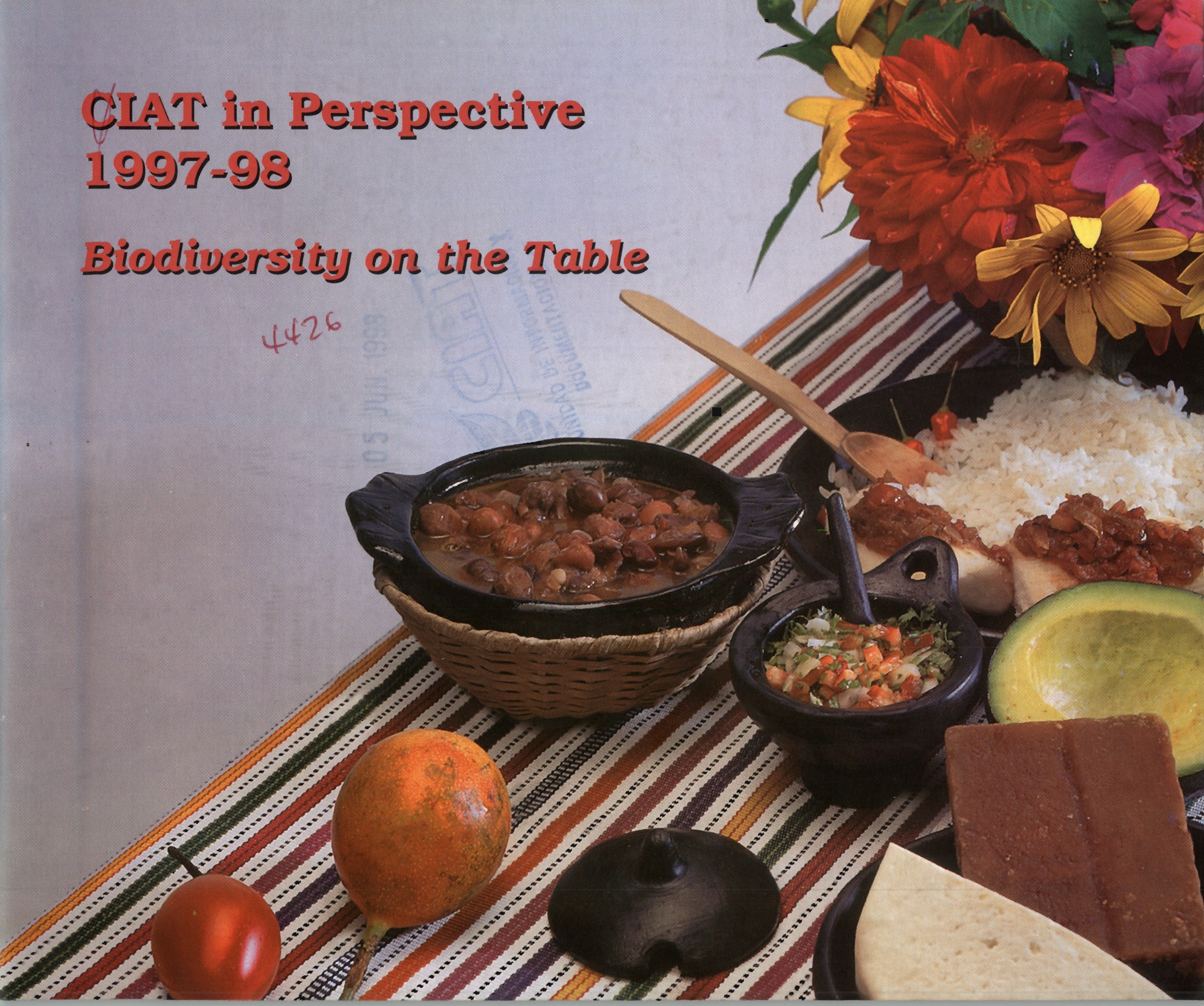
CIAT in Perspective 1997-98

Biodiversity on the Table



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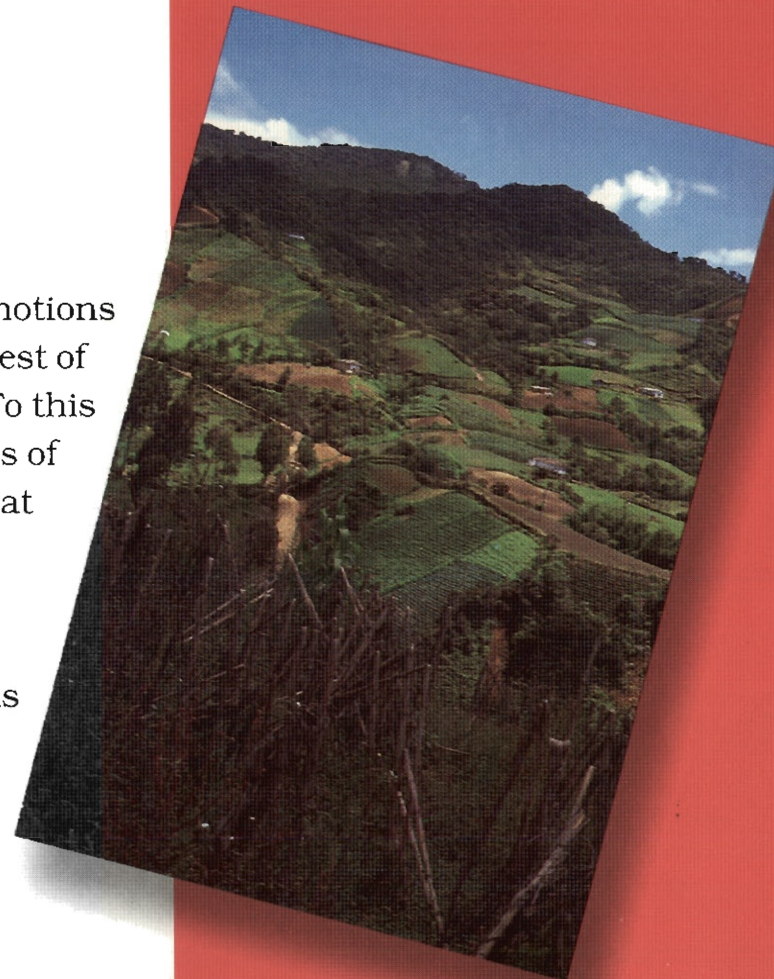
Farm family at Tien Phong village in northern Vietnam's Thai Nguyen province.

Perspective in Practice

To many people, the term "biodiversity" conjures up notions of places where humankind once trod lightly: the rain forest of the Amazon and the dry forests of many tropical regions. To this way of thinking biological diversity lies only in the species of trees, plants, insects, and other nonhuman creatures that inhabit these places.

Too often, the definition omits a vital component of biodiversity, one that depends on this diversity as much as any other species: the human. And far too often, when we speak of biodiversity, we overlook the variety of plant life that keeps humans alive. That agricultural diversity is an inseparable part of the master ecosystem that we call Earth.

As this annual report explains and illustrates, the International Center for Tropical Agriculture (CIAT) is dedicated to better understanding, protecting, and using agrobiodiversity, as well as major tropical agroecosystems that harbor it, for the good of the planet and all its inhabitants.



"We can't afford to neglect the fate of the world's plants."

David Brackett, Chairman, Species Survival Commission, World Conservation Union

Biodiversity on the Table

Grant M. Scobie
Director General

It gives me great pleasure to introduce this issue of *CIAT in Perspective*, which is our corporate annual report for donors, collaborators, and other friends. We value this opportunity to share with you our perspective on biodiversity and to provide you with a varied sampling of achievements and ongoing efforts to better understand, protect, and use this resource for the benefit of humanity, particularly the poor in developing countries.

A source of solutions

Please reflect with me for a moment on some implications of the report's subtitle: *Biodiversity on the Table*. To begin with, it underscores our view that the fate of biodiversity is tied to the state of tropical agriculture—to its prospects for putting more food on the table and more money in the pockets of the poor.

As we point out below, agriculture ought to become the central activity through which people in the tropics benefit from and nurture biodiversity. To accomplish that, though, requires a changed mentality and a lot of work.

Instead of viewing biodiversity merely as a victim of rapid change, we must learn to treat it as a source of solutions to the very problems—hunger, poverty, and inappropriate land use—that put this resource at risk. Rural communities, scientists, and political leaders will be able to protect biodiversity only if their conservation programs include concrete initiatives for sustainable use of biodiversity to provide food and boost incomes.

A walk around CIAT

Finding ways to manage biodiversity sustainably is not a simple business. It requires that we deal with numerous cultivated and wild species and the interactions among them in highly diverse ecosystems. It also demands that we work across scales—from the genome and the farmer's field to the landscape and even continental levels—because what happens at one scale invariably shapes events at the others. This complexity is manageable as long our work integrates scientific disciplines, involves intense cooperation among partners, and draws on the power of new research tools.

If you walk around CIAT headquarters and visit our outposted staff (in a way you are doing both by reading this annual report), you will everywhere observe "biodiversity on the table" as a focus for research and technology development. You will witness engaging work on this subject at work tables in the gene bank, on the benches in our biotechnology and other

Shelling a new variety of common bean at Loja, Ecuador.

labs, in our greenhouses and experiment fields, and even in the computer screens of our GIS specialists.

You will also note that people are doing research together, bringing different perspectives to common tasks. And you will meet, not just CIAT researchers, but colleagues from organizations like the Colombian Corporation for Agricultural Research (CORPOICA) and the International Plant Genetic Resources Institute (IPGRI), as well as a multitude of bright, eager students. We expect that soon they will be joined by staff of Colombia's Alexander von Humboldt Institute of Research on Biological Resources and the Amazonian Institute of Scientific Research.

Many of these scientists are dealing with crops other than those on which CIAT works directly, but they are very much at home here, working side-by-side with our own staff and in the same agroecosystems. If you accompany our scientists to farmers' fields, you will note that biodiversity is a central theme of our efforts to develop methods for involving rural people meaningfully in problem-solving research.

The spotlight on biodiversity

So, biodiversity is a common thread that runs throughout our work, drawing together scientific disciplines and research collaborators and binding both to the farmers they serve. Of course, biodiversity is also a subject of impassioned debate. And CIAT has a seat at the conference table, too, contributing to the lively discussion.

"There is considerable variation among Centres in producing core collections, with CIAT very much to the fore in utilizing GIS and molecular markers to produce core collections of Phaseolus beans and cassava."

From the Report of the Internally Commissioned External Review of the CGIAR Genebank Operations

Preparing seed of the forage legume *Aeschynomene americana* for storage at CIAT headquarters.

In November 1997 we hosted an Internally Commissioned External Review panel, which examined our activities in biotechnology and plant genetic resources, expressed a highly favorable view of our staff and their work, and offered useful recommendations for the future. A month later the Center's annual review put the spotlight on biodiversity once again. Presentations by CIAT staff at the event provided raw material for this annual report.

Those events took place against the background of developments having important implications for the international exchange of plant genetic resources. These include the Convention on Biological Diversity (which is part of Agenda 21, the blueprint for sustainable development that emerged from the 1992 Earth Summit) and the revised International Undertaking on Plant Genetic Resources.

In recent years the Center has taken steps to make its practice in germplasm exchange thoroughly consistent with new international agreements. We have also heightened our emphasis on biodiversity research, in keeping with the priorities of the Consultative Group on International Agricultural Research (CGIAR), which supports CIAT and 15 other centers. In this report we demonstrate, with a wide range of examples, what our scientists are doing to make sure that biodiversity is always on the table, providing food, livelihoods, and other necessities of life, especially for the planet's poorest people.

Partners in biodiversity research

CIAT's home base in Colombia is a medley of scientific disciplines, ranging from plant genetics to ecology and anthropology. The campus also hosts the outposts of numerous partner organizations, including national programs and international centers. One of the latter is the International Plant Genetic Resources Institute (IPGRI).

Founded in 1974, IPGRI promotes the collection, conservation, and utilization of plant genetic resources. Genetic diversity scientist David Williams is based at the Institute's Regional Office for the Americas at CIAT. It is one of five IPGRI regional offices around the world and covers North, Central, and South America as well as the Caribbean.

"The objectives of CIAT are very close in many ways to those of IPGRI," says Williams. "In the 2 years I've been here, I think our collaborative activities have become stronger. And we hope they'll continue to grow." Williams offers these examples of IPGRI-CIAT collaboration, work that is already under way or soon will be:

- CIAT's biotechnology specialists have helped with the molecular marker work in a project funded by the Inter-American Development Bank (IDB) and coordinated by IPGRI to promote the improvement of native fruit species of the American tropics.

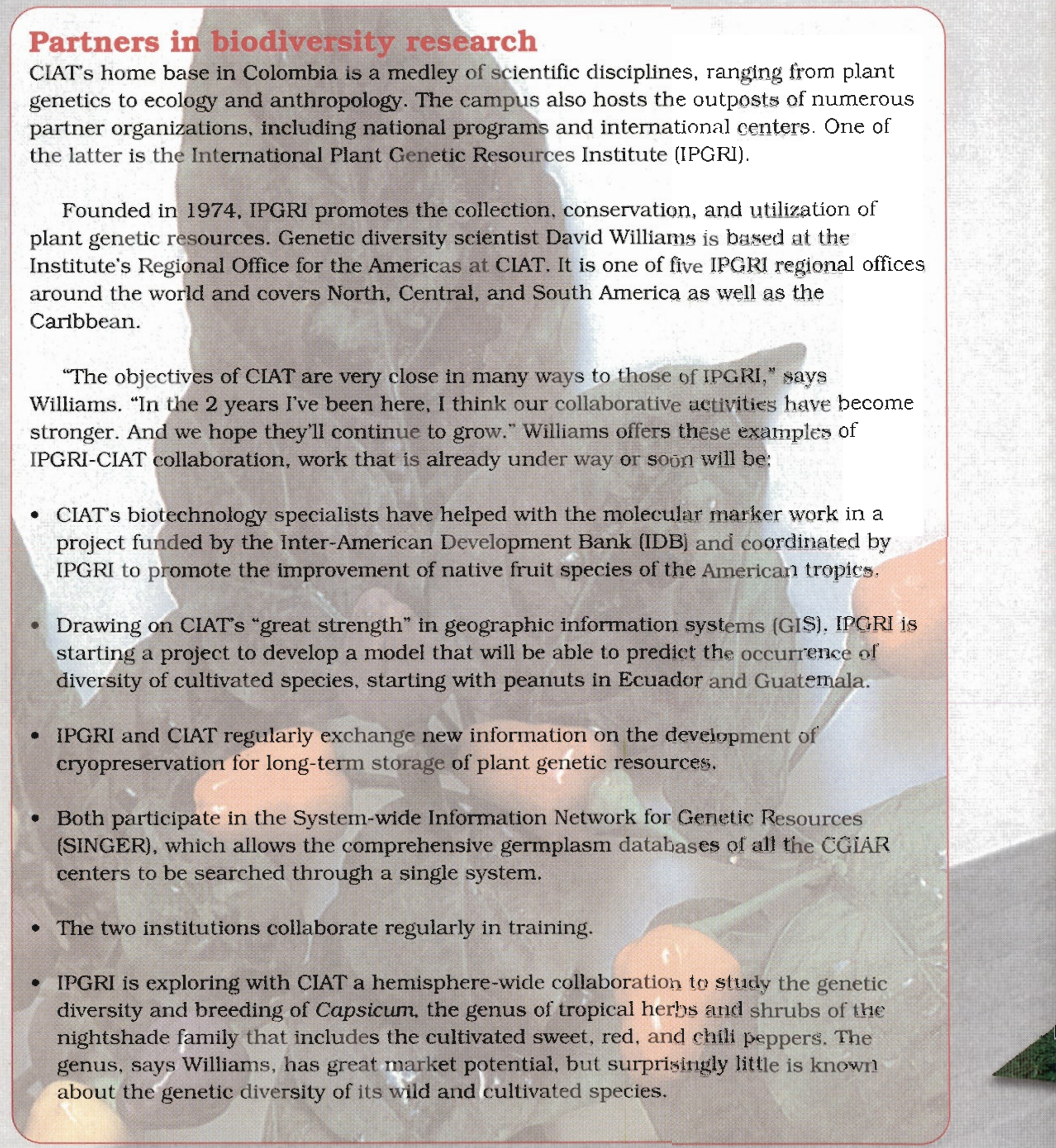
- Drawing on CIAT's "great strength" in geographic information systems (GIS), IPGRI is starting a project to develop a model that will be able to predict the occurrence of diversity of cultivated species, starting with peanuts in Ecuador and Guatemala.

- IPGRI and CIAT regularly exchange new information on the development of cryopreservation for long-term storage of plant genetic resources.

- Both participate in the System-wide Information Network for Genetic Resources (SINGER), which allows the comprehensive germplasm databases of all the CGIAR centers to be searched through a single system.

- The two institutions collaborate regularly in training.

- IPGRI is exploring with CIAT a hemisphere-wide collaboration to study the genetic diversity and breeding of *Capsicum*, the genus of tropical herbs and shrubs of the nightshade family that includes the cultivated sweet, red, and chili peppers. The genus, says Williams, has great market potential, but surprisingly little is known about the genetic diversity of its wild and cultivated species.



An edible variety of chili pepper (*Capsicum annuum*) that is also used as an ornamental.

By the way, we would appreciate it if you could leave a copy of *CIAT in Perspective 1997-98* lying on the table in your office for visitors to peruse and enjoy.

Why Worry about Biodiversity?

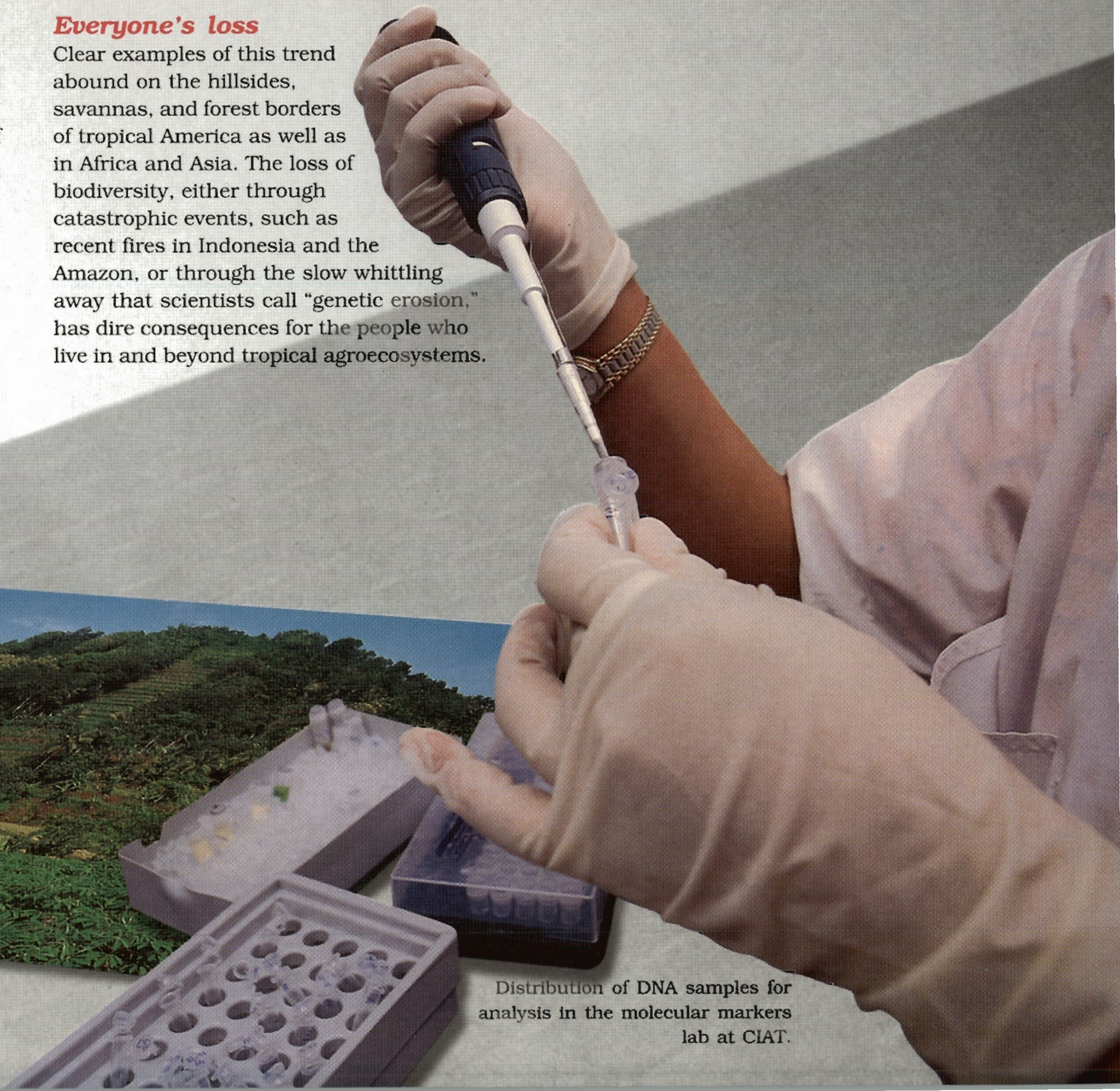
Around much of the globe, agriculture is the central point at which human activity threatens biological diversity. This is especially true in the tropics, where most of the world's biodiversity exists. Environments that are rich in genetic diversity are rapidly becoming degraded or eliminated as crop production expands farther into the forest and up the hillsides.

There are quite comprehensible reasons behind the expansion: Earth's population is expected to nearly double between the mid-1990s and the middle of the coming century; and a growing population will have to be fed. The structure of agriculture favors larger, more commercially intensive farming operations, as do growing world markets. Unfavorable government policies can drive the rural poor closer to both the margins of economic security and the margins of primary forests.

Everyone's loss

Clear examples of this trend abound on the hillsides, savannas, and forest borders of tropical America as well as in Africa and Asia. The loss of biodiversity, either through catastrophic events, such as recent fires in Indonesia and the Amazon, or through the slow whittling away that scientists call "genetic erosion," has dire consequences for the people who live in and beyond tropical agroecosystems.

Intensive cultivation in an upland environment of East Java, Indonesia.



Distribution of DNA samples for analysis in the molecular markers lab at CIAT.

They lose the wild relatives on which cultivated plants have depended for millennia to obtain the genes that secure their evolutionary vigor and survival. They lose valuable plant products, some of which have been used for centuries as natural health remedies, and others whose benefits may never be known once their habitats are altered. The people who depend on these systems at first hand and their fellow humans far downstream lose water supplies that have been ruined by erosion and toxic runoff. They are increasingly in danger of losing (as is the rest of the world) their definition of "the climate," as the burning of cropland makes its contribution to global climate change.

Within agriculture itself, the genetic base—the biodiversity—of production is being eroded not only because plants' wild relatives are disappearing, but also because of widespread agricultural practices that encourage the use of monocultures, emphasizing genetic uniformity at the expense of diversity. If farmers move to a single variety of cassava, maize, or bean in response to market demand, they are more likely to neglect their traditional landraces.

Better ways

Behind all of these issues, and pushing them forward faster than the planet has been able to cope with them, is the virtual certainty of greatly increased population growth. Most arguments in favor of protecting land from encroachment by agriculture fade when measured against a family's need to feed itself. Traditionally, people have responded to such pressures in straightforward ways: They have cleared more forest for crop production, pushed ever higher up steep hillsides in search of arable land, and applied chemicals in hopes of eradicating pests and diseases and restoring lost soil fertility.

Now it is clear that those ways are not always good for the planet's health, and in many cases they actively damage it. Better ways must be found, and—because of the inexorable push of population growth—they must be found soon.

At CIAT we work in the belief that biodiversity is a crucial part of the solution to the very problems that threaten our ability to feed ourselves—from the damage caused by insects and diseases to the poverty that afflicts much of the tropical world.

With the aid of powerful tools, ranging from molecular genetic markers to computer programs that depict biodiversity on large, colorful maps, to research collaborations between farmer and scientist, we develop ways to protect and use biodiversity sustainably in major agroecosystems. We also employ the genetic diversity of particular species to generate new cultivars that solve food production dilemmas and create new sources of income for rural people.

These products are of little value until people use and benefit from them. To make that happen, CIAT distributes improved seed, methods, and information in a variety of ways: for example, by sharing germplasm with cooperators worldwide, by organizing workshops with fellow scientists, by hosting researchers from national organizations in the Center's laboratories, and by producing information tools that run on ordinary computers. We feel that no single approach is enough to feed the world and sustain biodiversity. Instead, we weave together various approaches that cross the boundaries of geography and scientific specialization.

The days of "magic bullets" and "dramatic breakthroughs" are fast disappearing, and they are being replaced by a new understanding of the interrelated nature of the planet's problems and the solutions for them. Coping with a diversity of connected problems is far more complicated than dealing with individual components of agricultural production, but it is the only way to understand the diversity of nature and achieve durable solutions to those problems.

Crossing cultivated rice with wild *Oryza barthii.*

Members of the rapidly expanding human family from Colombia, Vietnam, and Uganda.

The Andean landscape of Ecuador's Loja Province.

Preserving Biodiversity in the Landscape

During a 1997 meeting held by the US National Academy of Sciences, there was widespread agreement that in the dozen years since the term "biodiversity" was coined, science has gained only a rudimentary understanding of the diversity of life. Knowledge is sorely lacking on the complex ecological relationships among species and on their ultimate contributions to the biosphere.

On one point there did seem to be sad agreement: The world is teetering on the edge of a sixth great wave of extinction, brought on by the gradual depletion of biological diversity, largely from loss of habitat. To help ward off this threat, CIAT scientists are examining patterns of land management and their effect on biodiversity at the continental scale and in major agroecosystems. The aim of this work is to provide tools, methods, and information that help guide the decisions and actions of policy makers, research and development workers, local communities, and farmers.

"There is virtual unanimity among professional scientists that, given present trends, the planet is likely to be ravaged biologically with the loss of one-quarter to one-half of all species within a century."

Thomas E. Lovejoy, Counselor for Biodiversity and Environmental Affairs, Smithsonian Institution, USA

Beyond Business as Usual

A powerful new tool for environmental management

One way in which CIAT helps improve environmental management—including biodiversity and other natural resources—is to develop menus, toolboxes, and palettes of information and make them available to global, regional, and national organizations. By providing the best information available, these tools help users understand current trends, anticipate the impact of new measures, and thus make better decisions about projects and policies.

A recent product of this work that has widespread application is the Spanish-language *Atlas of Environmental and Sustainability Indicators for Latin America and the Caribbean*, available on CD-ROM. A coproduction of CIAT and the United Nations Environment Programme (UNEP), Atlas CD (the short version of its name) is the work of CIAT environmental scientist Manuel Winograd with Andrew Farrow and Jeremy Eade, both specialists in geographic information systems (GIS). Theirs is the region's first computerized atlas on its subject.

What is innovative about Atlas CD, explains Winograd, is not the nature of the information it contains. Rather, it is the user-friendly interface that allows you to

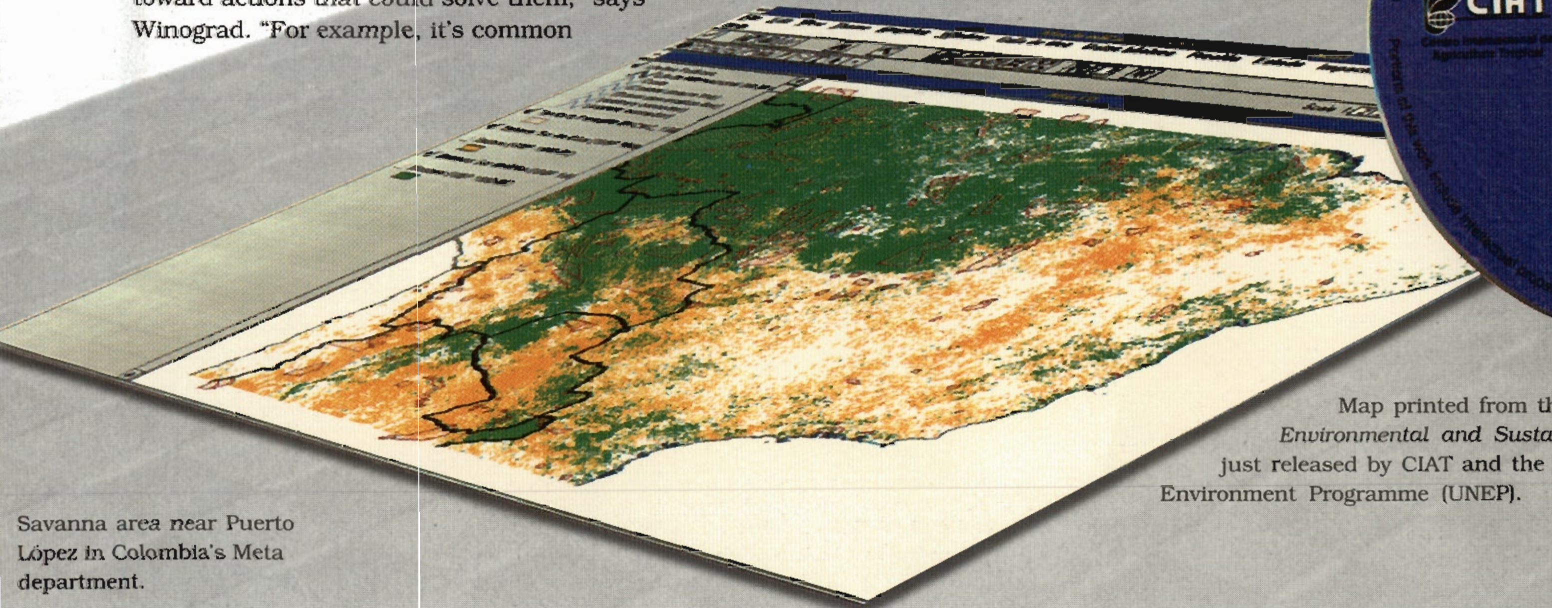
easily pull together and overlay on maps many kinds of indicators from a variety of reputable but separate sources. The interface organizes more than 200 social, economic, and environmental indicators into four general categories: pressure (on the environment), state (of the environment), impact/effect (of human activity), and response (through specific measures).

Under each of the four categories, indicators are available for 14 variables, such as population, economic development, agriculture and food, forests and savannas, biodiversity, fresh water, and atmosphere and climate. Several of these indicators can be displayed on the same map. The interface also allows the user to zoom into an area of interest for a more detailed image.

"The power of this tool lies in its ability to reveal gaps in our understanding of environmental problems and to point toward actions that could solve them," says Winograd. "For example, it's common knowledge that deforestation is at the top of tropical America's environmental agenda. But how many people realize that almost half of this deforestation is happening in dry tropical forests?" The rain forests receive far more public attention, because they contain more plant species and because their destruction may contribute more to global warming. But the dry forests provide habitats for a larger number of mammal species as well as for the wild relatives of important crops, such as beans, peppers, and tomato. And being closer to food-producing areas, these forests are under far greater human pressure.

Only 21 percent of tropical America's dry forest remains, compared to 88 percent of the rain forest still in natural vegetation. Yet, a larger share of the rain forest has been set aside in biodiversity reserves, notes Winograd. To save what little remains of the dry forest, policy makers urgently need to rethink decisions about biodiversity reserves, road building, agricultural development, and other actions that will determine the fate of this resource. Atlas CD will help them do that.

For those who wish to look beyond the big picture today, says Winograd, the program offers predictive models that compare two scenarios: "sustainable" and "business as usual." The models permit the



Map printed from the *Atlas of Environmental and Sustainability Indicators* just released by CIAT and the United Nations Environment Programme (UNEP).

Savanna area near Puerto López in Colombia's Meta department.

user to simulate the future of a particular ecological or "life" zone, such as tropical dry forests or subtropical savannas, according to selected variables. When the model is run, graphs projecting land use indicators over time can be viewed, along with an analysis of the projected changes. The model exists in text format now, but in a later version Winograd and his coauthors will add the capacity to develop maps of future scenarios. "This will give policy makers a new tool for analyzing the possible impact of their policies," he says.

The impact of human beings on biodiversity is evident in many of the maps produced by Atlas CD—for example, in those showing population growth and other social indicators, even in the land devoted to growing illegal crops, a practice that has direct effects on agriculture and the environment. "It's very interesting to talk about biodiversity," he says. "But if you really want to analyze biodiversity, you must look at in the full context of the development process. Biodiversity is a function of population, of economic pressure, of land use."

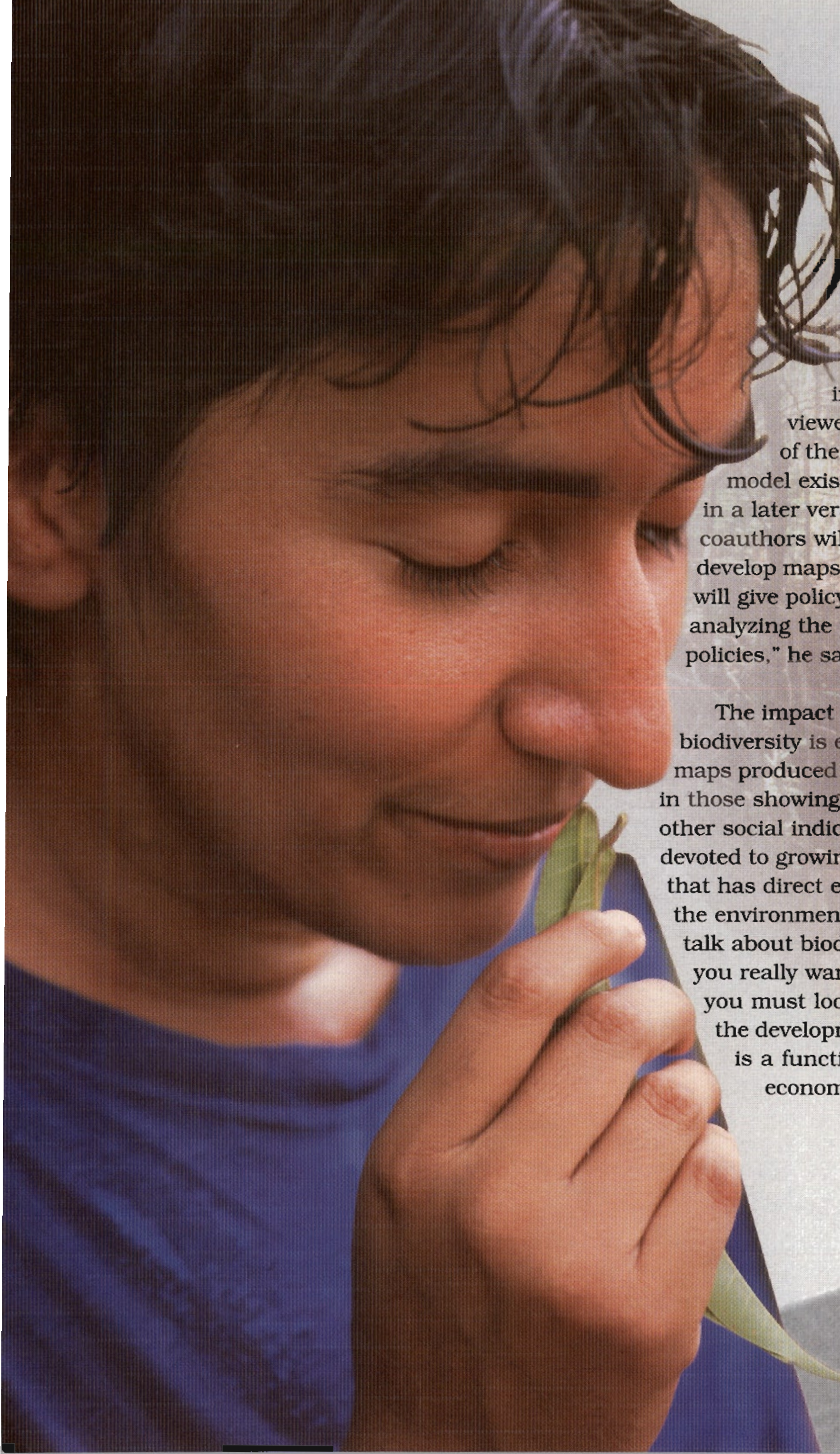
Gallery of Treasures

A unique reservoir of biodiversity at risk

Big-picture techniques for viewing the landscape drive home the fact that Colombia's vast savannas, called the *Llanos Orientales* or Eastern Plains, are much more than just grassland. This savanna region covers some 170,000 square kilometers and stretches from the Andes Mountains to the Orinoco River.

To the casual observer the *Llanos* seem almost treeless—good reason that they have been used for raising cattle since the time of the Spanish colonists and that CIAT has been interested for decades in encouraging the growth of highly productive pasture grasses and legumes. But another feature of the area has been widely overlooked: the narrow strips of forest that accompany the streams running through the *Llanos*. Called "gallery forests," these are repositories of much of the savanna region's biological diversity.

"The gallery forests are grossly underinvestigated—not thought of often as an integral part of the savanna," explains Erik Veneklaas, tropical ecologist at CIAT. Then he opens a map, produced with images from the US satellite Landsat, showing the streams that drain the *Llanos*. Alongside the streams, prominently displayed in red, are gallery forests. "In some places," says Veneklaas, "the galleries can constitute up to 20 percent of the savannas' total area. On average, it's 10 to 15 percent."



Biology student Adriana Fajardo is studying the rich biodiversity of gallery forests in Colombia's Eastern Plains.

The environmental importance of the gallery forests far exceeds their geographical size. The narrow but dense forests contain concentrations of biomass, plants and animals (including the capybara, the world's largest living rodent), and water. They are also strategically positioned in the landscape to regulate the flow of water and intercept sediment reaching the flood plain. Government policies do recognize the importance of gallery forests for watershed protection and have declared that forest corridors 30 meters wide must be left on each side of a stream. But in many places the regulations have been ignored.

Visits to families living beside the gallery forests near the Colombian *Llanos* town of Puerto López, in the department of Meta, show a high level of appreciation for the services the forests perform. Although some valuable timber species have become scarce, the species that savanna dwellers extract from the galleries—for fence posts, construction, or fuel—regenerate quite well.

Veneklaas confirms this widespread appreciation: "I think people have realized the value of the resources. But one of the reasons we're working there is that we expect that with better access and new agricultural technologies, population pressure will increase. Agriculture will intensify, and farm sizes, which are in the thousands of hectares now, will be smaller. There will be more households. Every farm will have the same needs or more for game, separation of fields, and water. And all that will come out of the gallery forest."

In its search for ways to protect these forests, CIAT has reached high into the sky, to images collected by satellites. Remote sensing specialist Nathalie Beaulieu employs GIS to combine satellite images as well as information digitized from maps and data collected in the field into graphic representations of environmental conditions on the ground.

In 1997 she was working with three different types of images covering an area between Puerto López and Puerto Gaitán, each providing different information. The images show pasture (including grassland that has been burned, a traditional method farmers use to regenerate pasture) and forest. Beaulieu and coworkers are now analyzing the subtle differences in density of the images, comparing what the satellites see with what researchers encounter on the ground. "Our aim is to

Satellite image of the Yucao River watershed in Colombia's Meta department.

The flower of the tree *Caryocar* sp. is commonly eaten by animals inhabiting the gallery forests.

Seeds of the moriche palm (*Mauritia flexuosa*).

produce a map that will show the areas that are still in native pasture," she says, "as opposed to improved pastures planted by farmers."

Some areas of the natural savanna are too fragile to support intensified grazing or crops, while in others, having more stable soils, it is possible to intensify agriculture. Monitoring of natural savanna environments will help land management planners determine what uses to encourage in specific areas. It will also help them understand the importance of the gallery forests and identify areas where this resource is at risk. Satellite images provided to CIAT by Japan's National Space Development Agency (NASDA), for example, have enabled Center scientists to map riverbanks along which the forest strips have disappeared or become dangerously narrow.

So far, reports Veneklaas, his team has identified five types of forest in the *Llanos*. The type usually depends on the size of the stream. At the head of a stream, there is often a forest dominated by distinctive stands of palms called *morichales*, named after the moriche palm (*Mauritia flexuosa*). Another sort of forest is inundated frequently for short periods. A dry forest lives closer to the border of the gallery and the savanna, and there is a transitional forest closer to the water. Another sort of forest remains flooded during the entire rainy season.

"Almost by nature, it's a fragmented forest," says Veneklaas. And it's all at risk, because if you cut down 1 hectare here and 1 hectare there, you'll isolate all of one section from all of another. This will reduce the genetic interaction between populations and even lead to the local extinction of species, that is, to the loss of biodiversity."

A Bad Bargain for Everyone

Effects of land use on biodiversity in the Peruvian Amazon

Biological diversity is important everywhere, but it has special significance on the border between cultivated land and the tropical forest. A team of CIAT researchers—agricultural anthropologist Sam Fujisaka, botanist German Escobar, and ecologist Erik Veneklaas—has studied the effects of logging, slash-and-burn agriculture, and road building in two Amazonian regions, most recently around the Peruvian frontier town of Pucallpa, on the Ucayali River, an Amazon tributary. Their findings have alarming implications for the farmers who struggle to make a living around Pucallpa and for the individuals who decide about policies and projects affecting land use in the area.

Fujisaka's team has conducted an extensive survey of plant species and their frequencies around Pucallpa under a variety of land management conditions. The scientists also interviewed 71 farmer-settlers in the area on what they saw as desirable forest plant species (and thus allowed to continue growing in their fields),

Weed-infested field near Pucallpa in the Peruvian Amazon.

the worst crop weeds, and both desirable and undesirable plants in fallows.

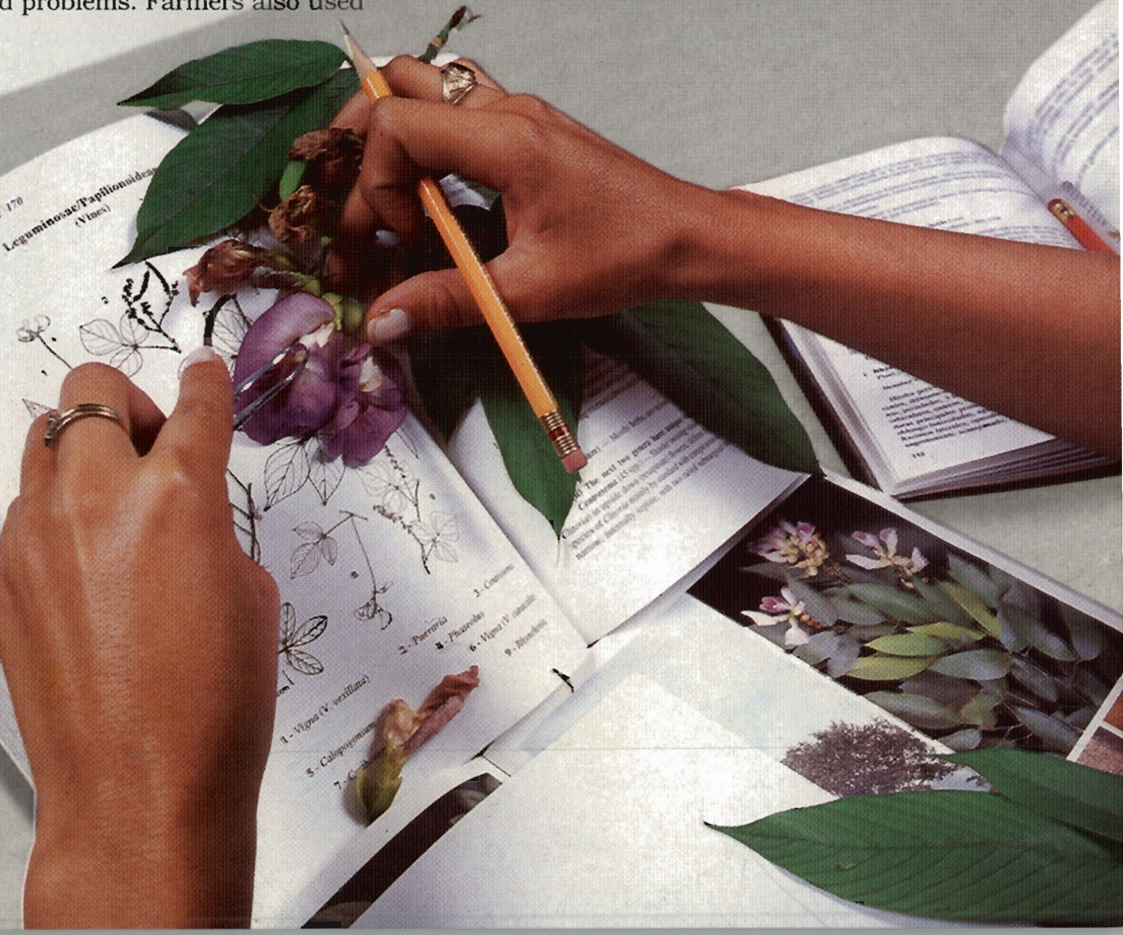
Typically, farmers in the region clear the forest and cultivate annual crops until declining productivity (the result of weeds and low soil fertility) forces them to abandon the field. As nature takes over again, the same weeds that competed with crops and other plants become components of the fallow that restores soil fertility for future cultivation.

Not surprisingly, the survey showed that the forest is richest in diversity, at 235 species. Once settlers converted forest to fields, usually through slash-and-burn, 143 of the forest species disappeared. As successive years of cropping changed the nature of field conditions, different sets of more competitive plants (known to farmers as "weeds") emerged in higher numbers. Forest plants, including trees that produce small numbers of large seed and depend on mammals and larger birds to disperse their seeds, were placed increasingly at a disadvantage. Plants that produce large numbers of seeds with greater longevity and are better adapted to open conditions took hold. As the fields aged under cultivation, the number of plant species from the forest declined.

Species increased again during fallow periods. "Fallows of 5 or more years were most similar to forest in terms of high number of species (183)," report the researchers. But these fallows differed from the forest samples, containing only a quarter of the forest species. When land was returned from fallow to cultivation, farmers found more weeds—the forest's revenge, as it were—many of them high seed producers that were adapted to field conditions of openness, poorer soils, and less soil moisture.

Farmers had little trouble identifying the species that were least desirable—those indicating soil degradation and posing severe weed problems. Farmers also used and valued selected species; almost a third of them left desirable plants in the slash-and-burn fields; most were commercially valuable softwoods. The farmers listed 66 plants as "desirable" in fallowed fields, including some plants with medicinal value and multipurpose palms and other trees.

Unfortunately, though, these species occur at low frequencies across land uses, reflecting their heavy exploitation. For example, in recent years extraction of the hardwood species *Dipterix odorata* has increased, as the government has reestablished control of the region, prompting some farmers to shift from coca to charcoal production.



Identifying plant specimens in the herbarium at CIAT headquarters.

Current patterns of land management around Pucallpa are thus a bad bargain for everyone. Farmers who come here in search of a better life through production of annual crops, such as rice and cassava, soon find themselves locked in a destructive and futile pattern of forest clearing and land degradation. Rapidly declining soil fertility and the proliferation of competitive weeds on land cleared from forest and fallows give them no alternative but to continue. The resulting disappearance of forest plants deprives settlers of many useful species and represents a potentially disastrous loss of biodiversity for society generally, both in and beyond Peru.

This study adds further weight to the evidence on the negative consequences of policies and programs that encourage settlement in forest margin areas as a means of boosting agricultural production or relieving population pressure in other places.

Solutions That Pay Today

Adoption of sustainable production systems in Colombia

All the top-notch agricultural research in the world cannot halt a narrowing genetic base, protect biodiversity, or help farmers in the tropics get out of poverty without the enthusiastic participation of the farmers themselves. Farmers in the tropics, more than their counterparts elsewhere, live close to the bottom line of financial health. Even if they see the long-term benefits of sustainable practices with their own eyes, they may not adopt them if they perceive a risk to their *financial* sustainability this year, or this season.

CIAT scientists and collaborators—including farmers—are working on many fronts to develop sustainable agricultural systems that are both ecologically sound and economically acceptable to end users. The Center has an extensive history with this work in Colombia's Cauca department, which is plagued by guerrilla violence and other social ills, rooted in the depression of the region's rural economy and the weakness of local institutions.

In 1990, CIAT began helping Cauca's farm communities set up Local Agricultural Research Committees (CIALs) to fill the gulf between farmers and agricultural researchers. The CIALs thrived in Cauca, multiplying rapidly to about 50 today. In 1993, drawing on early experience with these committees, CIAT helped establish the 16-member Consortium for Sustainable Agriculture in Hillsides (CIPASLA) to improve community management of natural resources in a 7,000-hectare watershed in northern Cauca. Supported by the Canadian, Danish, and Japanese governments, it has been widely praised for effectively integrating poverty reduction through a more intensive, diversified agriculture with environmental protection.

"The community organizations just took off like a shot, all on their own," says Ron Knapp, the CIAT soil scientist who manages the Center's project on hillside watersheds. Farm families came up with reforestation projects, installed buffer zones around streams and rivers, and learned to judge the relative merits of different development scenarios.

In addition to creating a new framework for community action and institutional collaboration, CIPASLA provided a niche for research on improved cropping systems. A visit to the Cauca community of Pescador, on the river of the same name, demonstrates work carried out by CIAT soil scientist Edmundo Barrios.

From high up a verdant hillside, he points out the project's components. On the hillside opposite, below a handsome church steeple, farmers are growing crops on slopes that are steep enough to cause concern about erosion. His project is

Agronomy student Edis Milena Quintero inoculating seedlings of a leguminous shrub (*Tephrosia* sp.) with rhizobia.

Background shows multipurpose leguminous tree (*Sesbania sesban*).

encouraging the planting of live barriers of elephant grass, imperial grass, and sugar cane that extend horizontally across the slopes, holding soil in place. In the valley between the two hills, the Pescador River runs through a buffer zone of trees.

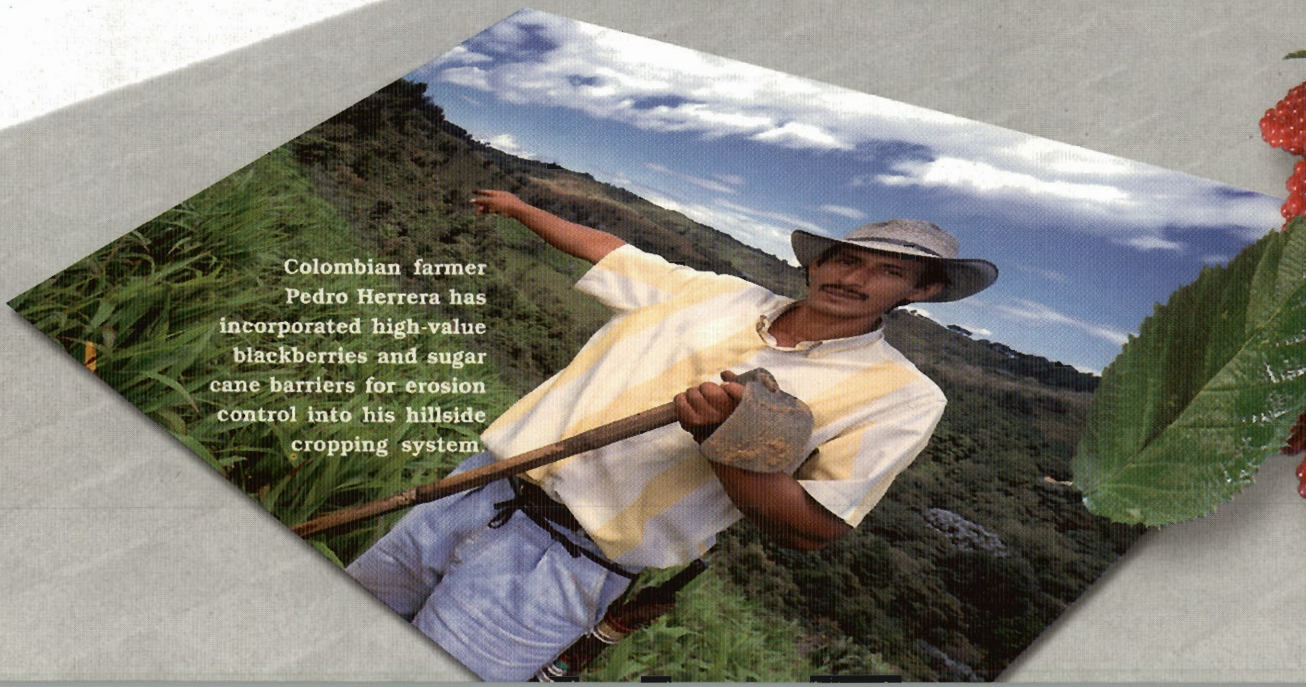
The project started, explains Barrios, with the main aim of "optimizing land use according to the landscape." The optimizing also had to be financially feasible; hence the use of particular species in the barrier strip. Sugar cane provides raw sugar for the household, while elephant grass and imperial grass provide high-quality feed for livestock. "Farmers do not always see erosion as a problem," says Barrios. "It's so slow. We need something that works on erosion but also helps the farmer financially, immediately."

The project is also demonstrating the wisdom of rotating crops according to their agronomic characteristics—growing short- and deep-rooted crops in appropriate places, for example. Traditionally, farmers in the area have grown continuous crops of maize, beans, and cassava, thus hastening the depletion of soil fertility. "We're encouraging the use of mixtures of legumes for cover crops, and we're starting to introduce agroforestry species into the pattern," says Barrios.

Farmers throughout the tropics rely on the regrowth of native vegetation in fallow land to restore soil fertility lost through cropping. But since this is a slow process, they face growing pressure from rising population and land scarcity either to reduce the length of fallows or increase the use of fertilizer. Where farmers' buying power is limited, they may resort to managed fallows, in which they plant trees and shrubs that replenish soil nutrients faster than normal, in addition to providing firewood. In search of a prototype system for managed fallows in hillsides, Barrios is comparing two leguminous trees and a shrub with natural fallow to determine their potential for speeding the regeneration of soil fertility.

One of Barrios's visitors is Aníbal Patiño, who works for the Corporation for Interdisciplinary Studies and Technical Advice (CETEC) and is a pioneer in environmental studies in the Cauca region. Patiño agrees that it is not always easy to convince farmers to gamble on change, even if the eventual payoff is a healthier genetic base for the crops that farmers plant.

Those who do adopt sustainable practices have found ways of generating short-term payoffs that make the change seem worthwhile. One such farmer is Pedro Herrera. He has planted live barriers of



Colombian farmer Pedro Herrera has incorporated high-value blackberries and sugar cane barriers for erosion control into his hillside cropping system.

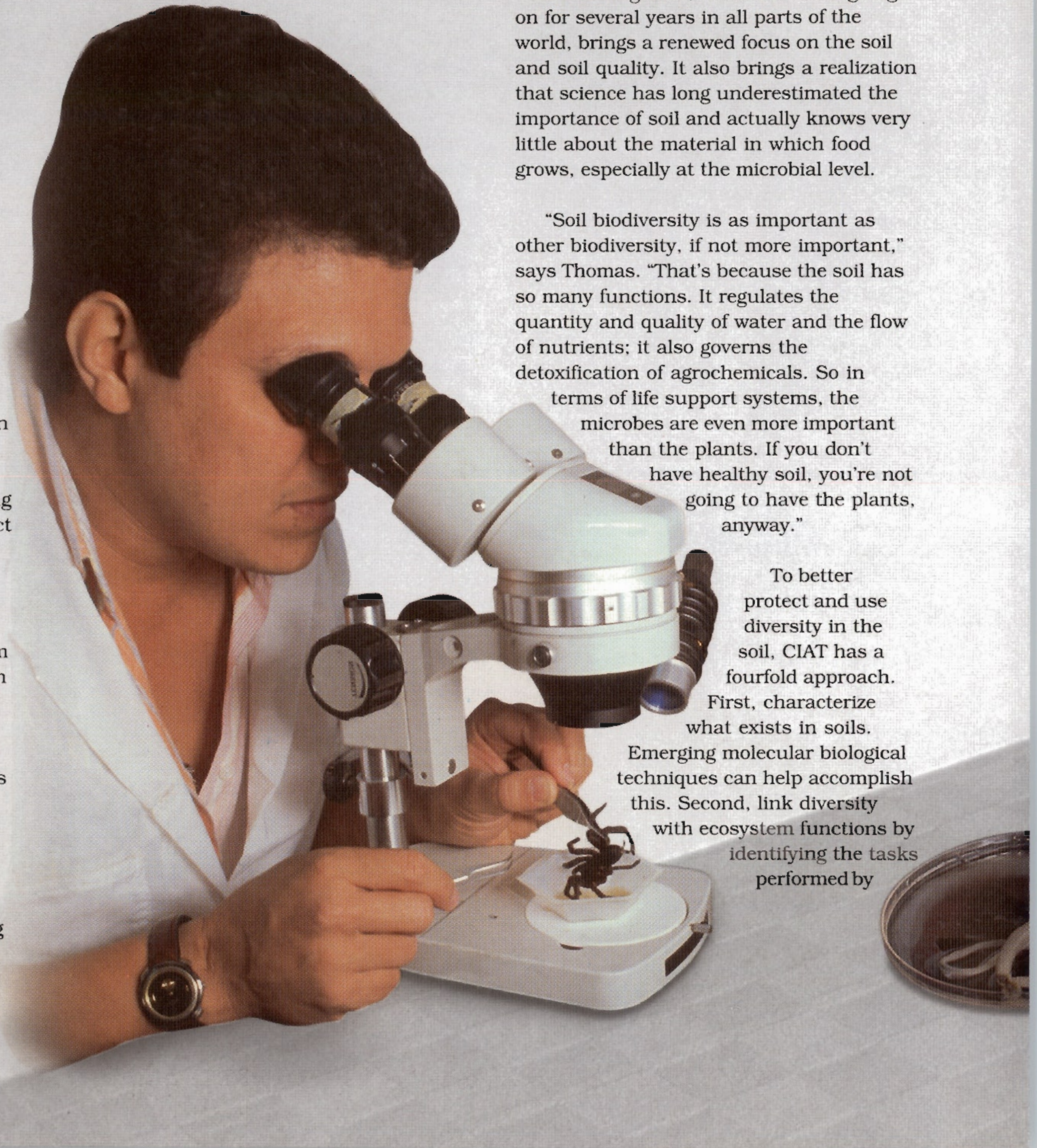
sugar cane across the steep slopes of his farm, and he has set aside the natural vegetation along a stream running across his property to protect community water supplies. Herrera can afford these ecological luxuries, because he has integrated the production of high-value blackberries and climbing beans into an already complex system of coffee, plantains, bush beans, maize, and pastures.

Biodiversity Down Under

Nature's early warning signs of soil degradation

For many people "agricultural sustainability" refers to the crop more than to the soil in which it grows or to the landscape surrounding crop and livestock production. In many parts of the developing world, farmers cannot afford to think or act otherwise. Those living at the edge of tropical forests, for example, have little choice but to grow crops until the fields lose fertility and then shift their cultivation to rich soil newly captured from the forests. More fortunate people invest in inputs, such as fertilizer, to sustain crop production a while longer.

CIAT soil scientist Richard Thomas sees a swing toward a new form of farming. In addition to purchased inputs, it makes use of biological processes, adapting germplasm to poor soil or climate conditions, relying on nutrient cycling to enrich the soil, and adopting or readopting efficient cultural practices such as intercropping, agroforestry, and crop rotations.



The changeover, which has been going on for several years in all parts of the world, brings a renewed focus on the soil and soil quality. It also brings a realization that science has long underestimated the importance of soil and actually knows very little about the material in which food grows, especially at the microbial level.

"Soil biodiversity is as important as other biodiversity, if not more important," says Thomas. "That's because the soil has so many functions. It regulates the quantity and quality of water and the flow of nutrients; it also governs the detoxification of agrochemicals. So in terms of life support systems, the microbes are even more important than the plants. If you don't have healthy soil, you're not going to have the plants, anyway."

To better protect and use diversity in the soil, CIAT has a fourfold approach. First, characterize what exists in soils. Emerging molecular biological techniques can help accomplish this. Second, link diversity with ecosystem functions by identifying the tasks performed by different soil components. Third, determine the effects of land use change on biodiversity. And fourth, translate this knowledge into practical tools that can be delivered to national and other organizations.

With support from the Inter-American Development Bank (IDB) and French and US governments, Thomas has studied the functions of earthworms for several years and is now expanding his underground horizons to study smaller creatures. "We're now trying to use soil microbes, rhizobia, as indicators of soil quality," he says. "When land degrades, you lose ground cover and the inputs of carbon into the soil from plants, which is bad for the soil microbe population. The total microbial biomass goes down."

Thomas and his colleagues reckon that decreasing numbers of rhizobia can serve as an indicator of soil degradation, perhaps long before farmers perceive the damage.

The beneficial bacteria invade the root hairs of plants, multiply, and contribute to the formation of nodules on the plant's roots. Within those nodules plants convert nitrogen into nourishing nitrates.

Counting bacteria sounds like a difficult task, but in the case of rhizobia it is not. "It's quite a simple thing," says Thomas. "We just take a piece of soil, mix it up with a solution culture, put it into a test tube, grow a test legume plant in there, and count the number of nodules that are formed on the plant. That gives us a quick and simple index." From the test, researchers can calculate the number of rhizobia in each gram of soil and have a clearer idea of the health of soil microbe populations.

Why all this concern about soil and indicators of soil's health? "It's important," says Richard Thomas, "because you want to take remedial action if the soil is beginning to degrade *before* you can actually see it degrading. By the time you see the damage, it might be too late to reverse it. And the cost of doing something at the point where you *see* the soil degrading is very high. If we can have some early warning signs that soil quality is breaking down, before the obvious massive losses of soil or of soil fertility, it'll be much cheaper to take action."

Soil science student Alexander Feijóo identifies macrofauna specimens taken from soils under different land uses, such as the fallow shown here in Colombia's Cauca department.

Beans in the market at El Guarne in Colombia's Antioquia department.

Protecting the Genetic Base of Crops

One of the most ominous threats to agriculture is a narrowing of the genetic base of important food crops, a process that started with their domestication and has greatly accelerated in modern times. Monocultures and market demands for uniformity are fast reducing the biological diversity of the production systems that feed the world.

This biodiversity is sorely needed to provide the raw materials with which farmers and plant breeders produce new varieties for a changing world. If the genetic base gets too narrow, our livelihoods and food security will be seriously jeopardized. CIAT scientists are acting in numerous ways to protect the genetic base of the production of beans, cassava, tropical forages, and rice. Some are introducing valuable genes from wild relatives into domesticated crops, with the aid of tools offered by biotechnology, while others develop methods to improve staple crops with farmer participation.

"The quality and dedication of the research staff, from the project managers to the technicians in the labs, are a major strength of CIAT."

From the report of an internally commissioned external review of genetic resources research at CIAT

Wild Relatives to the Rescue

Transferring stress resistance genes into common bean

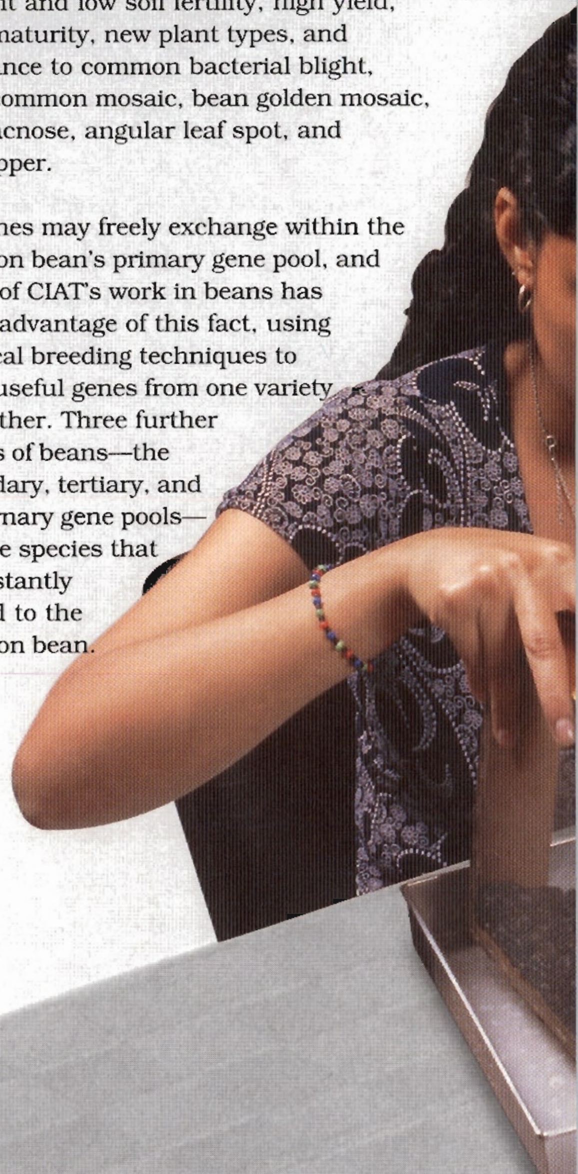
The common bean (*Phaseolus vulgaris*) has been a staple in the developing world for quite a while. Carbon dating of beans found in a cave in Mexico shows that they were in domestic use at about 5000 BC. Since then, the diversity of cultivated beans has become seemingly limitless, as have market and consumer preferences for different varieties.

But the genetic diversity of the world's third most important legume, after soybean and groundnut, is not always enough to overcome its susceptibility to insect pests, drought, and several diseases. The severe damage caused by these problems has led CIAT scientists on a continuous search for germplasm that can be used to breed better beans.

"The gene bank at CIAT has about 35,000 accessions of beans," says CIAT bean breeder Shree Singh, "of which more than 28,000 are common beans. Of these, about 26,500 accessions represent cultivated varieties, and 1,315 are wild types. We've already evaluated these accessions for major agronomic characteristics. The germplasm bank here is not a seed museum, but an active resource for germplasm research."

The list of characteristics that bean growers want in a flagship variety is extensive, and it differs greatly by region and goes far beyond seed color and shape. CIAT has winnowed the list down to 11 qualities it considers of strategic importance in order for the germplasm to be useful worldwide. They are tolerance of drought and low soil fertility, high yield, early maturity, new plant types, and resistance to common bacterial blight, bean common mosaic, bean golden mosaic, anthracnose, angular leaf spot, and leafhopper.

Genes may freely exchange within the common bean's primary gene pool, and much of CIAT's work in beans has taken advantage of this fact, using classical breeding techniques to move useful genes from one variety to another. Three further groups of beans—the secondary, tertiary, and quaternary gene pools—include species that are distantly related to the common bean.



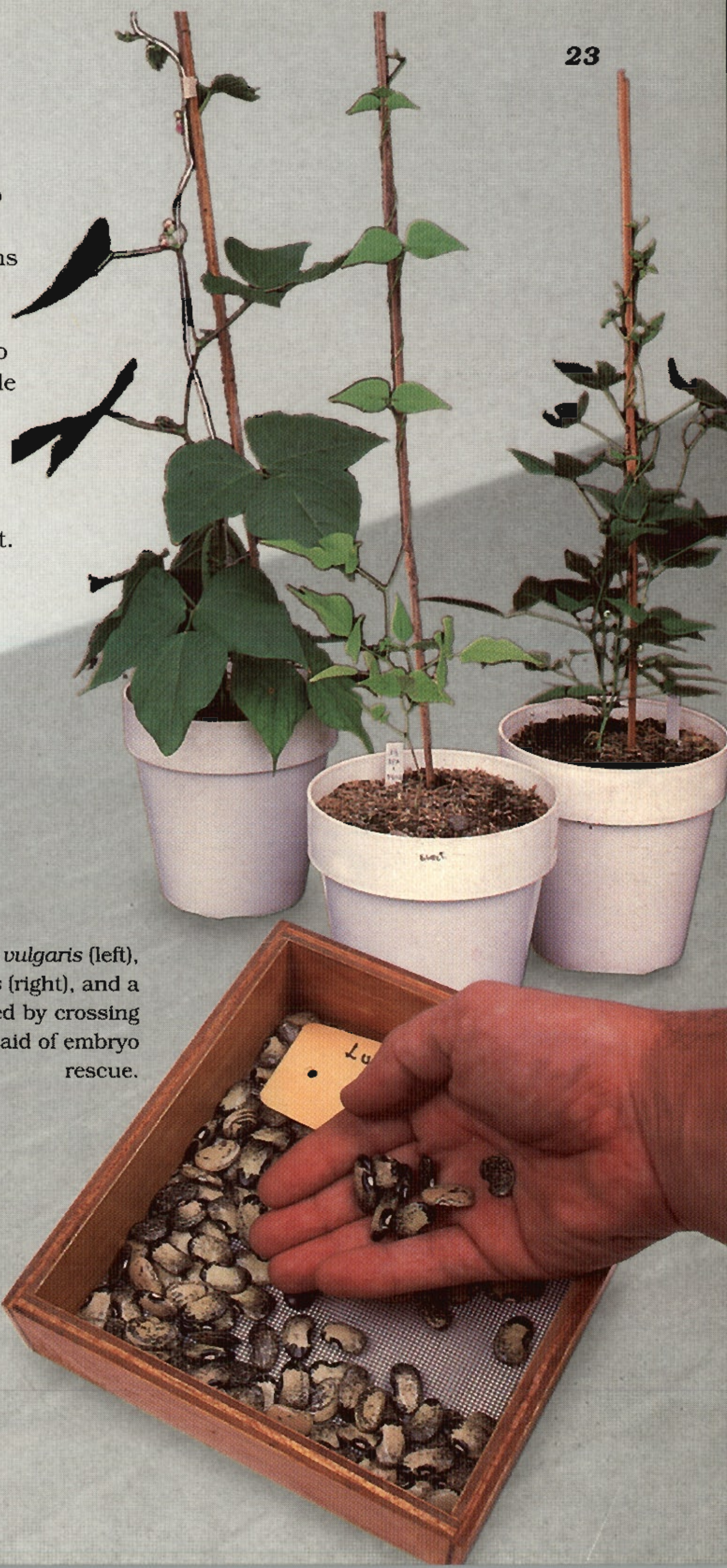
A seed producers' association in Ecuador's Loja province sorts improved bean seed for sale to neighbors.

The tertiary gene pool includes bean relatives that have most of the qualities farmers and plant breeders want: high levels of resistance to such bean killers as common bacterial blight (CBB) and bruchids, tolerance of drought, and an ability to coexist with leafhoppers. The unfortunate news is that the beans with the most desirable characteristics do not breed freely with common bean.

Singh explains that *P. acutifolius*, the tepary bean, is one of those species that contains attributes that would benefit the common bean: "extremely high resistance to bacterial blight, which is the most widespread disease of beans, as well as resistance to leafhoppers and storage bruchids. And they are the most drought resistant beans of all."

CIAT uses a method known as embyro rescue to effectively combine the desirable qualities of these two normally incompatible species. The technique can be used when an embryo produced from the cross of common and tepary bean cannot survive if left in the mother plant. The hybrid embryo is rescued and nurtured in an artifical gel-like bed of nutrients until it grows into a complete seedling. CIAT has improved the embryo rescue technique for large-scale production of hybrids between common and tepary bean.

CIAT technician Maryluz Cubides processes seed of *Phaseolus lunatus* (belonging to the genus's quaternary gene pool) for storage in the gene bank.



Phaseolus vulgaris (left), *P. acutifolius* (right), and a hybrid produced by crossing them with the aid of embryo rescue.

Similar methods are being used to overcome interspecies problems of hybrid incompatibility, the sterility of hybrid offspring, and loss of genes introduced from one gene complex into another. The resulting breeding lines have shown high levels of resistance to common bacterial blight. They are now being distributed for evaluation by national bean programs for other traits, including resistance to drought and low soil fertility and to leafhoppers.

Is it fanciful to think that all or even most of the characteristics people want in beans can eventually be combined into one plant? "It's not improbable at all," replies Singh. "Doing it depends on making maximum use of the genetic diversity available. That determines our ability to transfer wild genes into a form that can be grown in farmers' fields." Biotechnology, says Singh, can speed up the process tremendously—perhaps cut it in half.

Remarkable Resilience

Farmers' management of bean diversity in Rwanda

There are many places in the world where farmers have a great appreciation for biodiversity and strive to maintain it under the most trying conditions. Such a place is Rwanda, a small, land-locked nation in central Africa that plunged into war in 1994. The world's attention was riveted on the country as civilians, estimated in number at 500,000 or more, were killed in ethnic fighting.

To the incalculable loss in human life and property was added the potential destruction of much of the diversity of Rwanda's staple crops, including beans, which play a crucial role in the country's culture and economy. An estimated 2 million people fled their homes in the war, leaving their bean crops—the source for future planting material, as well as immediate consumption—in the fields.

Fearing that much of the genetic diversity of Rwandan agriculture would be lost, CIAT, other international research agencies, and both government and nongovernment organizations gathered under the banner of the "Seeds of Hope" project. With funds from a coalition of donors, the project multiplied Rwandan germplasm that had been stored in gene banks elsewhere, including the one at CIAT, and then restored the seed to farmers when the fighting ended.

But the project also examined the effects of war on crop production through surveys and intensive interviews conducted over three postwar growing seasons. In work supported by Canada's International Development Research Centre (IDRC), anthropologist Louise Sperling (a CIAT consultant) and colleagues compared the bean germplasm used before the war with that grown subsequently.

Bean harvest in southern Rwanda.

As a follow-up to this work, CIAT germplasm specialist Stephen Beebe has been using molecular marker techniques to determine with precision what actually happened to the bean germplasm. He has analyzed the diversity of about 360 Rwandan landrace varieties that had been collected before the war, in 1985, and compared them with some 150 landraces that were collected after the war, in 1996.

Preliminary findings, Beebe explains, "indicate that, indeed, there was less genetic diversity in the field in 1996 than there was in 1985. "Now, the first conclusion one might draw from this is that, as we suspected at the outset of the project, the war could have resulted in a loss of genetic diversity. But we have other evidence, based on the farmer interviews and on knowledge of bean pathology in the region, that that loss of diversity was due to other factors." Root rots are an especially likely candidate, he says.

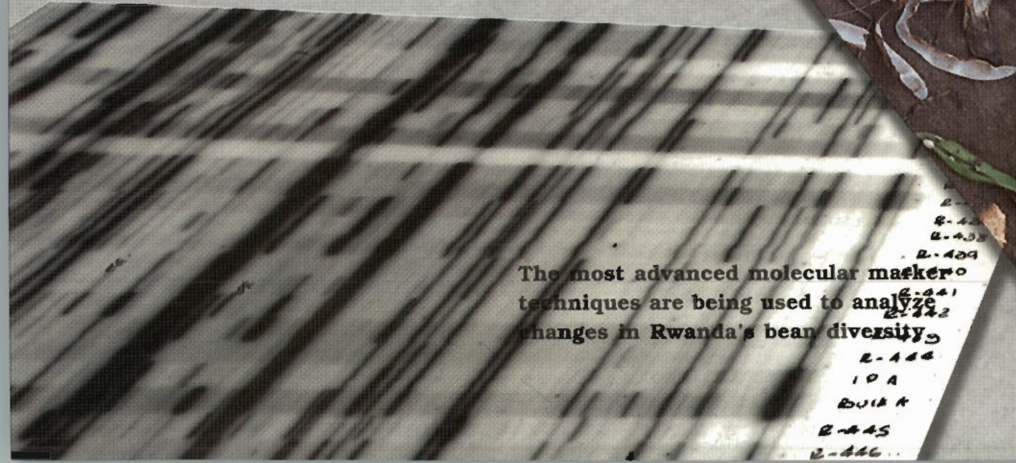
The finding, says Beebe, "has big implications for our ideas about conserving diversity on-farm. It may not always be possible or even desirable to conserve maximum diversity in farmers' fields. The experience in Rwanda suggests that farmers may shift their crop diversity in response to production needs."

In Rwanda women control the selection and growing of beans. Sperling sees strong evidence of their skills in a "swift acceleration in the adoption of improved climbing beans." According to the results of her late-1995 survey, 48 percent of bean farmers were growing the new varieties, up from about 40 percent before the war. Across the country she saw improved climbers gaining ground at the expense of local bush and climbing types.

This is happening, explains Sperling, mainly because the new varieties yield two to four times more and some "show exceptional tolerance to root rots." Serious outbreaks of this disease complex occur only in areas, like Rwanda as well as southwestern Uganda and western Kenya, where extremely high population density and land scarcity force farmers to exhaust the soil through ever more intensive cultivation. It is important to emphasize, says Sperling, that the shift to improved climbing beans resulted from farmers' conscious strategy to combat bean disease pressure, not from the war or from pressure to "modernize" production.

Sorting and cleaning of bean seed in Rwanda.

Bean seed samples at the Namulonge Experiment Station in Uganda.



The most advanced molecular marker techniques are being used to analyze changes in Rwanda's bean diversity.

Cassava harvest in East Java, Indonesia.

"Arguably, much more diversity could have been lost, were it not for the restoration effort and, more important, the precautions farmers took in protecting their seed stocks," says Roger Kirkby, the agronomist who coordinates CIAT's bean research in Africa, with funding from the Canadian, Swiss, US, and British governments. Seeds of Hope was a moving demonstration of the ability of institutions to respond rapidly and meaningfully to a poor country's crisis, but the situation also offered clear proof of farmers' resourcefulness.

Delivering Diversity

Farmers and scientists move new cassava into the field

Cassava, a starchy root consumed by more than 500 million people, relies heavily on genetic diversity to hold its own in some of the harshest farming environments in the world. The plant's long growing time (8 to 24 months or more) exposes it to numerous insect pests and pathogens. Typically, cassava is grown without pesticides or other chemical inputs, so to repel attackers it must make great use of internal genetic resistance. The conservation and use of cassava's diversity is thus essential for the food security of small farmers as well as their financial health.

CIAT scientists are using that diversity in more ways than ever and with the active participation of farmers and national programs. This is a formidable task; cassava is grown in vastly different agroecosystems, and if it is to do well, its germplasm must be tailored to local conditions and demands.

In several parts of Asia, notably Indonesia, Thailand, and Vietnam, new high-yielding cassava cultivars developed by national institutions and CIAT are replacing local traditional cultivars and without requiring expensive inputs. Kazuo Kawano, CIAT cassava breeder stationed in Thailand, notes that the new varieties are bringing substantial rewards for farmers. They are "almost invariably characterized by higher harvest index (the ratio of roots and to stems and leaves), meaning that less water and fewer soil nutrients are required to produce the same amount of root dry matter yield, compared with traditional cultivars." In northern Vietnam small farmers who convert their production from the new varieties into feed for piglets are raising their income by as much as US$500 a year.

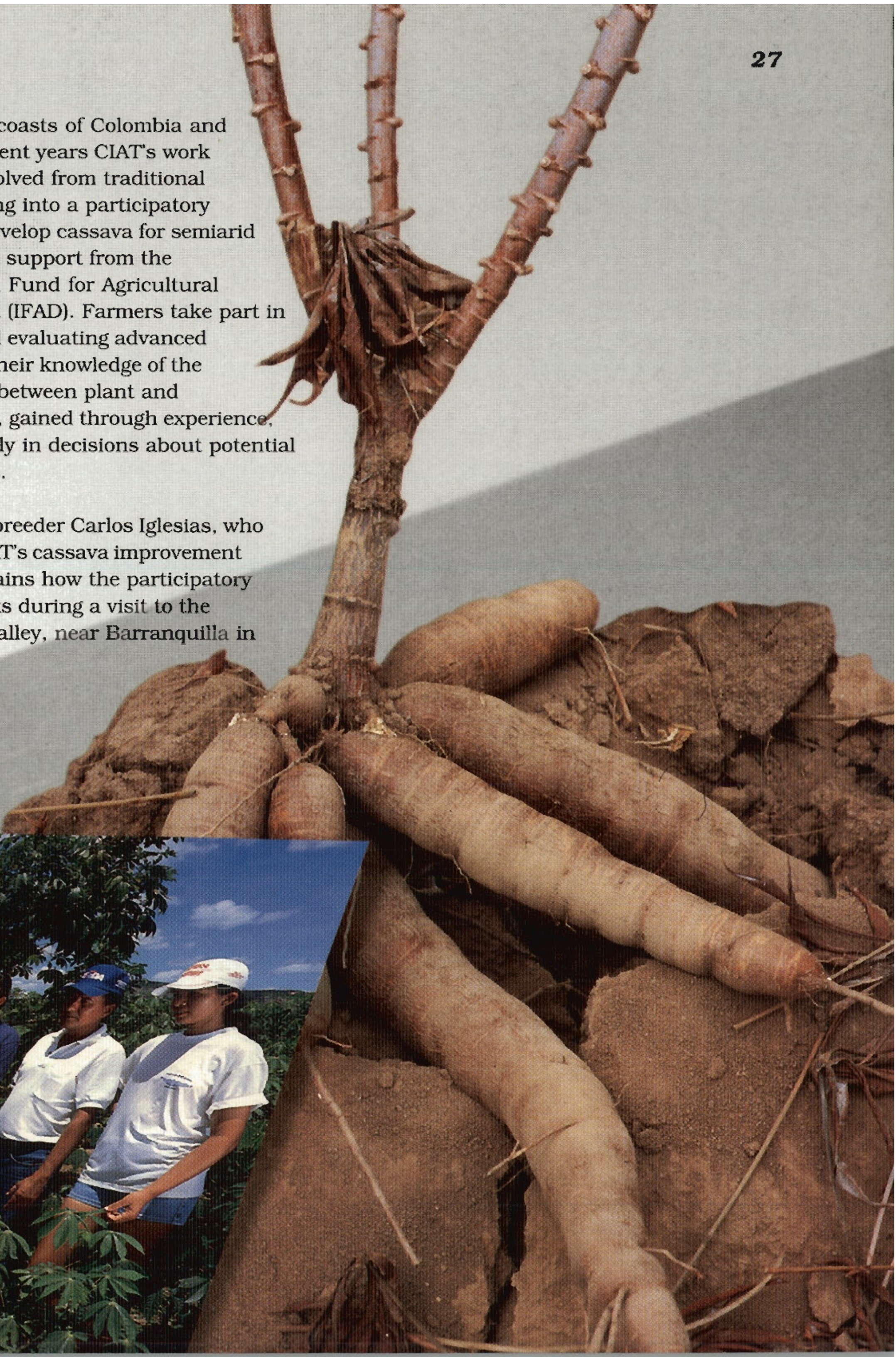
The adoption of high-yielding varieties does not mean that cassava genetic diversity is being abandoned. Kawano says that, with support from the Japanese government, CIAT has distributed in Asia more than half a million cassava genotypes in the form of hybrid seeds that come from "widely varied parental accessions" in the collection housed at Center headquarters. "The total amount of genetic variability thus delivered from the center of origin and diversification (Latin America) to Asia must far exceed the genetic variability introduced spontaneously to Asia in the past

3 centuries. We're actually increasing the diversity of cultivars in farmers' fields in many parts of Asia."

Just in case that diversity is not enough, biotechnology specialists at CIAT are looking to cassava's wild relatives, which constitute a rich source of genes for useful traits. To use the wild germplasm effectively, researchers must first determine the genetic organization and dynamics of populations of these species. A recent study carried out by geneticist Carolina Roa, using molecular genetic markers, showed that the domesticated cassava germplasm presents a narrower range of variation than most wild species. She also found that two wild relatives of Brazilian origin are genetically close to cultivated cassava, suggesting that they have potential for widening the crop's genetic base.

Farmers themselves are helping introduce more diversity in their fields on the Atlantic coasts of Colombia and Brazil. In recent years CIAT's work there has evolved from traditional plant breeding into a participatory scheme to develop cassava for semiarid regions, with support from the International Fund for Agricultural Development (IFAD). Farmers take part in selecting and evaluating advanced genotypes. Their knowledge of the interactions between plant and environment, gained through experience, figure strongly in decisions about potential new varieties.

Cassava breeder Carlos Iglesias, who manages CIAT's cassava improvement project, explains how the participatory scheme works during a visit to the Magdalena valley, near Barranquilla in



Farmer participatory cassava breeding in semiarid Northeast Brazil.

northern Colombia. With colleagues from the Colombian Corporation for Agricultural Research (CORPOICA), he tests germplasm here to find the cassava varieties that do best in the region's punishingly hot, dry climate. The trials take place on the land of cooperating farmers under a variety of conditions.

At virtually every stage of testing, Colombian and Brazilian farmers play a role. "The end users tell us what they want," says Iglesias, "and we supply it. By working closely with farmers, we learn a great deal about their agronomic problems, their opportunities, and their selection criteria; and we incorporate all this information into our breeding program. Once farmers decide they like a material, they start multiplying it and so do we, without questioning the farmers' judgment. We value the information the farmers have."

To Breed a Better Grass

Fighting the effects of Brachiaria *monoculture*

When a particular crop variety becomes widely popular, it is for a good reason. In the tropical world, especially, resistance to insects and diseases or tolerance to drought or infertile soils can make a star out of a variety.

Brachiaria, a genus of forage grass from Africa that was first introduced into tropical America several hundred years ago (probably as bedding material on slave ships), is such a star. One of its species, *B. decumbens*, is especially notable for its performance in the poor acid soils that characterize much of tropical America. Within a relatively short time, it has spread to about half of the 60 million hectares of land in the tropics and subtropics that are suitable for sown pastures.

Brachiaria, says John Miles, a forage breeder at CIAT, "is widely adapted to poor soils, resists weeds, produces seed well, and grows fast." Its effects are easy to measure in cattle, adds Carlos Lascano, CIAT ruminant nutritionist. "Where you could count on 20 kilograms of beef per hectare a year with native grasses, with *Brachiaria* you can obtain 200 kilograms."

"And that's the trouble," says Miles. *Brachiaria* is so popular that it is fast becoming a monoculture. "In some cases, *B. decumbens* is being taken to areas where other species might actually do better." And, like most monocultures, the grass is becoming vulnerable to insect depredation.

In the case of *Brachiaria*, the insect is the spittlebug. *Brachiaria* test plants that are deliberately infested with spittlebug in a segregated greenhouse at CIAT graphically illustrate how the insect got its name: The bug establishes itself at the plant's base, sucks the sap out of the plant, and exudes a foamy, white, spittle-like substance. The bug's nymphs start out

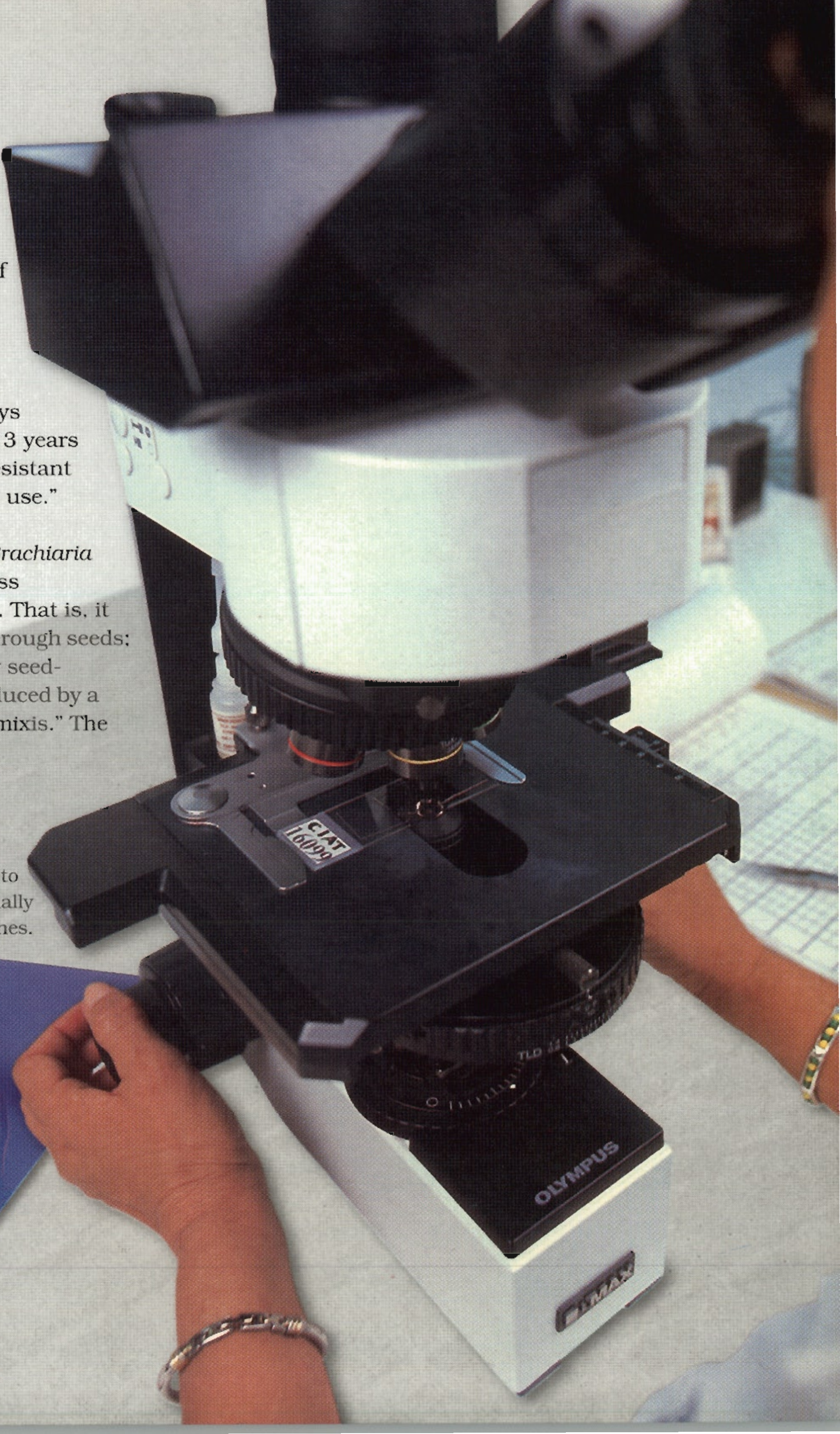
CIAT plant breeder John Miles and Embrapa colleague Cacilda do Valle examine experimental lines of *Brachiaria* at CIAT headquarters.

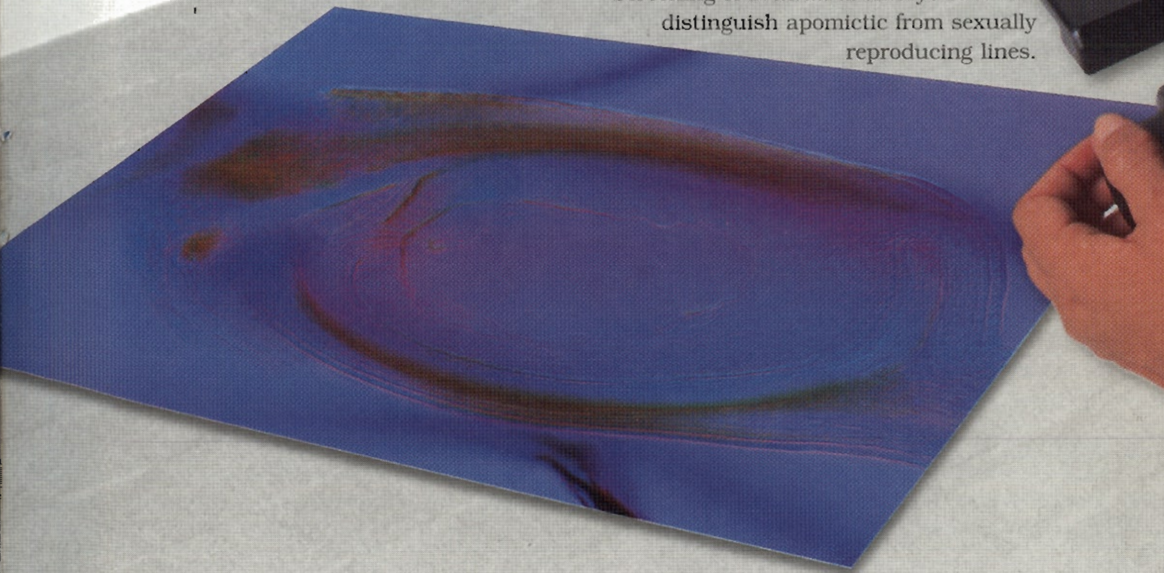
life inside the spittle, eventually emerging as adults to live on the plant's upper portions. "Spittlebug damage," reports a CIAT document edited by Miles and others, "can result in the complete loss of available forage."

The Center's typical reaction in a situation such as this is to look for *Brachiaria* with natural, genetic resistance to spittlebug and then use that germplasm to breed a better grass. Such a plant, *B. brizantha* cv. Marandu, was evaluated, selected, and released by collaborators with the Brazilian Agricultural Research Enterprise (Embrapa). But it is not tolerant of poor soils—a necessary quality in much of Latin America.

To solve the dilemma, CIAT worked with other international centers to gather accessions of *Brachiaria* in Africa, the grass's place of origin (and therefore the most likely place to find a *Brachiaria* that resists environmental constraints). CIAT began evaluating the approximately 700 accessions, found some that resist spittlebug and tolerate poor soils, and has begun regional trials in Colombia of about 20 of the candidates, with support from the Colombian government and CIAT's other core donors. "We expect," says Miles, "that within 2 or 3 years we'll have one or two resistant cultivars in commercial use."

One constraint on *Brachiaria* research is that the grass reproduces vegetatively. That is, it reproduces asexually through seeds; offspring are essentially seed-propagated clones, produced by a process known as "apomixis." The





Screening of *Brachiaria* embryo sacs to distinguish apomictic from sexually reproducing lines.

process precludes the offspring's inheritance of qualities from two parents. Thus, before scientists could breed *Brachiaria* effectively, they needed a way to "break apomixis" by forming hybrids from two parents.

Fortunately, both CIAT and Embrapa now have active *Brachiaria* breeding programs, which build on a genetic breakthrough achieved nearly 2 decades ago in Belgium. Scientists there created a compatible, polyploid, sexual plant that serves as a "bridge" for exchanging valuable genes between the naturally asexual species of *Brachiaria*. "With this plant and the invaluable *Brachiaria* germplasm collection at CIAT," explains Miles, "we can assemble desirable traits from the diversity of native strains of the grass into vastly superior varieties. Production of a molecular map of *Brachiaria* would greatly speed up the pace of research by allowing marker-assisted selection."

Even after CIAT and Brazilian scientists have produced varieties that fight spittlebugs and grow well in Latin America's soil conditions, the search will continue. "We're not looking for one resistant cultivar, so we can then call the job done," says Miles. "We want a whole array of cultivars with a diversity of attributes."

Breaking One Barrier, Building Another

Genes for better rice yields and disease resistance

The Green Revolution brought high-yielding varieties of rice and wheat to a world that badly needed them. The centers of the Consultative Group on International Agricultural Research (CGIAR) have been rightly honored for their participation in the effort, which combined new varieties with the use of fertilizer and other chemical inputs under irrigation. In Latin America rice production has doubled during the last 20 years, largely as a result of technologies developed for irrigated rice by national programs, with CIAT support.

In the meantime, however, a widespread awakening to the need for environmental protection has made intensive use of such inputs less attractive. And the yields of some of the Green Revolution crops, notably rice, have stopped their steady climb and now have reached what is widely viewed as a plateau.

But the number of people who need to be fed keeps on growing. According to economists' projections, Latin American demand for rice will be about 36 million metric tons a year by the year 2010. The present production is 20 million tons. "That's a big increase," says CIAT rice breeder César Martínez, "and it cannot be achieved under present circumstances. That's why it's very important that the yield ceiling be broken."

In Latin America the problem is complicated by the narrowness of rice's genetic base. Many of the improved varieties grown in the region come from an indica-type rice that originated in Asia. "When you get a narrow genetic base," says Martínez, "it makes the plant more vulnerable to pest and disease attack."

The tools exist to widen that base, and CIAT is busy using them, with support from the US Agency for International

Plant breeder César Martínez is crossing cultivated rice from the working collection at CIAT with wild *Oryza* to transfer genes for higher yield into the crop.

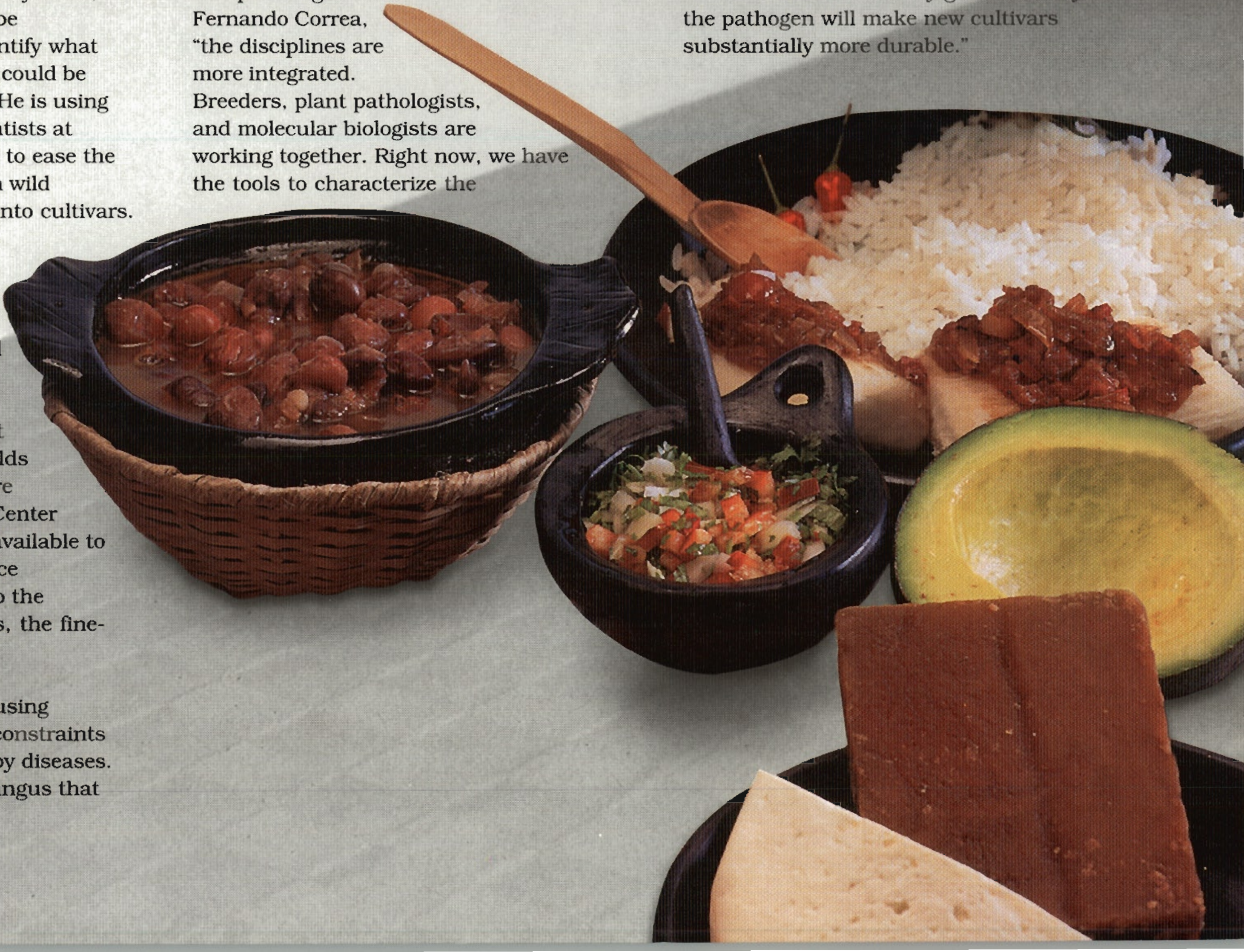
Development (USAID) and the Rockefeller Foundation. Martínez notes that, while in the past the region's breeders employed only a small number of landraces in their research, some 20 other species remain in nature, used only occasionally as sources of resistance to diseases or insects. CIAT is learning more about these previously neglected species and the genetic diversity they hold.

The variability is undoubtedly there, says Martínez, "but it has to be characterized. We have to identify what genes these species have that could be used in a breeding program." He is using techniques developed by scientists at Cornell University in the USA to ease the discovery of desirable genes in wild relatives and their transport into cultivars.

Now CIAT has segregating breeding lines, the result of a cross between a wild species known as *Orzya rufipogon* and an improved variety from Sri Lanka known as BG-90. Preliminary data indicate that some of the offspring have yields between 5 and 25 percent more than does BG-90 alone. The Center will make the breeding lines available to national programs for their rice improvement work. "They'll do the adaptation to local conditions, the fine-tuning," says Martínez.

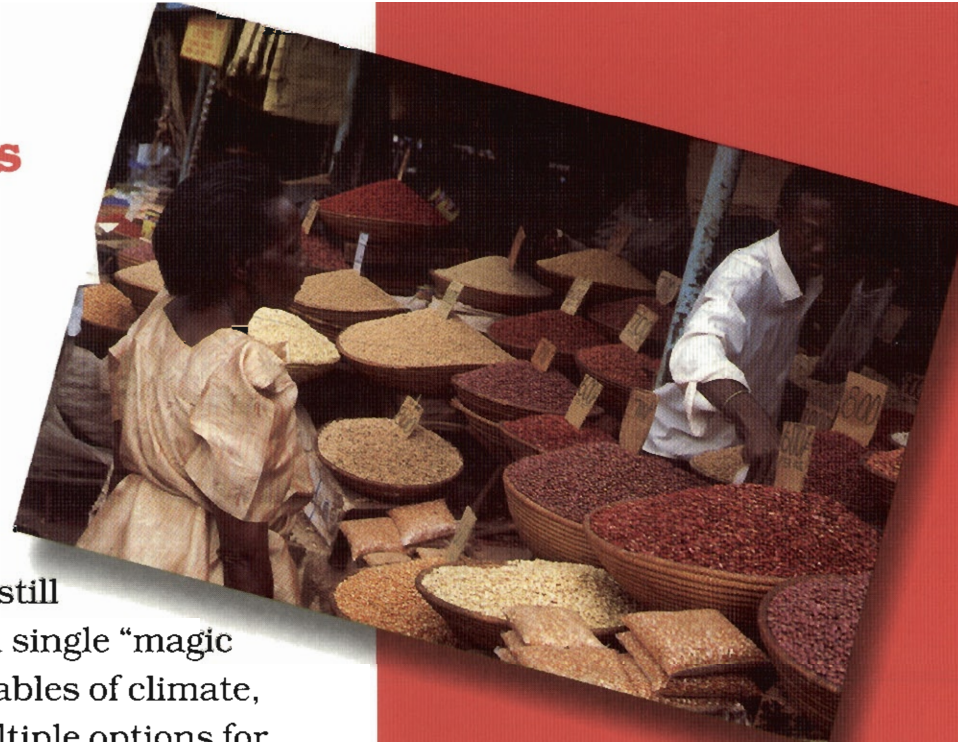
Other CIAT scientists are using biotechnology to remove the constraints placed on Latin America rice by diseases. One of these is rice blast, a fungus that attacks rice at all stages in its development. The fungus, *Pyricularia grisea*, is a real survivor; it produces new strains of itself constantly, so it can break the resistance of a new rice variety in 1 to 3 years.

In the past rice breeders searched for one gene in a rice line that conferred resistance to the pathogen, and they worked independently. "Now," says CIAT rice pathologist Fernando Correa, "the disciplines are more integrated. Breeders, plant pathologists, and molecular biologists are working together. Right now, we have the tools to characterize the genetic diversity and virulence of the pathogen. We're using molecular markers in both the plant and the pathogen to see what the diversity is in the field. If we understand that, and the action of individual genetic clusters of the pathogen, we'll be able to identify genes for resistance to each of these genetic families. Then we can start pyramiding these genes to create a barrier against the entire pathogen population. Combinations of genes that confer resistance to every genetic family of the pathogen will make new cultivars substantially more durable."



Grinding bean leaf tissues in preparation for DNA extraction.

New Tools, New Frontiers

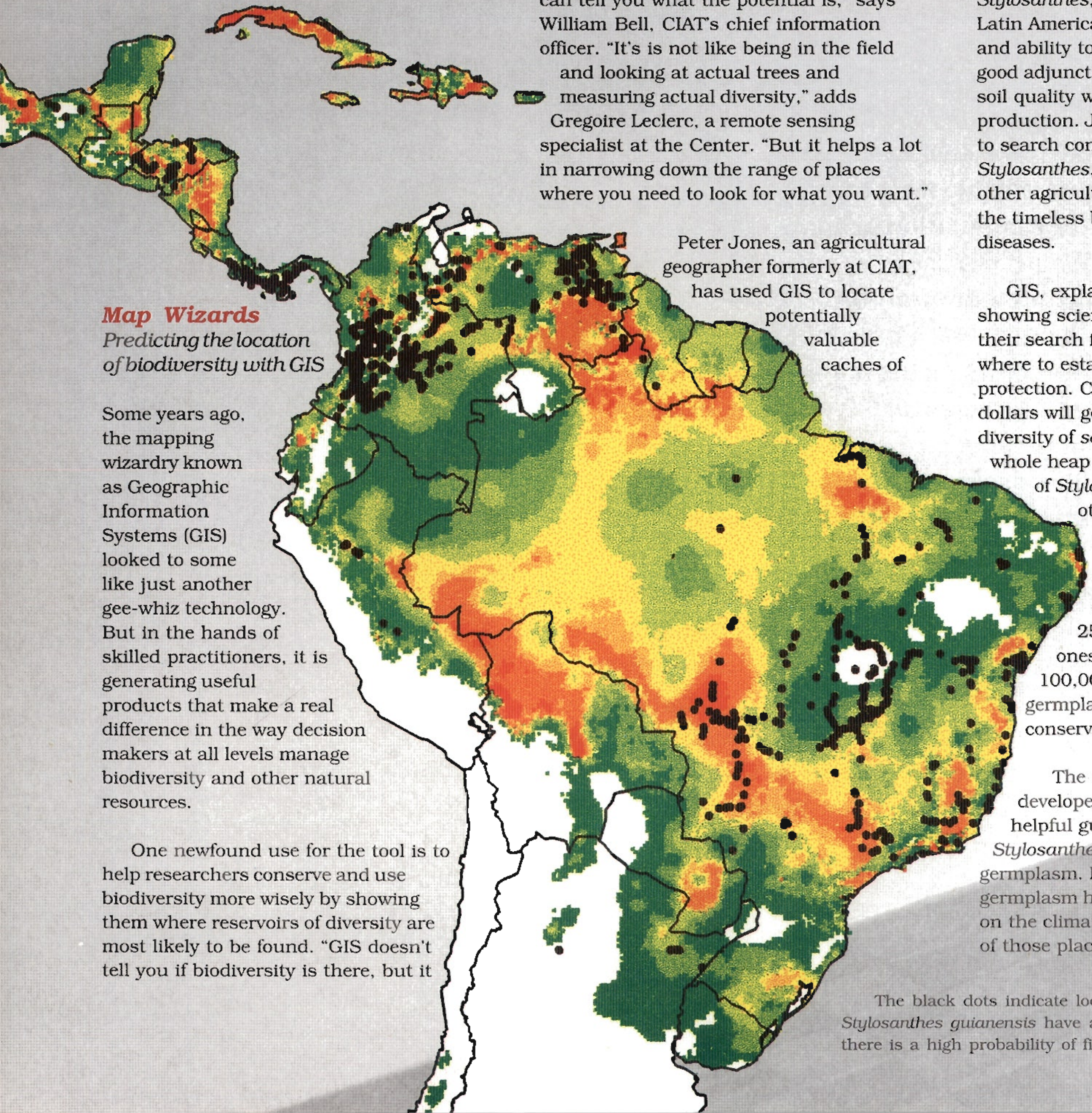


To help agriculture provide for a rapidly growing and urbanizing population in an evolving global marketplace —without sacrificing the biodiversity on which human life depends—is a huge but still manageable task. The solutions lie, not in a single "magic bullet" of research that addresses all the variables of climate, soil, water, and human preference, but in multiple options for the people whose livelihoods are built around biodiversity and for the places where it is rapidly disappearing.

One way CIAT helps is by developing new tools that greatly increase the effectiveness and lower the costs of our efforts to protect and use agrobiodiversity, while helping us address the human pressures that threaten to extinguish it. National organizations draw from our toolbox as well to meet needs and solve problems locally. With our partners in the North and South, we press on toward new frontiers.

"Many (countries of the tropics) are turning difficult circumstances to their advantage by using innovative and cost-effective approaches to conservation and sustainable use (of biodiversity)."

Jeffrey McNeely, Chief Scientist, World Conservation Union



Map Wizards

Predicting the location of biodiversity with GIS

Some years ago, the mapping wizardry known as Geographic Information Systems (GIS) looked to some like just another gee-whiz technology. But in the hands of skilled practitioners, it is generating useful products that make a real difference in the way decision makers at all levels manage biodiversity and other natural resources.

One newfound use for the tool is to help researchers conserve and use biodiversity more wisely by showing them where reservoirs of diversity are most likely to be found. "GIS doesn't tell you if biodiversity is there, but it can tell you what the potential is," says William Bell, CIAT's chief information officer. "It's is not like being in the field and looking at actual trees and measuring actual diversity," adds Gregoire Leclerc, a remote sensing specialist at the Center. "But it helps a lot in narrowing down the range of places where you need to look for what you want."

Peter Jones, an agricultural geographer formerly at CIAT, has used GIS to locate potentially valuable caches of *Stylosanthes*, a forage legume native to Latin America whose resistance to drought and ability to grow in acid soils make it a good adjunct to pasture grass, improving soil quality while increasing livestock production. Jones sees the need for science to search continually for new diversity of *Stylosanthes*, as it must with virtually all other agricultural plants, to keep ahead in the timeless battles with pests and diseases.

GIS, explains Jones, is useful for showing scientists where to concentrate their search for useful biodiversity and where to establish sites for in situ protection. Chances are that the limited dollars will go where there is the most diversity of *several* species. "If you have a whole heap of maps showing distribution of *Stylosanthes* and wild beans and other species in Latin America, then you can start overlaying them and studying them and saying, 'if we can afford to conserve germplasm in 25 places, where are the best ones?' If you're going to set aside 100,000 hectares to conserve germplasm, you don't want to be conserving just one species."

The model that Jones has developed is already being used as a helpful guide to collectors of *Stylosanthes*, cassava, and bean germplasm. It takes known locations where germplasm has been collected and, based on the climate and other characteristics of those places, displays the locations of

The black dots indicate locations where accessions of *Stylosanthes guianensis* have already been collected. In red areas there is a high probability of finding further samples of this species.

similar locales where collectors might profitably search. Combining the GIS data with information from another form of mapping—that is, genetic mapping with molecular markers—takes the model a step further. "With data on the genetic structure of species as well as climate probability maps," Jones says, "it will be possible to identify areas where there is a high probability of finding a large number of genetically diverse species together. It will then be possible to maintain this variability in the wild at lower cost."

Appropriate Biotechnology

Real insurance against a dreaded disease of rice

It is clear that the sort of appropriate biotechnology described elsewhere in this report is eminently beneficial for the developing world. One problem that cannot easily be solved without such tools is the rice "hoja blanca" virus. Endemic to Latin America, the disease is cyclical; it appears every 10 to 15 years. "But when you have it, you can have 100 percent loss," says rice geneticist Zaida Lentini. The virus is transmitted by a planthopper insect, *Tagosodes orizicolus*, known locally as "sogata," she explains. The occurrence of a disease epidemic depends very much on the population of the insects that serve as vectors. Farmers often resort to insecticides in an effort to control the planthopper, with devastating effects on beneficial insects nearby.

For years CIAT rice scientists have sought varieties that are resistant to the disease. After extensive analysis of the virus itself by Center virologist Francisco Morales and much effort on the the part of Center rice breeders, they found and introduced one source of resistance, which offers some protection to plants that are more than 25 days old. A search is now under way for others, especially those that confer resistance to the plant in its younger stages. After evaluating germplasm from all over the world, says Lentini, CIAT has identified half a dozen potential sources. "But it's clear that to put these into adapted material for Latin America will take years." To speed the process up, CIAT is using biotechnology techniques to confer resistance.

With funds from the Rockefeller Foundation, the Center and its collaborators began with the rice variety CICA-8, which is commercially grown in Latin America and is resistant to rice blast but highly susceptible to the rice "hoja blanca" virus. Then, in 1996 and 1997, with help from CIAT molecular virologist Lee Calvert, they incorporated the nuclear protein gene of rice "hoja blanca" virus into CICA-8. The nuclear protein protects the rice crop by impeding replication of the virus in the plants. "We've demonstrated that we can better protect the plant by doing this," says Lentini.

"If we can incorporate resistance to hoja blanca virus into this popular variety, it will be of direct benefit to rice farmers and consumers."

Artificial infestation of transgenic rice with *Tagosodes orizicolus*, the insect that transmits rice "hoja blanca" virus, to screen the plants for virus resistance.

So far, the resistance appears stable. It has been inherited by three generations of rice, and CIAT is ready to take the variety into field testing. Lentini is aware of the controversy inherent in any use of transgenic plant material, but she feels that what CIAT is doing is vital for speeding up the process of developing new breeding materials by finding new sources of resistance. "The main difference between genetic transformation and conventional breeding is in how you introduce the gene," she says. "In this case, instead of making crosses, we're just introducing the genes directly into the cell."

"Researchers have been using broad crosses for years to introduce valuable genes in crops. But they've never known, really, besides the gene they're putting in, what other genes are going in at the same time, and how these may affect the diversity of the species." One thing is clear, though: Pesticide use on rice must be reduced because of its effects on biodiversity through the contamination of soil and water. Rice "hoja blanca" virus has been a problem for 3 decades, says Lentini, and although some resistance has been achieved, some farmers still apply insecticides six to eight times during the 4-month growing season.

A recent study, notes Lentini, showed that European consumers consider pesticide residues in food to be twice as risky as genetic engineering. "We can show farmers how to control diseases without using so much pesticide. But they say, 'forget it; we need insurance.' So we're trying to hand them material that is highly resistant to the disease. *That's* insurance."

Selection of rice tissue cultures for gene transfer, using a "particle gun."

Molecules and the Marketplace

Adding value to tropical fruits through biotechnology

Passiflora is a genus of about 400 species of vines, trees, and shrubs. One of its best-known species is the passion fruit, named not for any purported romantic powers but because the arrangement of its stigmas, anthers, corona, sepals, and petals evoke Christian religious teachings about the final suffering of Christ.

Inés Sánchez, a biotechnology specialist with the Colombian Corporation for Agricultural Research (CORPOICA), is using tools and knowledge available at CIAT to make the fruit a more productive member of the economy in Colombia and elsewhere.

The Center offers the products of its research to developing countries in a variety of ways. Among them is collaboration with national research programs such as CORPOICA. Over the past 2 years, Sánchez has had full access to CIAT's expertise and laboratory equipment and support staff. She receives many benefits, she says, from the "great flow of ideas" that takes place on the CIAT campus. Sánchez also passes along what she learns at CIAT to her colleagues in CORPOICA. "I teach the methodology they apply here to my assistant in Bogotá, who then applies it to other crops," including beans, potatoes, and other foods, she says. Sánchez herself is also studying the genetic diversity of Colombia's germplasm collection of *Musa*—banana and plantain. Two big problems here are the diseases black sigatoka and yellow sigatoka.

Market demand for passiflora once was high but then declined. "That's where my work comes in," says Sánchez. "Through plant breeding, we'll be able to position passiflora once again as one of the most important fruits in Colombia." She is using molecular markers to assist in the taxonomical classification of Colombian passiflora's 115 species and wild relatives. "With the markers, we'll have not only a classification, but a way to identify traits that we need, like resistance to two viruses that threaten the fruit. We're also looking for a product with uniform color, flavor, and texture for export. And at the same time, we're trying to find resistance to anthracnose fungi. If we can develop a product that has all these qualities, we'll be able to find a stable market for it."

Daniel Debouck, manager of CIAT's genetic resources conservation project, is enthusiastic about the sort of collaboration represented by Sánchez's work. Debouck, whose work in bean diversity is widely known and highly regarded, is responsible for managing close to 71,000 accessions of germplasm, covering almost 1,000 biological species, ranging from small herbs to large trees. One of the most useful contributions CIAT makes, he explains, is to provide information that better enables people to address biodiversity issues at the local level. We can say: "This is what you have. This is the unique diversity you're dealing with. And here are some tools and guidelines that will help you manage it."

Products of various passiflora species from Colombia.

To Live Forever

Alternative methods for conserving cassava diversity

To conserve the biodiversity of agricultural plants, science traditionally has used two main approaches: one is in situ conservation, or conservation of germplasm in its original habitat, where it can evolve in response to changes in the environment, and the other is ex situ conservation, which generally means storage under controlled conditions in gene banks. Such storage areas are widely used for tucking away samples of seeds, filed with "passport data" indicating their origin and other useful information, against the time when they might be needed for research or to replace germplasm lost in a catastrophe. Storage time is reckoned in years, or even decades.

But plants that are propagated vegetatively, not sexually, require special arrangements for germplasm storage. Their planting materials come not from seeds, but from the vegetative parts of the parent plant. This is true of some of the world's favorite foods, such as banana, potato, and cassava.

Since the late 1970s, CIAT has protected cassava diversity by maintaining the crop in vitro—literally, "in glass"—through the process known as tissue culture, in which plant cuttings are regenerated in flasks or test tubes in artificial media. Generation after generation of cassava has been produced in this way, maintaining the world's largest cassava collection (5,537 clones) for years. But there has been a cost: Each time a cassava clone is "recycled," says biotechnology specialist William Roca, it can be maintained for only 8 to 22 months before having to be recycled again.

Daniel Debouck, manager of CIAT's genetic resources conservation project, thinks it is important to keep as many conservation options open as possible. "We have a duty, a social role," he says. "In our collections, we're maintaining thousands of landraces. We have a responsibility to maintain them as safely as possible. So genetic conservation is a kind of general approach; it is not linked to a single technique."

Cryopreservation is one of the alternatives. This involves storing germplasm in liquid nitrogen at 196 degrees Centigrade below 0. At that temperature, explains research assistant Roosevelt Escobar, "growth stops altogether. This gives us the opportunity to maintain a base collection forever, at least in theory." CIAT has recently begun using cryopreservation (sometimes referred to as cryoconservation) with cassava. So far, researchers have found no negative effects in clones grown out after this type of storage.

Cassava fresh from the farmer's field.

In the meantime CIAT agronomist Claudia Guevara is continuing work on tissue culture in a search for further alternatives to traditional methods of conserving cassava. Her team is experimenting with two methods of slowing down the growth of cassava stored in tissue culture. The two alternatives, water deficit through osmotic substances and ethylene control, should reduce growth markedly. Guevara expects to at least double the time before each clone has to be subcultured—thus greatly reducing the costs involved. She will also safely store duplicates of the clones elsewhere.

With the water deficit method, researchers lower the osmotic pressure of the tissue's cells by sugar alcohols, growing the plant in simulated desert conditions. "You're slowing down its metabolism," she says. The trick is determining the correct amount and combination of the compounds; too much will kill the plant.

The ethylene control method makes use of the fact that the substance ethylene (the same natural chemical that causes tomatoes and bananas to ripen) is produced within tissue culture test tubes as a product of respiration. Its action can be altered by ethylene-inhibiting chemicals that prolong the viability of the cultures. After 9 months one of the test media reduced the length of plantlets by a third, compared with the control. Various concentrations of another ethylene-inhibiting chemical also reduced growth and kept the plants viable with multiple sprouts. These preliminary results have opened the way for a new experiment with selected treatments and larger number of cassava varieties.

Guevara believes that the best protocol can then be adapted and applied to other crops—not just vegetatively propagated species, but tropical fruits and forest species as well. "I hope this work will help save biodiversity by making low-cost preservation methods available to other institutions that can't afford cryopreservation," she says.

Cassava shoots growing in a gel-type "artificial seed" after storage in liquid nitrogen at -196 degrees Centigrade.

Cassava clones maintained in the in vitro gene bank at CIAT.

Friendly Fungi

The search for tropical endophytes that protect grass without harming cattle

Agriculture offers no exceptions, only confirmation, to the general rule that everything in life is a tradeoff. Endophytes are microscopic fungi that live within plants without harming their hosts. In the case of many grasses in the temperate world, the endophytes actually help their hosts by being toxic to would-be invaders, such as insects. Grasses infected with endophytes are much prized on the golf courses of the North; they do not require chemicals to control diseases or insects.

The tradeoff is that in some species of endophytes the toxicity that repels pests also sickens cattle that graze on the grass. But strains exist in which this is not the case, and these are safe for use in pasture grasses. It was long assumed that no such endophytes could be found in tropical grasses. But recent CIAT research, supported by the Japanese government and conducted in cooperation with the country's National Grasslands Research Institute, suggests otherwise.

"Plants with endophytes persist longer, resist drought better, and have a big root system that grows deep into the soil," says Segenet Kelemu, plant pathologist in CIAT's tropical forages project. Her task is to find strains within the natural endophyte population of the tropics that provide benefits to plants with no deleterious effects on animals. After 2 years of searching, she has found endophyte fungi in grass that are "very similar to those found in the temperate climate."

Using essentially low-tech tools and old-fashioned reasoning, she pored through the literature on cattle toxicity and found that it had been reported in some cattle that grazed on *Brachiaria*. There are many species of *Brachiaria*, so Kelemu confined her search to those that were known to be resistant to insects and whose specific locations were known. Now she has isolated a fungus and is working on identifying its species.

"If we can have endophytes with all the beneficial effects of plant protection and drought resistance but without the toxicity, that would be a big step forward," she says. "The beauty of these endophytes is that once the plant is infected, the association is permanent. When you deliver the endophytes in the form of seed, farmers can keep them forever as long as they manage the seed well."

Leaves from identical *Brachiaria* plants (background photo) artificially infected with a pathogen. The undamaged leaves contain endophytes that protect them from the disease. *Brachiaria* has helped intensify livestock production across much of tropical America.

Diversity's Best Friend

Farmers conserve bean mixtures in Peru

In the effort to conserve the biodiversity of agricultural plants, the farmer is a valuable ally. Often, the alliance among conservationist, scientist, and farmer is difficult to forge because market forces or government policies push the farmer toward agricultural practices that work against diversity—for example, monoculture and deforestation by burning.

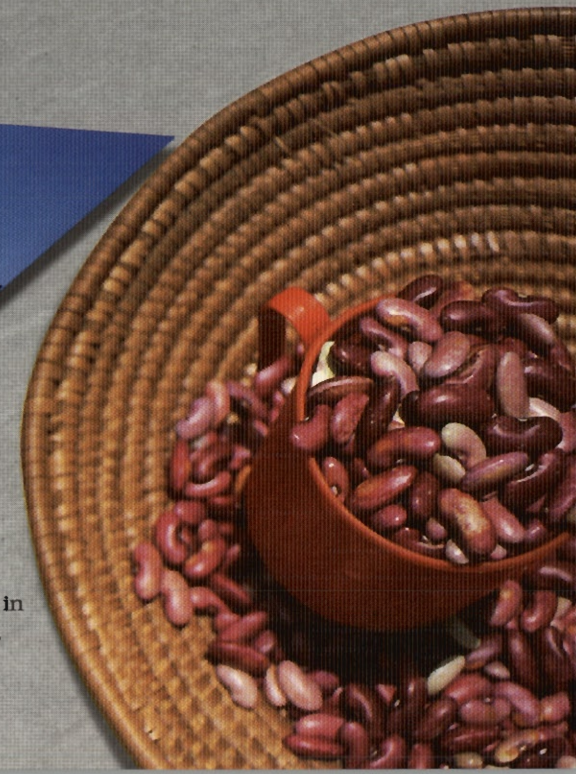
That is not the case in Cajamarca, a community in Peru's high Andes. In the Cajamarca Valley, where the land is flat and green, farmers grow alfalfa for their dairy cattle—not necessarily a major contribution to diversity. But higher up Cajamarca's steep, rocky slopes, farmers make the best use they can of an environment that is marginal for bean production. Not only is the soil poor, but the slopes are visited by frost, hail, and drought. This meager land, however, is the custodian of a great deal of bean diversity, owing almost certainly to the fact that the area is believed to be one of the crop's centers of origin.

CIAT anthropologist Sam Fujisaka has been studying bean diversity in Cajamarca and finds that it is the farmers who are diversity's best friends. "Their solution to the problems of their environment has been to grow a *variety* of crops," he says. "So most of those farmers have a number of Andean cereals and high Andes tubers, plus beans. By maintaining that variability, they know that some beans will do better whatever the conditions are, and others will do worse. Now, since they can't predict what the particular problems will be, the mixture makes a lot of sense."

The researcher says farmers have told him, "this year all the seeds of *these* will do well because there was a drought, or because there was a frost followed by a drought, then *these* will do all right."

Cajamarca's bean farmers have not ignored new bean cultivars introduced by their national government or other agencies (often with support from CIAT in a Swiss-funded project), but the new varieties have not replaced the traditional mixtures. "The modern varieties have assumed a place side by side with the traditionals," says Fujisaka. "The farmers value having a highly heterogeneous mixture of seed."

CIAT is studying the farmers' systems in hopes of finding ways to transfer them to other areas where there is interest in participatory in situ conservation. Such replication, says Fujisaka, "would be one of our biggest products." Also, CIAT would like to formulate ways to work more closely with small farmers to maintain diversity. The Center is discussing with the growers a local seed exchange, in which farmers would be able to augment their own mixtures with those of their neighbors. In cooperation with Peru's National Institute of Agricultural Research (INIA) and a local conservation group known as ASPADERUC, the CIAT team identified a "core collection" of more than 200 different beans. These were returned in groups to interested farmers in three communities, and farmers have begun planting the collection to maintain local bean diversity and make it more widely available.



Beans at the market place in Peru's Cajamarca Valley.

CIAT's Project Portfolio

The Impact of Agricultural Research

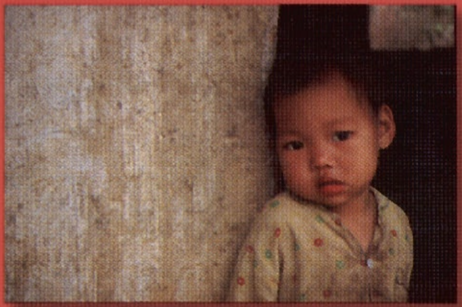
- Impact: The Difference Science Makes
- Project Profile
- Impact Summaries
- Databases:
  - Trends in beans (Africa and Latin America and the Caribbean)
  - Trends in cassava (Africa, Asia and Latin America and the Caribbean)
  - Trends in cow milk (Latin America and the Caribbean)
  - Trends in livestock (Latin America and the Caribbean)
  - Trends in rice (Latin America and the Caribbean)
- Document Collections
  - Abstracts on the Impact of Agricultural Research
  - Publications 1997
- Recent Research Reports
  - Annual Report 1997
- Tools
  - Modelo de Análisis de Excedentes Económicos (MODEXC)

Impact Information on the World Wide Web

We invite you to visit a new section of CIAT's home page containing information about the impact of agricultural research. It includes brief summaries of impact studies carried out by CIAT in cooperation with national programs, technical reports providing detailed accounts of those studies, a searchable database containing abstracts of published impact studies, and a series of databases on trends in beans, cassava, livestock products, and rice. We've also provided an economic model for analyzing both past and expected research impact.

In the following pages, we present other information available on our Web site that may be useful to readers of *CIAT in Perspective*. Any comments about this and our impact information will be most appreciated.

http://www.ciat.cgiar.org



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Our Mission

What To contribute to the alleviation of hunger and poverty

Where in tropical developing countries

How by applying science to the generation of technology that will lead to lasting increases in agricultural output while preserving the natural resource base.

Our Project Portfolio

CIAT's research is conducted through the projects listed below. These provide the elements for integrating research within the Center and for organizing cooperation with our partners. (Brief profiles of the projects are available upon request.)

Institutional Links
The Impact of Agricultural Research
Methods of Farmer Participation and Gender Analysis
Partnerships for Agricultural Research and Development

Crop Improvement
Improved Beans for Africa and Latin America
Regional Bean Networks in Sub-Saharan Africa
Improved Cassava for the Developing World
Rice Improvement for Latin America and the Caribbean
Tropical Grasses and Legumes for Multiple Uses

Agrobiodiversity
Integrated Conservation of Neotropical Genetic Resources
Enhancing Biodiversity Through Biotechnology

Pests and Diseases
Integrated Pest and Disease Management

Soils and Systems
Improving Soil Quality in Marginal Environments
Sustainable Systems for Small-Scale Farmers
Rural Agroenterprises for Small-Scale Farmers

Land Management
Community Management of Natural Resources in Hillside Watersheds
Land Use and its Environmental Impact

Our Crop and Agroecosystem Focus

CIAT conducts international research on four commodities that are vital for the poor: beans, cassava, tropical forages, and rice. Our work on the first three has a global reach, while that on rice targets Latin America and the Caribbean region.

In Latin America our research on natural resource management is organized largely on the basis of three fragile agroecosystems: hillsides, forest margins, and savannas. CIAT scientists also address key resource issues in our crop research for Africa and Asia.

Institutional Links

CIAT is part of an emerging global system of agricultural research and development, whose strength depends, not just on the excellence of individual members, but also on the energy they invest in joint endeavors. For that reason we work hard to build ties with other institutions through research partnerships based on projects.

Our expanding circle of partners includes other international centers, national research institutes, universities, nongovernment organizations, and the private sector. We work with them under a variety of innovative arrangements, such as consortia and networks, at the local, regional, and global levels. Through strategic alliances with advanced institutes, we bring valuable scientific expertise to bear on the central challenges of tropical agriculture.

As a service to its partners, the Center provides varied offerings in training and conferences and specialized services in information and documentation, communications, and information systems.

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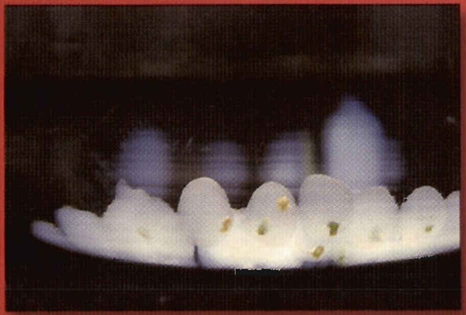

* Left during the reporting period.

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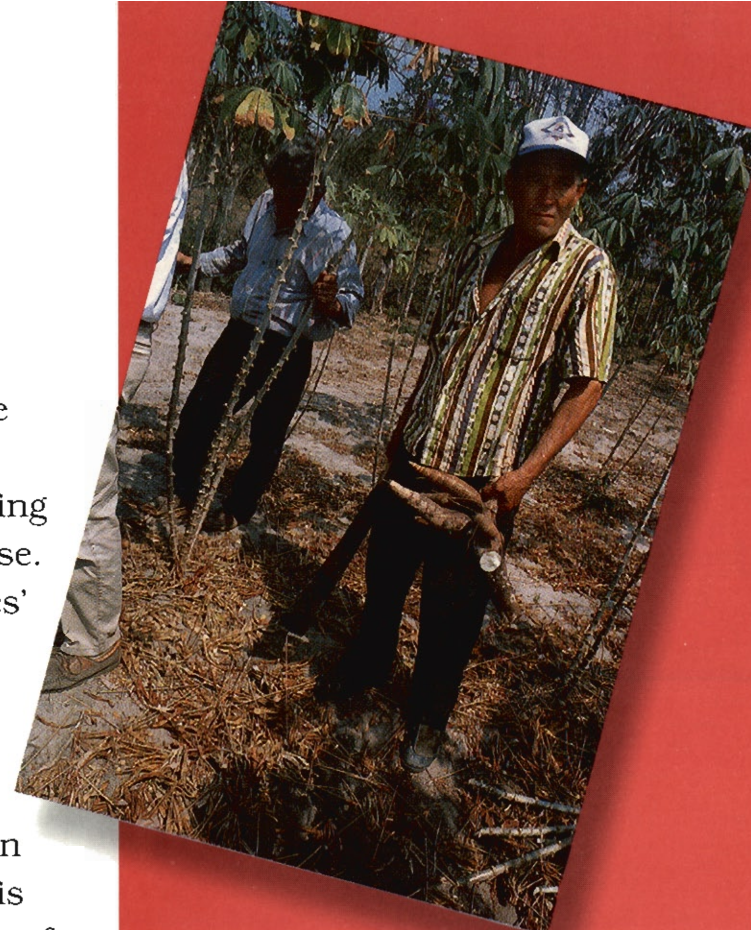
Cassava planting material in northern Colombia.

The Power of Perspective

The rain stopped in November 1997 in the valley of the Magdalena River and had not started again 3 months later. People on motorcycles, bicycles, horse carts, and foot were going to the river to fill plastic containers with water for their daily use. One plant continued to triumph above the drought: the tropics' universal crop for poor people, cassava.

Tomás Fontalvo, a farmer near the community of Malambo on the east side of the Magdalena, proudly shows visitors his farm, a diverse place with maize, sorghum, pigeon peas, cattle, and cassava. Fontalvo eagerly devotes part of his land to germplasm trials. The plants in his plots contain genes of cassava from Asia, Africa, and elsewhere in Latin America. Each neat section has traits that could help researchers and farmers shape cassava to the punishing environment of northeastern Latin America and to potential changes in market demand.



"I feel that I'm participating in research. I'm taking part in the selection and breeding of this cassava. I'm helping the community."

Tomás Fontalvo, Colombian Farmer

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