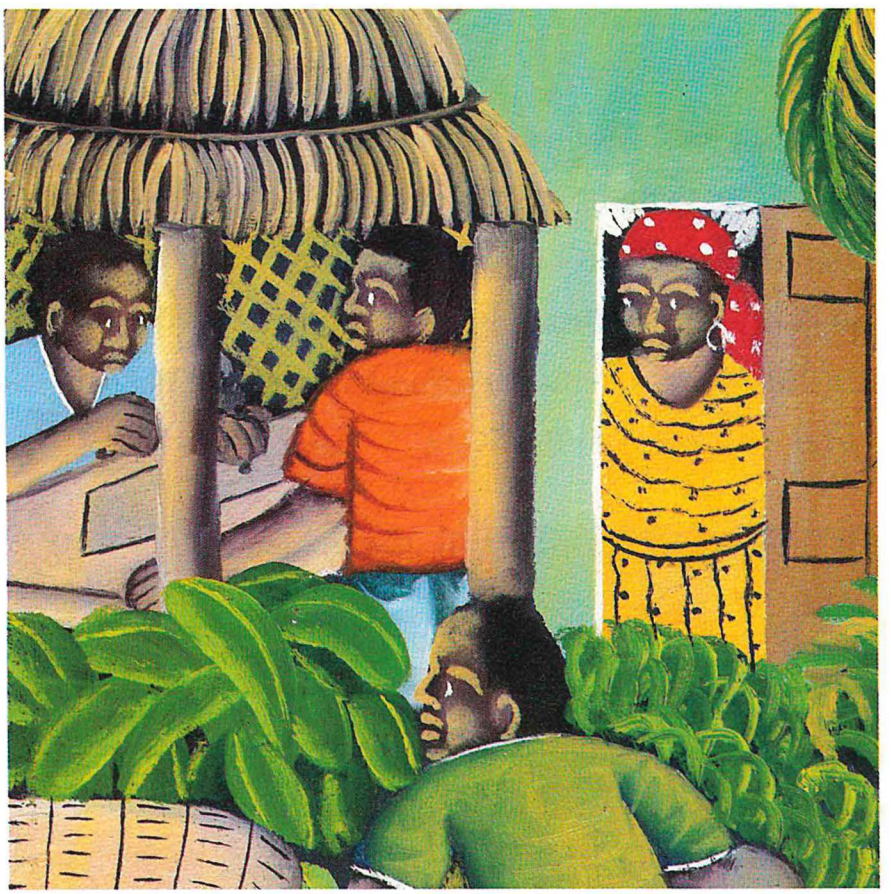
■ **The drying and quality of natural rubber.** Natural rubber is sold according to technical specifications; certain characteristics depend almost entirely on processing conditions (chemical, mechanical, thermal) of the product during its initial preparation. It became apparent during initial exploratory testing that an interaction occurred between drying conditions and product quality. A study is under way to model the quality kinetics of granules of known origin. Thanks to a computer-driven drying loop, samples are prepared under different thermal conditions. Molecular size, oxidizability and thermodynamic response of the product are examined. One or several physico-chemical criteria should be determined to adapt drying to the desirable quality.

■ **Sawing tropical timber: new equipment.** A saw mill has been designed for high-quality planking, based on the "Moreau" flow principle. It consists of three new-concept machines that orient the wood so as to avoid visible faults, such as transverse warping, radial cleavage and warping against the grain during drying. The assembly can accept huge trunks such as those of tropical treees (up to 1 m 70 dia and 6 m long). A semi-automated 1/10 mock-up of the complete saw mill exists and a patent is pending.

AGRICULTURAL

In drawing up agricultural policies, world market competition, regional dynamics and producers' behaviour are some aspects to be taken into consideration. Researchers can supply policy-makers with analyses, models and innovations to help them cope in an extremely complex world.

POLICIES AND CHANGES



More competitive coffees

The fall in the world market price for coffee caused a serious financial crisis in the African coffee industry and underlined its lack of competitiveness. The present return to higher prices will not compensate for the collapse of productivity. Which agricultural policies could be applied to regain lost market share? An analysis of its Asian and Latin American counterparts gives some guidelines as to how to proceed effectively.

When the international agreement which had regulated coffee prices for 40 years was broken in 1989, the ensuing fall in prices rocked the coffee industries in all coffee-producing countries. But Africa was harder hit than the others. This continent, which produced 35% of the world's coffee in 1973, now accounts for only 20%.

Why did African coffee resist less well than others? Now that prices seem to be rising, what can be done to help the coffee industry retrieve its competitiveness after 10 years of decline? CIRAD was asked by the French Ministry of Cooperation to make a comparative study of the coffee industries of the three coffee-producing continents, Africa, Asia and Latin America. The aim? To understand why some industries succeeded in overcoming the difficulties while others failed, and draw whatever conclusions could be helpful at a political level.

STRONG COFFEE

Coffee is one of the main export crops of Africa's humid tropical countries. It accounts for 95% of export earnings in Uganda, 80% in Burundi, 60% in Rwanda. In Kenya, Côte d'Ivoire, Togo and Cameroon, it weighs considerably in the trade balance — from 5 to 18%. As it is produced mainly by small farmers, coffee plays a major role in the distribution of currency revenues in rural districts. In Côte d'Ivoire, until 1989, more than 2 billion French francs per year were distributed in this way in the rural zones.

Analysis of the world coffee market shows that Africa has become less competitive mainly because of the fall in sales of

Africa today accounts for only 20% of world coffee production.

robusta; although Côte d'Ivoire was the leading producer of this type for many years, Africa's share of the market fell from 78% in 1978 to 44% in 1990, whereas its share of the arabica market remained steady at 12%.

But robusta consumption is increasing. After its production was considerably reduced during the 1970s, due mainly to the war in Angola and political upheaval in Uganda, robusta has returned to its previous share of a third of the world market. What are the reasons for this comeback? First, robusta is less expensive: at 10 francs per kg, poorer countries prefer it to arabica which costs 13 francs. Second, robusta is more easily made into instant coffee than arabica, and demand for this form of coffee in traditionally tea-drinking countries is on the rise in Asia and Eastern Europe especially. Lastly, coffee drinking is increasing in Mediterranean countries, where people like strong coffee and therefore import robusta, while in Northern Europe, where they buy arabica almost exclusively, consumption appears to be at a standstill.

Asia still spared

The market for robusta has been growing very strongly, therefore, for the past 10 years. Africa's position in that market has fallen spectacularly because new growers have appeared to challenge it in previously secure markets: Brazil and Ecuador in Latin America, and especially Indonesia, Thailand, and Vietnam in Asia, whose robusta production has increased almost exponentially since the

In Asia, extension of the farmed acreage compensates, for the time being, for the aging of the orchards.

1980s. African robusta, which accounted for 70% of supply in 1970, now accounts for only 50%.

Why was Africa unable to resist Asian competition whereas Latin America retained most of its slice of the market? What are the structural factors of competitiveness? What strategies should be drawn up to enable Africa to regain its lost place?

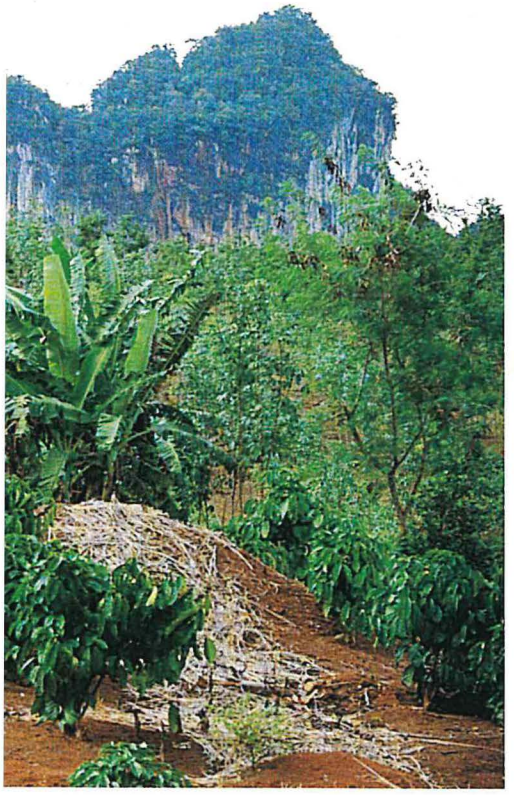
Historically, coffee-growing followed a pioneer pattern everywhere in the world. As forests were felled, coffee was planted in these naturally fertile clearings. For years, coffee-growing in all countries progressed spontaneously in this way, enriching growers and governments, which often took a lion's share of the coffee revenues. But this extending growth model finally stops when available land runs out, when plantations grow old and when soils are exhausted. As soon as he finds better-paid work, the coffee grower abandons his plantation.

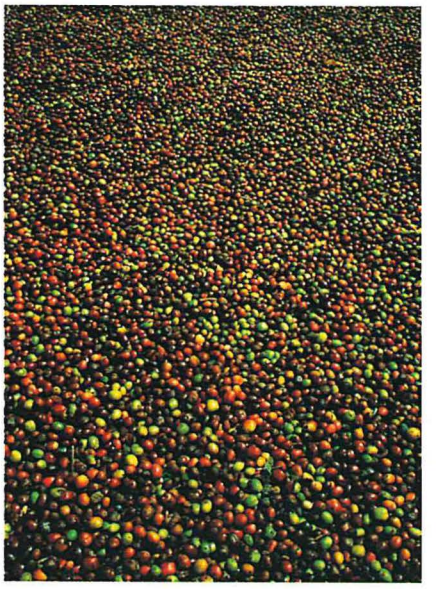
This downturn was already apparent in Latin America in the 1930s and began in Africa in the 1970s. Asia, where extensive coffee-growing began later, has so far been spared; the extension of farmed acreage compensates, for the time being, for the aging of the orchards and partially explains Asia's dynamic stance in today's market.

SOLIDARITY

Latin America has found ways of adapting to the far reaching modifications in the sector, although not without difficulty. In Brazil, Colombia and in most of the Central American countries, where labour is scarce and expensive, crop intensification has breathed new life into coffee growing. High-yield varieties have been introduced: the dwarf varieties facilitate harvesting; planting is denser, and shade trees normally grown in coffee plantations have been done away with; soils are being richly fertilized. Between 1964 and 1989, production in Costa Rica leapt 140% even though farmed acreage increased by only 40%. Work productivity trebled, yields quadrupled.

It is true that the high prices on the world market during that period helped to encourage modernization of Latin American coffee-growing, but success is due more to the recycling of coffee revenues back into the coffee industry. The government instigated the creation of growers' cooperatives, while subsidizing replanting and fertilization. Competition from this powerful





cooperative movement forced the private sector to limit its income and improve its services and formed the basis for restructuring the coffee industry. Today, there is solidarity among everyone concerned — government, intermediaries, growers — to defend sector interests within the national economy as well as on the export market.

And in Africa? On that continent, extensive growth came to an end later, at the time when coffee prices began to fall. Governments intervened to ensure growers a relatively stable price until 1989, which had the effect of immobilizing evolution within the industry. Moreover, national governments used coffee revenues to finance other activities, neglecting reinvestment in the sector. And in the absence of any growers' organization, the intermediaries — importers, industrialists, collectors — found themselves in a quasi monopolistic situation of which they took full advantage, pocketing a large part of the coffee revenues without improving their services.

Suggested paths

To the above must be added the agroclimatic conditions, which are less favourable than in Latin America or Asia, higher fertilization costs, weed killers and especially transport because of the cost of energy and the lack of infrastructures.

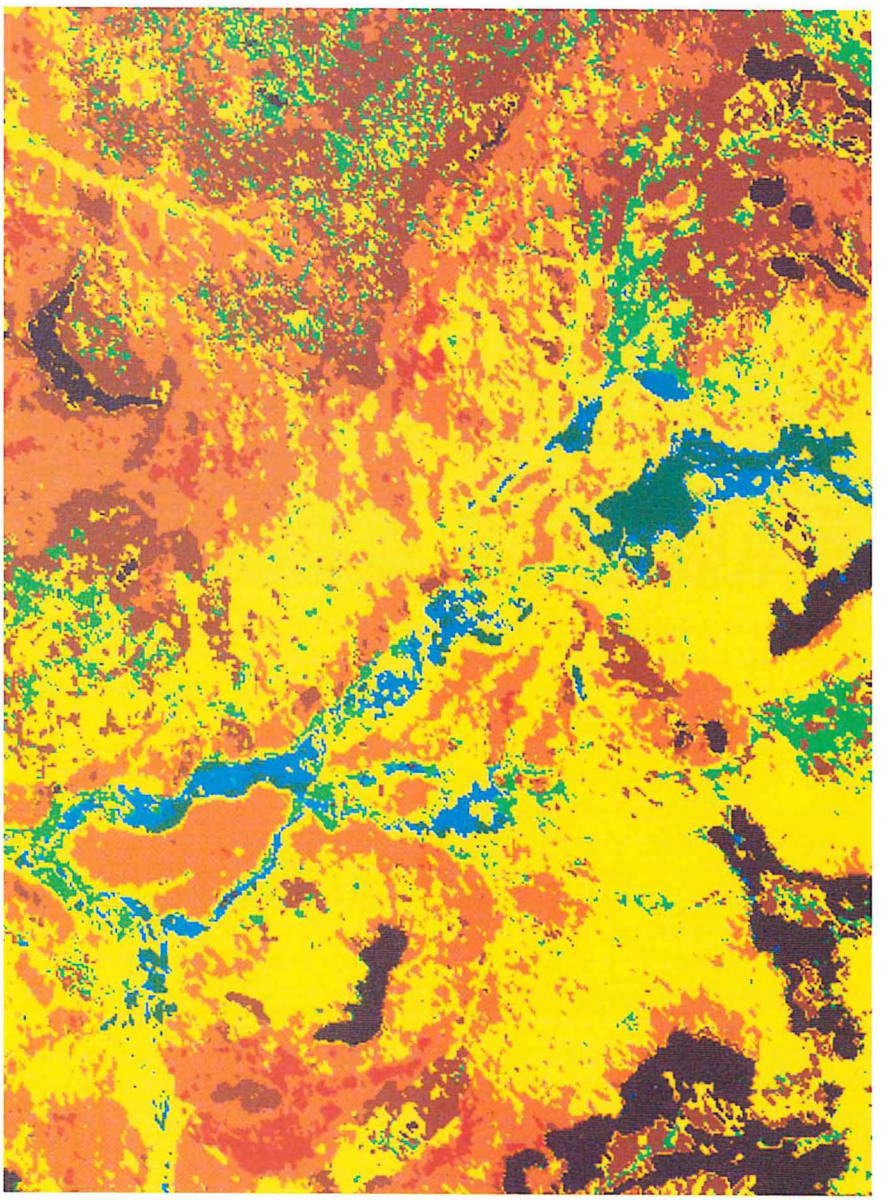
For the African robusta coffee growers to become competitive again, productivity must be improved at all stages — growing, collecting, processing — with reinvestment of coffee revenues in the sector by all members of the industry, including governments. Although not necessarily to be copied, the experiences of the Latin American countries suggest paths towards organizing the industry and the role that growers' associations can play. The economic and sector policies to be drawn up should encourage farmers to work together and should help to finance planting or replanting. Coffee revenues should also pay for research, which plays a key role in selecting improved varieties and setting up better crop systems: easy-to-grow hybrid varieties and intercropping in extensive systems; dwarf coffee plants, mechanized clearing and pruning, weed killers in more intensive systems.

The African countries hold some trump cards for winning back the coffee market: they have long and solid experience in coffee growing, relatively inexpensive labour, and some still have an abundance of exploitable land. The coffee growers on that continent will surely know how to play their hand.

For further information:

CIRAD-CP
Unité de recherche
en économie des filières
42, rue Scheffer
75116 Paris, France

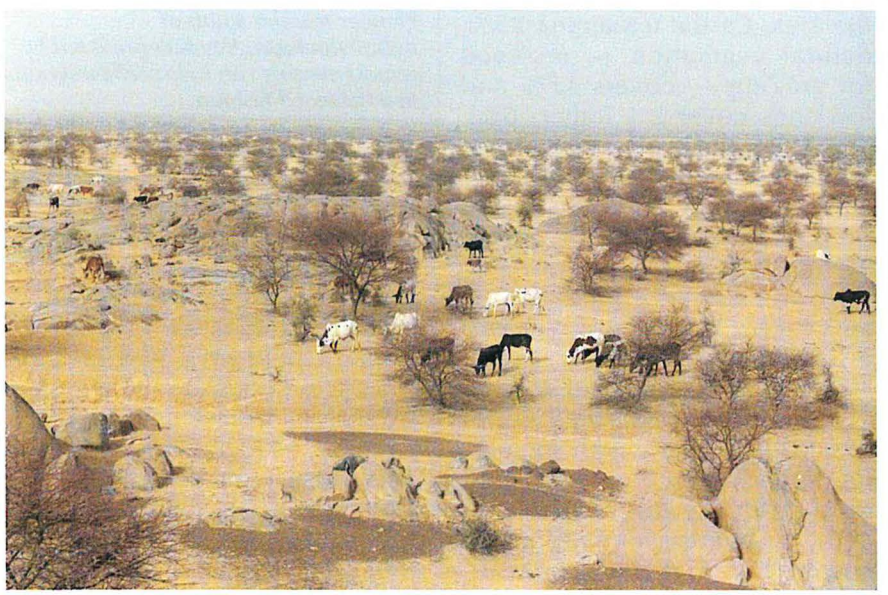
Planners need up-to-date information. They want to understand how wild and farmed areas change under pressure from climate or populations. Remote sensing is a powerful research tool which can replace or complement traditional methods of enquiry. A system is being set up in developing countries to give them new ways of observing, evaluating and forecasting.



Ground map of north Yatenga: an example of the tools that remote-sensing can provide for project development. The crops (in yellow) are clearly delimited from the other zones, particularly degraded soils (orange), hills (brown) and natural vegetation (green).

Remote sensing: a tool for policy-makers

Remote sensing is a technique for observing the earth's surface by analyzing satellite data and aerial photographs. CIRAD has been using this technique for the last 10 years in its work on agricultural development. Data are transformed into images and computer-processed for interpretation.



The development of animal husbandry should make use of the remote sensing inventory of grazing resources.

Analysis is validated by means of field observations. Starting from a precise sample, researchers can extrapolate to understand what is happening over wide areas of farmland, grazing land or forests scanned by the satellite.

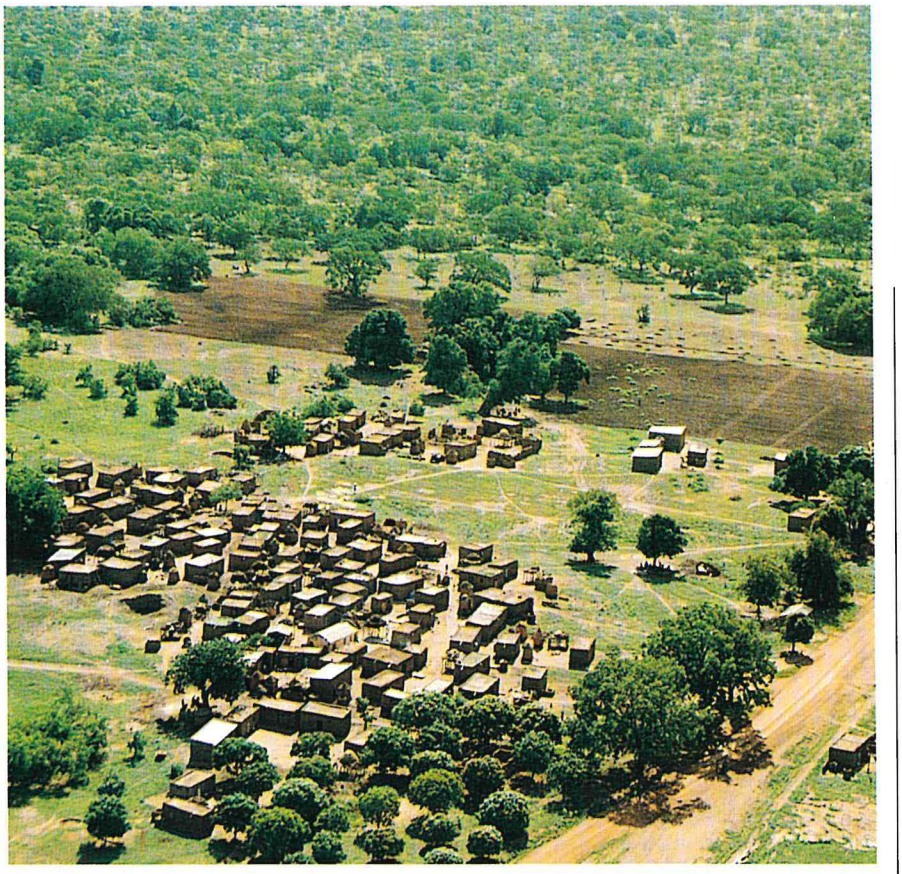
Because it is present in developing countries, CIRAD has been able to carry out important methodological research concerning remote sensing and has obtained many practical results. Now it is going a step further and helping to install an on-site remote sensing unit in Burkina Faso.

DATA EXCHANGE

The remote sensing unit set up in Kamboinse within Burkina Faso's agricultural research institute (INERA) has a three-fold mission: to train specialists, support other research programmes and apply remote sensing to rural development.

Similar to that in CIRAD's remote sensing laboratory in Montpellier, the equipment used for numeric and visual processing of satellite data enables data and methods to be exchanged and projects to be shared. It includes a magnetic tape reader, software for processing Didactim and Multiscope images, high-definition colour screens with graphics cards, and a fine-resolution printer for producing colour documents.

The products are maps and statistical data concerning phenomena observed on a regional



Pioneer frontier south of Bobo-Dioulasso: the data provided by remote sensing can help settle migrants in a balanced fashion.

or agricultural zone scale. The remote sensing unit's contribution to a food crop project in the north of Yatenga is a good example of how useful it can be.

The project, which was launched in 1991, covers four *départements* of Yatenga province, or roughly 360,000 hectares of northern Burkina Faso. The sponsors of this big project wanted at their disposal a land distribution study, maps and statistical data. In particular, they needed to know with precision the contours of the land, the hydrographic network, vegetation types, cultivated and non-cultivated zones and the degree of environmental degradation. Moreover, land distribution dynamics were to be analysed by studying the evolution of several representative villages over time.

End of the rainy season

The study was carried out on the most recent available image of the region, at the end of the rainy season, when vegetation is most abundant. It was taken in 1990 by the Spot satellite. In order to study changes in the phenomena under study, aerial photographs taken in 1952 (Institut géographique national, France) and in 1984 (Institut géographique burkinabè) were also analysed.

The Spot image shows present land distribution. Numerous forays into the four *départements* were used to validate the interpretations made. The image showed that 35% of the whole region is cultivated, i.e. about 135,000 ha. Degraded or hard-to-cultivate zones (hills, hardpans, rocky sites) cover 40% of the area. Of the remaining 25%, natural vegetation — reserved for grazing — covers 17% and lowlands cover 2% (other: 6%). These results clearly indicate that farmland cannot be extended.

Comparison with the aerial photographs taken of about 10,000 ha showed the progression of cultivated land: in the Lossa zone, for example, this was evaluated to have been 11% in 1952, 21% in 1984 and 45% in 1990. The process was widespread, took place with increasing speed over the years, and resulted in the use of available land for farming already noted above. This was due to the region's rapid population growth of 3.5% per annum.

Soil degradation and vegetation types — including many zones almost devoid of vegetation — also stood out clearly. The disappearance of plant life is caused mainly by decreased rainfall, with ensuing soil erosion and the gradual impoverishment of organic matter. One might think that farming the land rather than leaving it as savanna or steppe would be a way of limiting this process. On the contrary, extensive farming does not protect the environment and only tends to aggravate the situation. Certain zones which were under cultivation in 1952 were no longer in use in 1984, having become sterile.

Another consequence of increasing farmed land even though soil degradation is worsening, is that natural grazing land is converted into arable land. Cropping and herding compete with each other for land, to the detriment of the latter.

Twenty-four maps

This analysis of the evolution of northern Yatenga from the 1950s onwards provides the managers of the development project with the key to their intervention. Pressure from uninterrupted population growth, the spread of environmental degradation, saturation or near-saturation of arable land, competition between cropping and herding — the chain of phenomena seems unbreakable. There is no solution other than intensification. But intensification should be rationed to ensure renewal of natural resources and preservation of livestock.

Graphic representation of these observations provides a better understanding, particularly as regards their geographic spread. The remote sensing unit's report is accompanied by 24 maps on a 1/50,000 scale: 16 maps of broad units describing the physical environment, of vegetation, of cultivated areas, and an additional 8 maps showing evolution of the sample-study villages.

A whole series of studies based on remote sensing has been undertaken since the unit was created in 1991. Two other themes illustrate their diversity.

A research project in methodology is using remote sensing as a tool to inventory grazing resources for the animal production programme. The method was conceived at the experimental station in Dori, in the northeast, and will be applied to the study of potential grazing in northern Yatenga — a logical follow-up to the study described above.

In the Gorom-Gorom region, a similar inventory of a sample area has been undertaken for the "Sahel Burkina" programme and should provide data that will be used to decide how to rationally develop livestock herding in harmony with the environment.

Pioneer front

The demographic pressure prevalent in the north and centre of Burkina Faso is causing populations to migrate. They head for the most part towards Bobo-Dioulasso, a region which has been relatively underpopulated until now, and where farming possibilities are certain to be better. But as these migrations are self-motivated, little is known about what happens in the newly occupied land.

A Landsat image shows land distribution in 1987; three recent Spot images are now being processed. Today the pioneer front is located to the south of Bobo-Dioulasso, and some scattered settlements even further south, around Sideradougou, are signs that it is progressing. Land that was cleared for farming has been detected and the areas estimated. A yearly comparison should make it possible to follow the front's displacement. These data will be valuable to the authorities when they intervene to channel migrations into more environmentally suitable locations.

For further information:

CIRAD-CA
Programme cultures
vivrières paysannes
BP 5035
34032 Montpellier Cedex 1, France

INERA
Cellule de télédétection
03 BP 7192
Ouagadougou 03, Burkina Faso

Anticipating farmers' behaviour

Economic policies often designed to encourage rural development do not produce the expected results. Policy-makers need to foresee the effects of policies if they want them to be efficient. Agricultural household models built up by economists can assist by simulating farmers' reactions to change, after validation.

Understanding the farmer's motives for choosing to specialize in herding.

If economic studies of small production units, e.g. farms in developing countries, have considerably developed over the last decades, it is because those responsible for rural development have come to understand their necessity. They clarify how the farmer makes his decisions and which factors are important in his choice.

PRODUCE AND CONSUME

Classic microeconomic theory has developed models, known as agricultural household models, which are applied not at the producer level, but at the household level,

i.e. the group of persons living under the same roof, working in the same fields and together taking decisions which concern their community life. Each household is considered as a firm, which produces, and as a family, which consumes. The supposed purpose of the household is not to produce a maximum amount for the highest possible income, but to arrive at an optimal blend of consumption by the household of its own production, purchases of manufactured goods and leisure (leisure being noncommercial activities such as preparing food, cleaning the home, taking care of the children, socializing...). In economics, this is called "maximizing the utility function".

The reference model in microeconomic theory is *Agricultural Household Models*, by Inderjit Singh, Lyn Squire and John Strauss (Johns Hopkins University Press, 1986). Basically, this model is founded upon four hypotheses: markets, whether food-product or labour markets, are perfect (at any given time the farmer can sell or buy any product, including labour); prices are fixed, determined by the market (the behaviour of the producer has no influence on prices); prices asked by the producer and those paid by the consumer are the same (the farmer sells and buys at the same price); there are no production uncertainties (even climatic uncertainties are not taken into account).

Usually, after analysing sample households, economists determine the characteristic utility and production functions according to the model; i.e. they formulate the equations and then calculate the parameters by econometrics.

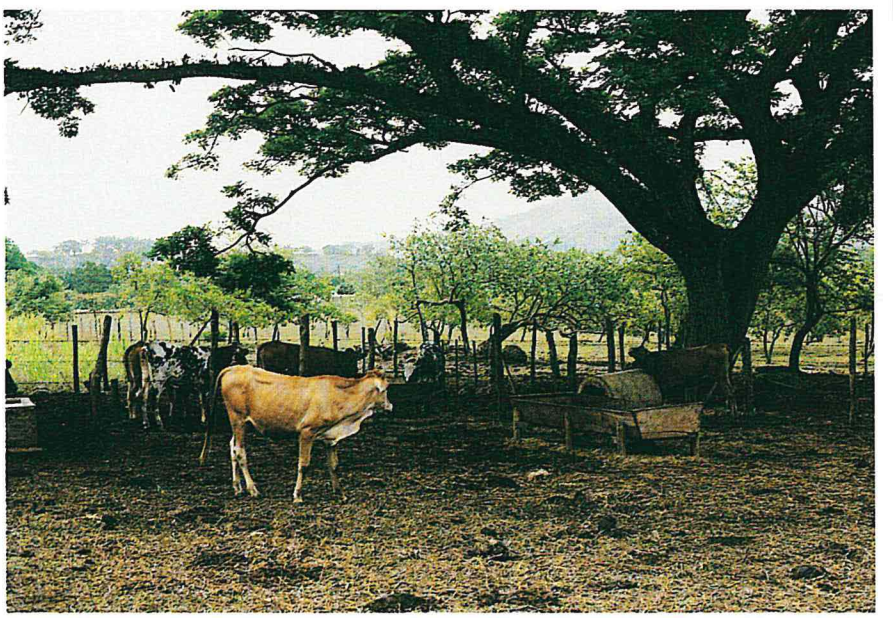
Behavioural norms

The approach outlined here is quite different. CIRAD researchers tested the Singh, Squire and Strauss model in a real situation in Nicoya peninsula, in Costa Rica, to determine to what extent it took into account the behaviour observed and which of the hypotheses needed to be modified to fit reality. The work was based on 3 years of field observations, from 1984 to 1986, after a survey of farming systems.

The Nicoya region is a mountainous rural zone in northwest Costa Rica, far from large urban centres. The two main agricultural activities are growing food crops — beans (the surplus of which is sold), maize (usually for home consumption), rice — and extensive livestock herding for meat.

Family choices concerning production and consumption differ according to land availability. Family behaviour, in reality very complex, was expressed as behivoural norms before being compared with the theoretical behaviour of the model.

For example, it was observed that, as they increase exploited areas, families increase their food crops to some extent but devote the largest portion of the additional land to herding. However, only holdings of more than 150 ha give up food cropping altogether in favour of herding. The Singh, Squire and Strauss model predicts that, as the holding increases, the family increases its specialization to either cropping or herding, depending on daily labour costs.



The maize cultivated in the Nicoya region of Costa Rica is generally for home consumption.

Which of the hypotheses must be corrected first to explain the choices made by the Nicoya region farmers between cropping and herding?

Market imperfections

The first postulate to be questioned is the existence of a perfect labour market, which leads to forecasting total specialization. There is a labour market in the Nicoya region, but it behaves imperfectly. During the rainy season, when agricultural activity is in full swing, it is difficult to find labourers. In the dry season, on the other hand, herders can hire workers for fence-mending and grazing-land maintenance since there is a surplus of labour. Then again, family labour and hired labour are not interchangeable in the opinion of the farmer, who views his family workers as more qualified and efficient. He will readily hire someone to weed grazing land or build a corral, but he might well hesitate to put the worker to ploughing or sowing, which require more technical knowledge and contribute to the success or failure of the following harvest. These two imperfections in the labour market lean the same way, and their inclusion in the model would nudge the balance towards herding.

The second postulate to be revised is that concerning the perfect mobility of the production factors, labour and land. It is conceivable that once the work at hand has been accomplished, labourers can change from herding to agriculture and vice versa without too much difficulty. The

Bean crops require little investment.

land, however, is a much less mobile factor, especially from herding to cropping: once grazing land has been trodden for months by livestock and overrun by persistent grasses, it is very difficult to use it for food cropping.

Another example: the Nicoyan farmers grow enough beans for their own consumption and to sell; they grow enough maize for their own consumption; but they generally grow less rice than they consume.

Here again the model's forecasts do not correspond to observations: the agricultural households for whom land is a limiting factor cultivate more maize and rice than expected. Again, certain hypotheses must be revised. First of all, that concerning the perfect market for basic cereals: there is a 20% difference between the purchase and sale price. The household has every reason, therefore, to grow the maize and rice it needs, even when their labour productivity, calculated to the sale price for the cereal, is lower than the salary it could earn in off-farm activities. Furthermore, prices being equal, the farmers of the region prefer their local varieties which they have been growing for a long time, especially maize, to the varieties found on the market, which do not have the same cooking qualities for regional dishes. Besides, the farmers' choice to produce maize and rice rather than to sell their labour is probably a reflection of their uncertainty about finding off-farm activities when they want it, because of the bad labour market situation.

Renting or sharecropping?

The last example concerns how the use of land is acquired. When a choice is possible, the Nicoya region landless farmers prefer to rent-in land for growing beans and to sharecrop to grow rice. The model does not entirely explain this choice, since it calculates that, in both cases, land rental is more advantageous than sharecropping.

Beans, sown by broadcast, require little investment, but rice requires soil preparation before planting, obliging the farmer to rent oxen and a plough. Rice also needs more fertilizer. Most landless farmers do not have the means for such an investment. So they sign a sharecropping agreement, whereby the owner takes responsibility for preparation and inputs, even if their labour productivity is lower than on rented land. Therefore, a temporary cash constraint should be included in the model, since the model only considers the global family budget, not taking chronology into account. The farmer has to finance planting before he can harvest.

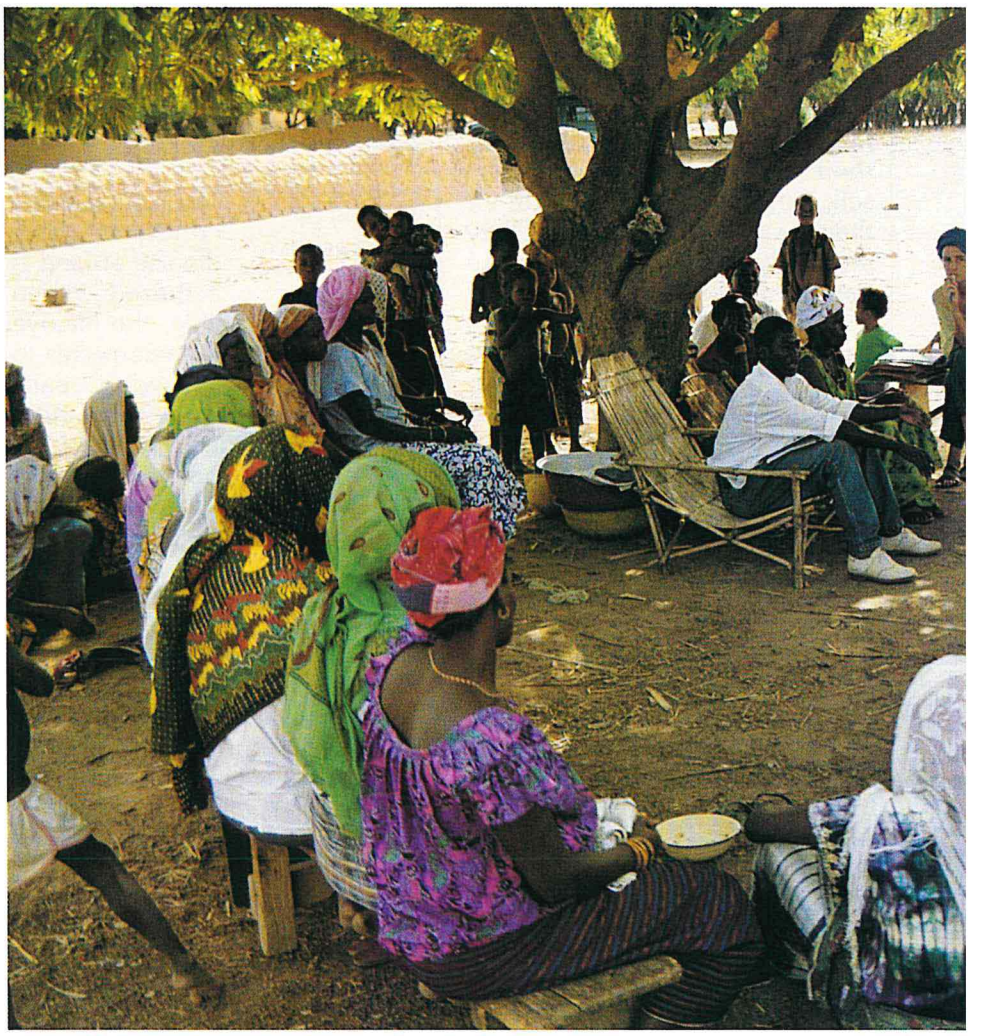
Comparing the behavioural norms, gathered from a detailed analysis of farming reality with the theoretical framework of the model, shows the type of corrections that have to be made to enable the model to improve the consideration of the behaviour observed. After the validation at a regional level, the model can be used as a decisional tool for development managers, enabling them to direct agricultural policies with an understanding of their effects on rural populations.

For further information:

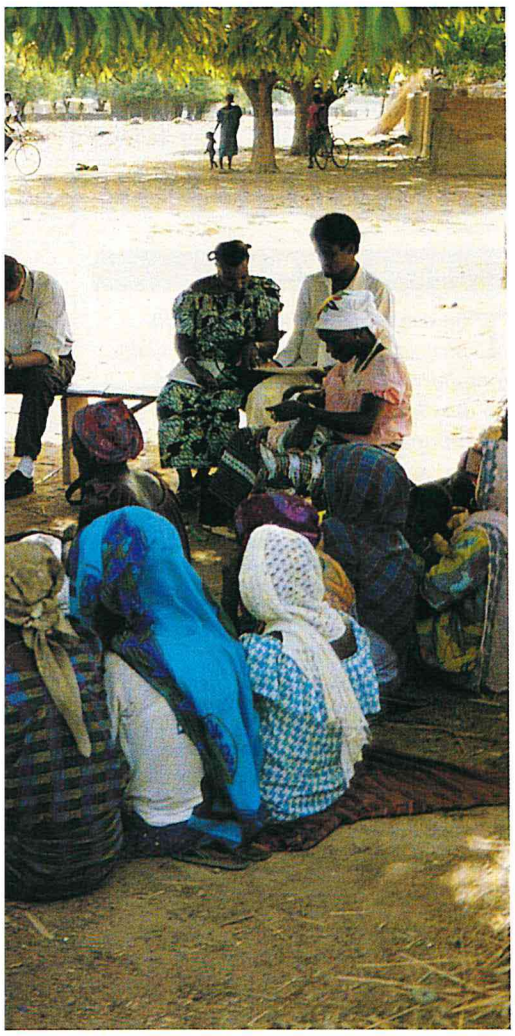
CIRAD-GERDAT
Unité de recherche en prospective et politique agricole
42, rue Scheffer
75116 Paris, France

They only lend to the rich? This is an out-of-date idea. In Burkina Faso, the poorest producers in the Yatenga region have access to loans that have been adjusted to their means, and repay them more promptly than many speculative borrowers. As their production systems were no longer viable, they invented new ones. Women are playing a leading role in this economic revival. The rural credit system, a development tool, is spreading and a mutualist movement is envisaged.

Credit conditions are discussed by the group: joint guarantees between borrowers in organized groups ensure debt recovery. Above, a loan agent collects repayments after the market.



Rural credit for small producers



The people of northern Yatenga, a Sahelian province of Burkina Faso, have always lived precariously. But in 1984, their systems of production and, as a result, their strategies were thrown into chaos because of severe drought. In order to help them surmount this critical situation, researchers and development agents worked with them to find totally new solutions, which were based on credit. This required a sound knowledge of their living conditions and traditional social relations, then an analysis of the changes in these structures.

New survival strategies

In this region of fast-growing population, there are two clearly distinguishable groups. The Fulani are herders, and masters of the land. With their herds of dairy zebus they trace ancestral routes of transhumance, coming back periodically to the same places. The Rimaïbé are farmers who crop mostly millet and are dependent upon the Fulani. This dependency is not devoid of advantages for the Rimaïbés: although they are bound to hand over their surplus grain to the Fulani, the latter in turn are duty-bound to assist the Rimaïbé. The two groups long ago established an equilibrium and lived in almost complete self-sufficiency, milk and grain being the two basic items in an active bartering system.

Only 120 mm of rain fell in 1984, after a succession of very dry years. There was no grass, there was no milk. The Fulani went south, in search of grazing land. Instead, they found trypanosomiasis, which wiped out their herds. They came back to their homeland to take up new ways of making a living; they sold what few cattle remained and bought goats and sheep, even though this hurt their already weakened social status. By doing so, they were able to quickly rebuild herds that were easier to feed. They also began to clear land for cropping millet, something they had never done before. But despite all this, it was apparent that they could not produce enough food for their families, so they began to sell their small ruminants and home-made products to pay for additional grain. The Fulani thus entered a money-based system

Cattle for the Fulani represented capital. Today, they rear small ruminants that they buy and sell.

which they barely knew, since their cattle had always been their capital.

INVESTMENT CAPITAL

This terrible period was even worse for the Rimaïbés. They were liberated from their duties toward the Fulani, who could no longer keep their part of the contract, but lost their advantages. In particular, they lost the manure: this contributed to the decrease in millet production, already sorely affected by lack of rain. They, too, looked for combined incomes in service activities and built up small herds.

As a result of drought, the traditional social contract between two complementary groups was broken. Their systems began to resemble one another, and both groups had to find ways to earn a living.

In this dire situation, where even ensuring enough food was problematic, it was the women's initiative to create new activities and their role in the family economy has not stopped growing since. Traditionally, Fulani women were in charge of milking and selling milk and the Rimaïbé women, of cultivating their own plot, produce from which was sold for family maintenance (clothes, medicine...); the husbands were responsible for providing food. But from this time on, the women started to fatten a few goats or sheep, made soap, mats, kitchen utensils, prepared pancakes, rice- or couscous-based dishes, and sold their homemade produce on the market, which revived. But they needed investment capital, however modest, to start up these activities.

All this brought together Burkina Faso's agricultural research institute (INERA), and CIRAD to work towards improving cropping and breeding techniques. But it also incited them to encourage the development of new diversified activities through a system of loans, and to study more closely a group that is usually ignored: the women.

CALCULATE THE RISKS

The first loan experiments began in 1988 in Banh, then in Ziga, in Mossi country, a little further south. They were based on different loan schemes worldwide, and especially on that of the Grameen Bank in Bangladesh. The researchers demonstrated the impact of loans on income and nutrition in the case of 600 beneficiaries and confirmed their capacity to repay the loans. Regulations were developed as to what made one eligible for a loan: the investment in the development of a definable economic activity — the building of a herd of small ruminants, fattening of livestock, food processing — and social pressure between borrowers organized in solidarity groups guarantees repayment. The loan agents are themselves specially trained farmers, whose experience enables them to calculate technical and financial risks. They travel from village to village on motorbikes.

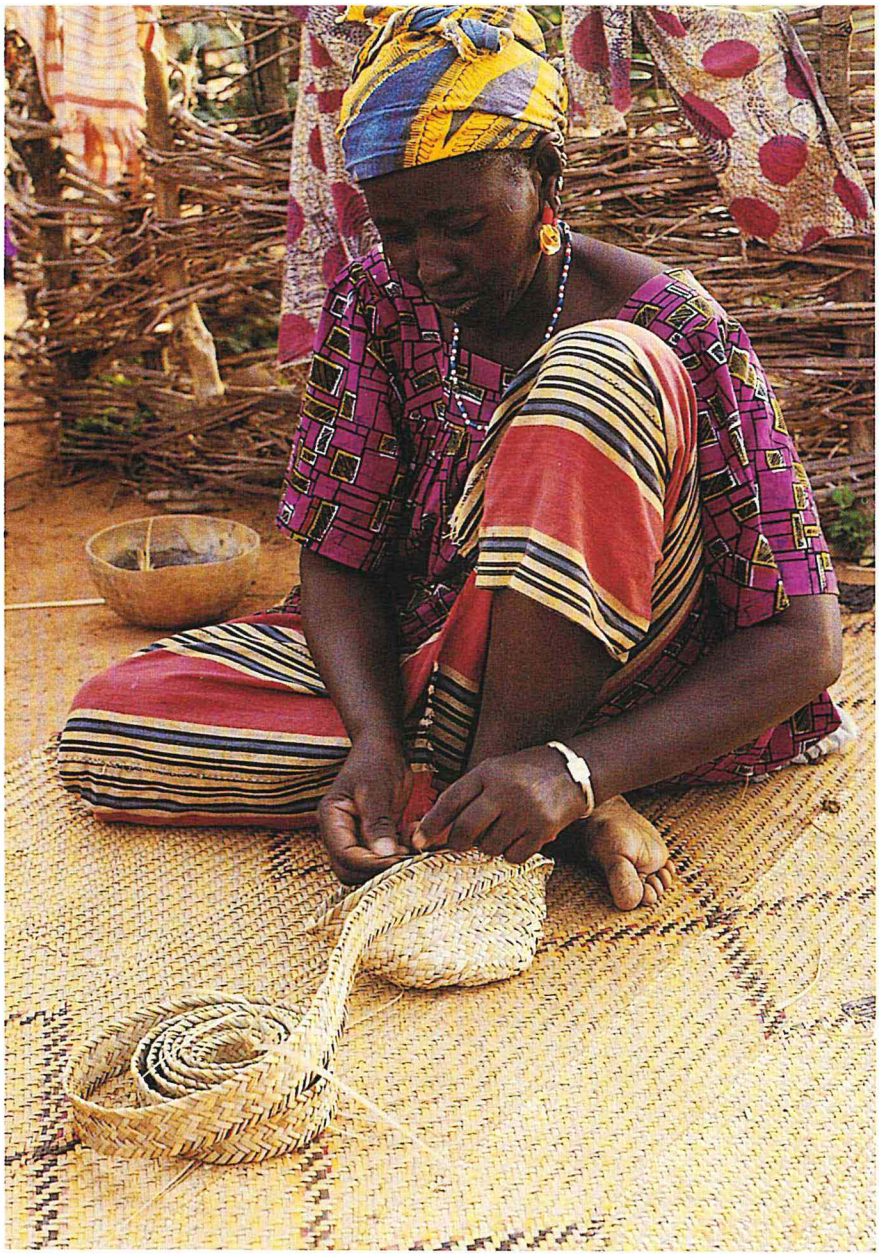
But CIRAD would not become a bank; so it formed an association with a Burkina NGO for law, Sahel Action, and the Burkina Caisse nationale de crédit agricole (national bank for agricultural credit). The former operates in the field, the latter brings in capital in the form of credit

Procedures and training

The extension of the rural credit project and the creation of a viable long-term institution will be based on the elaboration of appropriate operational procedures and the training of loan agents.

The following have been created so far: an experimental method to design new financial products, and used by the loan agents in the field; the Crédis software, for managing a great number of loans; a matrix of social accountancy, for analysing the effects of the loan on families and markets.

Thirty field agents were trained in 1993. After completing a year each of theoretical and practical training, each agent processes more than 500 loans. Regional heads will complete their theoretical training in France under the aegis of CEFEB, Centre d'études financières, économiques et bancaires of the Caisse Française de Développement. ■



The women found new income-generating activities. It is principally the women who use the credit facilities.

from the French Caisse de développement (development bank).

From Yatenga, the project for the promotion of small rural loans spread to three other provinces: Soum, bordering on Yatenga and just as poor; Ganzourgou in the centre and Tapoa in the east, each with better climates and therefore more prosperous. In 1993, 6000 loans — concerning a population of about 60,000 people — were attributed. The very modest average size of the loan (15,000 francs CFA), is nevertheless equivalent to the annual income of the borrower. The weekly repayment is collected by the travelling agents after the market. The recovery rate for the year is 98%. Women make up 80% of the clients, and many of them earn more than the men.

A MUTUALIST MOVEMENT?

These results show clearly that loans can be made to very poor but organized producers, that they generate profitable activities and, moreover, that repayments are more certain to be made than in the case of speculative projects.

Such a loan can — and should — be attributed by the lending establishment with an aim of financial sustainability. In this case, the interest rate is 24%, 10% of which is marked as return on capital and 14% for operating costs. In addition, producers assign 10% of the total loan to a village fund. In the long run, this fund could replace the capital brought in by the development bank, whose competence nevertheless would continue to be useful, even in the future.

This outlines the move away from a semi-experimental stage to a wider operation (more than 50,000 families) which would require a permanent institution: interest produced covers operating costs as in any economically-run enterprise, and the accumulation of shareholders' equity permits the users to become independent of outside capital. Could this change in scale be accompanied by a mutualist movement, of the Raiffeissen type? Research into this type of question is now being undertaken.

A seminar on rural loans was organized in Ouagadougou in 1992 by CIRAD, the Ouagadougou University and Ohio State University. And even though CIRAD is not always directly implicated, at least five projects that are now in progress were inspired by its methods in Mali, Mozambique, Niger and Madagascar.

For further information:

CIRAD-SAR
Programme développement local
et dynamiques institutionnelles
BP 5035
34032 Montpellier Cedex 1, France

Other Highlights

■ **A RICE DATA BANK: OSIRIZ.** Created by CIRAD, the Caisse française de développement (French Development Bank) and the Office national interprofessionnel des céréales (Interprofessional Office of Cereals), Osiriz collates data daily from different world sources concerning prices and quantities traded of various qualities and types of rice, making it possible to follow the international market in the short-term and to prepare national or regional monographs. It also has at its disposal an analytical package for rice-growing policies which simulates the macroeconomic effects of measures designed to improve national rice-growing competitiveness. It will soon be supplemented by a microeconomic analytical package, built on information gathered from those involved in rice-associated activities. Three years after its conception, Osiriz continues to seek new partners to create an even larger network, especially in the South.

■ **TROPICAL FRUIT AND VEGETABLES: A MARKET MONITOR.** The market monitoring system created by CIRAD collects information concerning the production and marketing of tropical and Mediterranean fruit and vegetables for use and publication. It has several computerized databases at its disposal: volume and value of European imports and exports for 50-odd fresh or processed fruits, raw material prices on several world markets and at different stages of marketing, European Commision regulations concerning fresh and processed fruit and vegetables, bibliography. This information system will soon be completed by a consumer typology database, consisting of a database per country and per fruit. It can be used for market research and economic syntheses targeting researchers, rice industry professionals and political decision-makers. The market monitoring system also publishes *Fruitrop*, a monthly economic and statistical news bulletin on world fruit and vegetable markets.

■ **PUBLICATION: *LA COMPÉTITIVITÉ DES BOIS TROPICAUX*.** CIRAD was requested by the Ministry of Cooperation to take part in a study on the competitiveness of African timber which revealed that this is less competitive than in the past. African timber is at a disadvantage compared with Asian timber on several counts: the high cost of log transport, the absence of tax measures to encourage on-site processing, competition from new materials, the fact that the State and industrialists have not reinvested some of the profits from the forest in the production sector. But there is still hope for Africa: home markets are expanding, resources are still abundant, and the continent has a long tradition of rational and environment-friendly forest management. Recent demand confirms the optimism of these conclusions: Indonesian and Malaysian supplies have dried up, and Japan, the main importer of tropical timber, has started importing African timber which, combined with the devaluation of the CFA franc, augurs well for new development of the sector.

■ **RURAL TIMBER MARKETS IN NIGER.** The environmental administration of Niger, helped by the SEED research office and CIRAD, has created about 30 rural timber markets, which function autonomously and openly. The legitimate management by the villagers of their own natural timber resources has been re-established by this restructuring of the fuelwood industry. These increasingly numerous markets are outlets and instruments for forest management, but

they are also meeting and negotiating places for lumberers, shepherds, pickers... etc.

■ ***Le développement agricole au Sahel.*** This five-volume synthesis, collated and published by CIRAD, presents the results of 30 years' research and development in this African region. Despite an often hostile climate and hardly encouraging economic policies, forces of innovation are growing in the Sahel. The Sahelian farmer rapidly adopts new technology when he can see that it contributes to maintaining or improving his way of life. The task is now to construct a favourable economic and institutional environment — markets for agricultural produce, access to loans, strong professional organizations — so that this capacity to innovate can develop.

■ **Farmer organizations in the Sahel.** As government support is withdrawn, Sahelian farmers are organizing to take over the economic functions that have been left to private initiative: purchasing of input materials, credit, marketing and conversion of agricultural produce, equipment maintenance, land planning and management. These numerous organizations, whether initiated locally or as part of larger structures, are the manifestation of the rural communities' will to take responsibility for their own future. They are directed by people with a long farming tradition, by members of the community knowledgeable of what is done beyond the village walls, and by a growing number of NGOs. Despite its dynamism, this associative movement in the Sahel is vulnerable and performance varies from group to group. For an organized agricultural profession to materialize, the transfer of responsibilities must be accompanied by transfer of financial and material resources and, most important, of competence; today's priority is farmer training and teaching.

■ **Mathematical modelling of farming systems.** CIRAD has applied linear programming to the modelling of farming systems, first on a village, then on a regional, scale. The objective is to determine the technical, economic, social and organizational conditions necessary for sustainable agriculture in tropical regions. The models elaborated make it possible to identify blocking factors and to test beforehand the solutions proposed to deal with them. In addition, a local economic system in Burkina Faso has been drawn up in spreadsheet form. This form of overview takes account of monetary flows and their impact, and can therefore be used to monitor, evaluate and focus research and development projects in rural areas.

■ **Privatization and decentralization of agricultural services.** Liberalization policies advocate the privatization of services to agriculture which are public in many countries: purchasing of input materials, marketing, credit, veterinary services, public research. CIRAD has established criteria for defining the public or private nature of these services. In addition, public services have been studied in light of the concepts of subsidiarity and decentralization to determine their optimum geographical locations. Apportionment between public and private domains on the one hand, between central and decentralized domains on the other, increases the range of possible institutional choices for reforming the role of services to agriculture well beyond mere privatization.

■ **Effects of the structural adjustment policies.** Structural adjustment policies, which came into force in many developing countries in the 1980s, are theoretically to the advantage of the agricultural sector. They attempt to correct the broad lines of former economic policies which were prejudicial to agriculture — especially the high customs tariffs and overvalued exchange rates. CIRAD carried out a comparative survey in several Latin American countries to assess their effects. It is true that agricultural prices have risen compared with those of other products. But this positive effect is often countered by the deterioration of infrastructures and services to agriculture due to budget restrictions.

■ **Environmental imbalance.** CIRAD has published *Prospective des déséquilibres environnementaux liés à l'agriculture dans les pays tropicaux* (Prospective environmental imbalance in relation to agriculture in tropical countries), a report, financed by the Ministry of Research and Technology, based on studies of the production systems in Africa, Asia, and Latin America, and on expert analyses. This synthesis sets out to define the checks and balances in sustainable agriculture and to analyse how they alter under conditions of demographic stress and social conflict. A list has been drawn up of dangers concerning soil fertility, water use and forest exploitation. Imbalance in the financial, employment and food sectors is also discussed.

List of abbreviations

ADEME, Agence de l'environnement et de la maîtrise de l'énergie, France
AFVP, Association française des volontaires du progrès, France
AIT, Asian Institute of Technology, Thailand
ANVAR, Agence nationale de valorisation de la recherche, France
BAD, Banque africaine de développement, Côte d'Ivoire
BSFT, Laboratoire de biotechnologie des symbioses forestières tropicales (CIRAD-ORSTOM), France
CAMDA, Centre d'application de méthodologie pour le diagnostic des maladies animales, France
CEFEB, Centre d'études financières, économiques et bancaires, France
CEMAGREF, Centre national du machinisme agricole, du génie rural, des eaux et des forêts, France
CERAAS, Centre d'étude régional pour l'amélioration de l'adaptation à la sécheresse, Senegal
CERF, Centre d'études, de recherche et de formation, France
CETEC, Corporación para Estudios Interdisciplinarios y Asesoría, Colombia
CFD, Caisse française de développement, France
CFTRI, Central Food Technological Research Institute, India
CIAT, Centro Internacional de Agricultura Tropical, Colombia
CIDT, Compagnie ivoirienne pour le développement des textiles, Côte d'Ivoire
CILSS, Comité permanent inter-Etats de lutte contre la sécheresse dans le Sahel, Burkina Faso
CMDT, Compagnie malienne pour le développement des textiles, Mali
CNCA, Caisse nationale de crédit agricole, Burkina Faso
CNES, Centre national d'études spatiales, France
CORAF, Conférence des responsables de la recherche agronomique africains
CRBP, Centre régional bananiers et plantains, Cameroon
CRDI, Centre de recherches pour le développement international, Canada
CSIRO, Commonwealth Scientific and Industrial Research Organization, Australia
CTA, Centre technique de coopération agricole et rurale, The Netherlands
DORAS, Development-Oriented Research on Agrarian Systems Project, Thaïland
ENSIA, Ecole nationale supérieure des industries agricoles et alimentaires, France
FAC, Fonds d'aide et de coopération, France

FAO, Food and Agriculture Organization of the United Nations, Italy
FDGDC, Fédération départementale des groupements de défense des cultures, France
FED, Fonds européen de développement, Belgium
FOFIFA, Centre national de la recherche appliquée au développement rural, Madagascar
ICRISAT, International Crops Research Institute for the Semi-Arid Tropics, India
ICSB, Innoprise Corporation Sdn. Bhd, Malaisia
IDEFOR, Institut des forêts, Côte d'Ivoire
IDESSA, Institut des savanes, Côte d'Ivoire
IER, Institut d'économie rurale, Mali
IFC, Institut français du caoutchouc, France
IFREMER, Institut français de recherche pour l'exploitation de la mer, France
IFRPD, Institute of Food Research and Product Development, Thailand
IICA, Instituto Interamericano de Cooperación para la Agricultura, Costa Rica
IITA, International Institute of Tropical Agriculture, Nigeria
INERA, Institut d'études et de recherches agricoles, Burkina Faso
INRA, Institut national de la recherche agronomique, France
ISABU, Institut des sciences agronomiques du Burundi, Burundi
ISRA, Institut sénégalais de recherches agricoles, Senegal
MSIRI, Mauritius Sugar Industry Research Institute, Mauritius
NGO, Non-governmental organization
NOAA, National Oceanographic and Atmospheric Administration, USA
NRI, Natural Resources Institute, Great Britain
NVI, National Veterinary Institute, Ethiopia
OIE, Office international des épizooties, France
ONF, Office national des forêts, France
ONIC, Office national interprofessionnel des céréales, France
ORSTOM, Institut français de recherche scientifique pour le développement en coopération, France
PCARRD, Philippine Council for Agriculture and Resources Research and Development, Philippines
SEAMEO, Southeast Asian Ministers of Education Organization, Thailand
SEDECOM, Servicio de Desarrollo y Consultorio para el Sector Cooperativo y de Microempresas, Colombia
SODEPRA, Société pour le développement des productions animales, Côte d'Ivoire
SUAD, Service d'utilité agricole de développement, France
UAPPY, Unión de Asociaciones de Productores y Procesadores de Yuca, Ecuator

CIRAD addresses

Headquarters

42, rue Scheffer
75116 Paris
France
Telephone: (1) 53 70 20 00
Fax: (1) 47 55 15 30
Telex: 648729 F

Montpellier Research Centre

2477, avenue du Val
de Montferrand
BP 5035
34032 Montpellier Cedex 1
France
Telephone: 67 61 58 00
Fax: 67 61 59 86
Telex: 480762 F

CIRAD Departments

CIRAD-CA
Département des cultures annuelles
2477, avenue du Val de Montferrand
BP 5035
34032 Montpellier Cedex 1, France
Telephone: 67 61 58 00
Fax:67 61 59 88
Telex: 485221 F

CIRAD-CP
Département des cultures pérennes
12, square Pétrarque
75116 Paris, France
Telephone: (1) 53 70 20 00
Fax: (1) 45 53 68 11
Telex: 645491 F

CIRAD-FLHOR
Département des productions
fruitières et horticoles
26, rue Poncelet
75017 Paris, France
Telephone: (1) 40 53 70 50
Fax: (1) 40 53 04 26

CIRAD-EMVT
Département d'élevage et de médecine vétérinaire
10, rue Pierre Curie
94704 Maisons-Alfort Cedex, France
Telephone: (1) 43 68 88 73
Fax: (1) 43 75 23 00
Telex: 262017 F

CIRAD-Forêt
Département des forêts
45 bis, avenue de la Belle Gabrielle
94736 Nogent-sur-Marne Cedex, France
Telephone: (1) 43 94 43 00
Fax: (1) 43 94 43 29
Telex: 264653 F

CIRAD-SAR
Département des systèmes agroalimentaires et ruraux
Halle de la technologie
73, rue Jean-François Breton
BP 5035
34032 Montpellier Cedex 1, France
Telephone: 67 61 57 01
Fax: 67 61 12 23
Telex: 485221 F

CIRAD-GERDAT
Département de gestion, recherche, documentation et appui technique
42, rue Scheffer
75116 Paris, France
Telephone: (1) 53 70 20 00
Fax: (1) 47 27 58 13
Telex: 648729 F

French Overseas Departments and Territories

Guadeloupe
M. le délégué
Station CIRAD-FLHOR de Neufchâteau
Sainte-Marie
97130 Capesterre-Belle-Eau
Telephone: (590) 86 30 21
Fax: (590) 86 80 77
Telex: 919121 GL

French Guiana
M. le délégué
BP 701
97387 Kourou Cedex
Telephone: (594) 32 04 30
Fax: (594) 32 42 27
Telex: 910323 FG

Martinique
M. le délégué
BP 153
97202 Fort-de-France Cedex
Telephone: (596) 71 92 01
Fax: (596) 63 07 24

New Caledonia
M. le directeur
BP 73
Païta
Telephone: (687) 35 36 84
Fax: (687) 35 32 23

Réunion
M. le délégué
Station de La Bretagne
97487 Saint-Denis Cedex
Telephone: (262) 52 50 09
Fax: (262) 52 68 60
Telex: 916033 RE

Other Countries

Brazil
M. le délégué
SHIS – QI 11
Conjunto 6, casa 7
71 625-260 Brasilia DF
Telephone: (55) 61 248 41 26
Fax: (55) 61 248 23 81

Burkina Faso
M. le délégué
01 BP 596
Ouagadougou 01
Telephone: (226) 30 39 42
Fax: (226) 30 76 17

Burundi
M. le correspondant
c/o Isabu
BP 795
Bujumbura
Telephone: (257) 22 33 90
Fax: (257) 22 87 29

Cameroon
M. le délégué
BP 2572
Yaoundé
Telephone: (237) 21 25 41
Fax: (237) 20 29 69
Telex: 8202 ou 8531 KN

Chad
M. le correspondant
Laboratoire de Farcha
BP 433
N'Djamena
Telephone: (235) 51 30 07
Fax: (235) 51 33 02

Comoros
M. le délégué
(based in Réunion)

Congo
M. le correspondant
BP 1291
Pointe-Noire
Telephone: (242) 94 31 84
Fax: (242) 94 40 54
Telex: 8303 KG (att. CIRAD)

Costa Rica
M. le délégué pour l'Amérique latine et la Caraïbe
Apartado 1127
2050 San Pedro
San José
Telephone: (506) 225 59 72
Fax: (506) 225 09 40

Côte d'Ivoire
M. le délégué
01 BP 6483
Abidjan 01
Telephone: (225) 22 18 69
Fax: (225) 21 43 68
Telex: 23220 CI

Fiji
M. le correspondant
PO Box 16213
Suva
Telephone: (679) 387 554
Fax: (679) 387 855

Gabon
M. le correspondant
CATH
BP 643
Libreville
Telephone: (241) 73 65 76
Fax: (241) 73 65 76
Telex: 5900 GO

Guatemala
M. le délégué
(based in Costa Rica)

Guinea
M. le correspondant
c/o MCAC
Ambassade de France
BP 570
Conakry
Telephone: (224) 44 42 62 (IRAG)
Fax: (224) 41 34 30 (MCAC)
Telex: 22400 GE (att. CIRAD)

Honduras
M. le délégué
(based in Costa Rica)

Indonesia
M. le délégué
Sutimah building, 3rd Floor
Jalan Kemang Raya N° 2
Jakarta Selatan 12730
Telephone: (62) 21 799 28 67
Fax: (62) 21 799 30 44
Telex: 47243 IA (att. CIRAD)

Madagascar
M. le délégué
BP 853
Antananarivo
Telephone: (261) 22 71 82
Fax: (261) 22 09 99
Telex: 22591 MG

Malaysia
M. le correspondant
(based in Singapore)

Mali
M. le délégué
(based in Burkina Faso)
M. l'adjoint au délégué
BP 1813
Bamako
Telephone: (223) 22 42 93
Fax: (223) 22 87 17

Mauritius
M. le délégué
(based in Réunion)

Nicaragua
M. le délégué
(based in Costa Rica)

Niger
M. le délégué
(based in Burkina Faso)

Panama
M. le délégué
(based in Costa Rica)

Philippines
M. le correspondant
c/o PCARRD
Los Baños 4030
Laguna
Telephone: (63) 500 14 or 20
Fax: (63) 500 16
Telex: 40860 PM

Republic of South Africa
M. le correspondant
Agribis c.c.
PO Box 1435
Gallo Manor
Sandton 2052
Telephone: (2711) 706 7654
Fax: (2711) 706 7654

Senegal
M. le délégué
37, avenue Jean XXIII
BP 6189
Dakar-Etoile
Telephone: (221) 22 44 84
Fax: (221) 21 18 79
Telex: 21562 SG

Singapore
M. le correspondant
Selegie Complex 14-275
257 Selegie Road
Singapore 0718
Telephone: (65) 337 26 00
Fax: (65) 337 62 69
Telex: 34563 RS

Thailand
M. le délégué
AIT, AFE Program
GPO Box 2754
Bangkok 10501
Telephone: (662) 524 54 72
Fax: (662) 524 62 00

United States of America
M. le correspondant
Development Research Associates
2025 I Street, NW
Suite 524
Washington DC 20006
Telephone: (1) 202 872 05 76
Fax: (1) 202 872 84 91
Telex: 440452 UI

Vanuatu
M. le délégué
Station de Saraoutou
BP 231
Santo
Telephone: (678) 36 320
Fax: (678) 36 355
Telex: 1001 NH

Vietnam
M. le correspondant
c/o ISA
121, Nguyen Binh Khiem
Q1 Ho Chi Minh City
Telephone: (84) 823 09 49
Fax: (84) 829 76 50

Production: Service des éditions du CIRAD
Unité centrale d'information scientifique et technique (CIRAD-GERDAT)

Publication managers: Michelle Jeanguyot
Martine Séguier-Guis
All articles were drafted in collaboration with the teams conducting research work at CIRAD

Translation into English: TransCriptum, Vendargues

English editor: Brian Wills

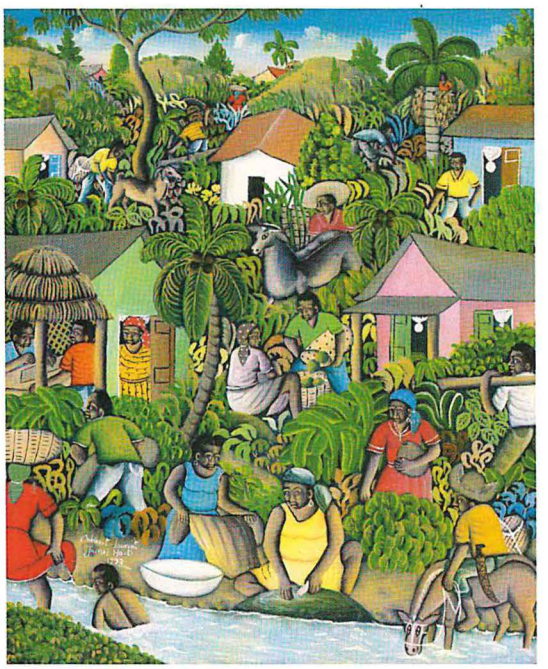
Graphics: Thierry Erwin

Layout and production: Louma productions, Aniane

Printing: Publicep, Montpellier

French *dépot légal*: *septembre 1994*

Original title: *Images de la Recherche*



Cover picture
« La rivière » from Wilbert Laurent, Haïti

Illustration credits
p. 10: B. Lidon ; p. 11, 12: N. Ahmadi ; p. 13: B. Lidon ; p. 14, 15: C. Daniel ; p. 16: T. Erwin ; p. 17: C. Daniel ; p. 18, 19, 20, 21: P.-C. Lefèvre ; p. 23, 24: D. Vincenot ; p. 25: D. Vincenot, E. Parisot ; p. 26, 27, 28, 29: G. Trébuil ; p. 34, 35, 36, 37: H. Jeanjean ; p. 38: P. Guizol ; p. 39: F. Besse ; p. 40: P. Guizol ; p. 41: F. Besse ; p. 42: J. César ; p. 43: J.-F. Giovannetti ; p. 44: G. Forgiarini, F. Caillliez ; p. 45: R. Lancelot ; p. 46: B. Vercambre ; p. 47: B. Vercambre, M. Betbeder-Matibet ; p. 48: B. Vercambre, T. Erwin ; p. 54: T. Erwin ; p. 55, 56, 57: M.-P. Carron ; p. 58, 59: C. Lanaud, G. Blaha ; p. 60: C. Lanaud ; p. 62, 63: J. Chantereau ; p. 64: T. Erwin ; p. 65: D. Debert ; p. 66, 67, 68, 69: CERAAS ; p. 70, 71: J. Lazard ; p. 72: J.-F. Baroiller ; p. 73: J.-Lazard ; p. 78: N. Zakhia ; p. 79: N. Zakhia, D. Dufour ; p. 81: D. Dufour ; p. 82: J. Lazard ; p. 84: T. Erwin, J.-C. Dumas ; p. 85: T. Erwin, Cepralmar ; p. 86: CIRAD-Forêt ; p. 87: ONF ; p. 88, 89: CIRAD-Forêt ; p. 90: G. Vaitilingom, CIRAD-CP ; p. 91, 92: T. Erwin ; p. 93: CIRAD-EMVT, G. Vaitilingom ; p. 98, 99: C. Lanaud ; p. 100: G. Trébuil ; p. 101: A. Rival ; p. 102: L. Falquevert ; p. 103: G. de Wispelaere ; p. 104: P. Morant ; p. 105: C. Fovet-Rabot ; p. 106, 107, 108, 109: V. Ribier ; p. 110: L. Falquevert, K. Elsasser ; p. 112: K. Elsasser, L. Falquevert ; p. 113: L. Falquevert

Centre
de coopération
internationale
en recherche
agronomique
pour le
développement

42, rue Scheffer
75116 Paris
France