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Perspective in Practice

Step by meticulous step, you move ahead, struggling to keep your balance on the unpredictable surface beneath your feet—the family farm. But you know the forces swirling around you, especially bad weather and economics, are beyond your control. They may knock you down at any moment.

Making a living from small-scale agriculture in the tropics is a lot like walking a tightrope in a thunderstorm. Through its biophysical and socioeconomic research, CIAT helps such agricultural acrobats reduce risks and exploit new opportunities that may, like patches of blue sky, appear from time to time amid the turbulence.

In this issue of *CIAT in Perspective*, our annual report for 2001-2002, we look at the multiple risks faced by small-scale tropical farmers and describe research aimed at making rural communities more resilient. Webster's defines resilience as "an ability to recover from or adjust easily to misfortune or change." Among the diverse resources we provide to enhance rural resilience in the face of a constantly changing environment are improved crop varieties, information tools for predicting risk, and social capital based on participatory research.

Public Goods for Rural Resilience

Director General's Message

bject poverty is the daily burden of more than a billion human beings. A particularly insidious aspect of this predicament is people's inability to cope with unexpected risks and threats or, in better times, to seize upon new opportunities.

I see CIAT's comparative advantage in tropical agricultural research as our capacity to supply a wide mix of international public goods, which can make poor farmers both more resilient in the face of adversity and more responsive to new economic options. Our basket of public goods—improved crop varieties, pest and disease control measures, soil conservation techniques, and so on—must and does include "social" technologies. These are tools and methods for helping poor farmers systematically learn, experiment, and organize themselves for rural innovation. That way, they are able not only to exploit the fruits of formal biophysical research by organizations like CIAT but also to design their own solutions to problems.

Adoption of social technologies in Bolivia

During a recent trip to the Bolivian shores of Lake Titicaca, I met a group of farmers who have successfully set up small agroenterprises. Some members are making and marketing high-quality sweaters from locally produced wool. Others grow, mill, and package quinoa, a traditional Andean grain that is gaining popularity among European and North American consumers.

What really impressed me was that these and other small-scale entrepreneurs have picked up and applied two of CIAT's social technologies. One is our system of farmer-run local agricultural research committees, best known by the Spanish acronym CIALs, which is also being used by several potato-producing communities (for further details, see pages 17-19). The other is our method for identifying new market opportunities for rural products and building small agroenterprises around those opportunities.

Potatoes and quinoa are not part of CIAT's crop research mandate. But through the efforts of two long-time CIAT partners—the Foundation for Research on Andean Products (PROINPA) and the International Potato Center (CIP)—our social technologies have found a receptive clientele among rural Bolivians who produce these commodities, particularly Quechuan farmers. As these indigenous people of the Andes have a strong capacity for community organization, the CIAL method of local agricultural experimentation and sharing of results comes very naturally to them.

During our field trip, I was glad to hear a representative of the UK's Department for International Development (DFID) comment that the Bolivian farmer groups provide "proof of concept" of the CIAL methodology. This supports CIAT's view that this participatory research method, now used by about 250 groups in eight Latin American countries, is an excellent way to promote local rural innovation and social capital accumulation, the pillars of farmer resilience.

Economic levers: Cassava and tropical fruits

Liberalized international trade presents small tropical farmers with both risks and opportunities. Cheap imports of feed maize from North America, for example, are hurting small maize producers in many parts of tropical Latin America these days. Yet CIAT has been able to demonstrate the great potential of cassava as an alternative animal feed. Given the right growing conditions, large volumes of cassava roots and protein-rich leaves can be efficiently produced, processed into high-quality feed, and sold at internationally competitive prices. As a tropical crop, cassava is an underexploited lever for enhancing small farmers' social and economic resilience in the face of globalization.

Tropical fruits, both for export and domestic consumption, also hold great economic promise for developing country farmers trying to cope with economic change. As permaculture crops, fruit trees have the added bonus of helping to conserve soil. Under our new strategy and medium-term plan, CIAT will undertake research, aimed at helping rural people identify and seize new opportunities for producing and commercializing these high-value crops.

Our current efforts to help poor farmers transform risky rural livelihoods into resilient ones include many other avenues of investigation. These range from the improvement of staple crops to overcome micronutrient malnutrition among women and children to the use of geographic information systems and modeling tools to predict the impact of climate change on crop yields. A conviction guiding all our work is that access to a wide and complementary mix of biophysical and social technologies is the best way to help rural communities adapt to, and thrive in, a rapidly changing world.

Joachim Voss
Director General, CIAT

In memory of Chusa Ginés and Verónica Mera

On 28 January 2002, María Jesús ("Chusa") Ginés and Verónica Mera lost their lives when the aircraft they were aboard crashed into the Cumbal volcano on the border between Colombia and Ecuador. CIAT management and staff as well as friends in many partner organizations mourn the tragic loss of these two valued colleagues. To their families, we extend our sincere condolences.

A memory of both Chusa and Verónica to be long cherished is that these two key players in the Latin American Cassava Biotechnology Network (CBN) dedicated their lives to the advancement of the rural poor, especially women farmers.

Chusa, an expert in plant genetic resources who held a PhD in molecular biology, served as the network's coordinator. Verónica, who held an MSc in the management of agricultural knowledge systems, was a social scientist on the project, simultaneously working toward a PhD in sociology. Both women were based in Quito, Ecuador.

Supported by the Ministry of Foreign Affairs of the Netherlands and Canada's International Development Research Centre (IDRC), CBN serves as a bridge between biotechnologists and small cassava farmers, processors, and consumers. It attempts to ensure that the needs and views of these clients feed directly into biotechnology research on the crop.

Coordinating what some have referred to as a “green biotechnology” network was a role for which Chusa was well suited. As a friend and colleague of hers recently wrote in a Canadian newspaper, “Chusa was a firm believer that modern science could be blended with traditional ingenuity to find local and long-lasting solutions.”

In memory of Chusa and Verónica, IDRC has agreed to provide CIAT with funding for a study fellowship program. It will offer scholarships for young women and men from developing countries to complete studies in the area of agrobiodiversity and its conservation.

Improving Rural Livelihoods

CIAT’s Medium-Term Plan for 2002-2004

Last year CIAT unveiled its strategic plan for 2001-2010. At its heart is a long-term vision of sustainable livelihoods for millions of poor farm families throughout the developing world. To aid them in their arduous exit from poverty, we believe three critical conditions must be met: more competitive small-scale agriculture, improved agroecosystem health, and robust rural innovation.

The Center is now implementing the first phase of that strategy through its medium-term plan for 2002-2004. Below we highlight several innovations in CIAT’s research agenda and organizational structure that will shape our work in the coming years.

Soils institute

Soil is a living biological system in which agriculture is literally grounded. But it is also one of our most threatened natural resources, particularly in Africa. For many small farmers in the tropics, heavy use of inorganic chemical fertilizers to build soil fertility is not a realistic option because of the expense involved. So it is essential to devise sustainable soil management techniques that make efficient use of local resources like crop residues and forage plants. CIAT’s experience in Africa, Asia, and Latin America has shown that such methods can be successfully designed and applied when formal soil science is carefully blended with the site-specific experience and know-how of small farmers.

To pursue this approach on a large scale, CIAT has recently completed a merger with the Tropical Soil Biology and Fertility (TSBF) Programme and created the Alliance for Integrated Soil Fertility Management in Africa with the International Centre for Research in Agroforestry (ICRAF).

Rural innovation

For CIAT, science is a means to an end: sustainable rural livelihoods. Linking research to grassroots development is therefore a top priority. Our recently launched Rural Innovation Institute pulls together several threads of CIAT’s action research. These are projects aimed at helping rural communities and NGOs learn about their local environment, solve problems, and exploit new agricultural technologies and markets. Our ongoing work in the area of participatory research and agroenterprise development have been reassigned to the new institute.

“But the Rural Innovation Institute isn’t meant to act as an extension service,” explains Douglas Pachico, CIAT’s director for research. “It’s there to investigate the development process itself and make our other research efforts more relevant and successful. It has the special role of examining how rural communities can build social capital and gain access to information that will help them be more innovative."

The institute has launched a new project titled Information and Communications for Rural Communities. Among its key outputs will be organizational approaches for gathering and sharing information and knowledge. These include the design of community telecenters and Web-based information systems. The new project will help CIAT consolidate and expand the experience it has gained in these areas during the past few years.

Research organization

In the past most CIAT projects were organized around two broad themes: plant genetic resources and natural resource management. Our new structure integrates these efforts under a single research directorate, allowing for tighter coordination of these two rapidly converging domains.

To ensure that our research responds to the needs of our various partner organizations in Latin America, Africa, and Asia, three regional coordinators have been appointed. Each will monitor the relevant agricultural and policy environment and ensure that the priorities of national and regional research programs, as well as those of farmer associations and community development organizations, are taken into account in CIAT activities.

Tropical fruits

Growing tropical fruits is labor intensive and can provide steady employment and income even to families with very small parcels of land. The long production cycle of fruit trees also contributes to soil conservation. With demand for tropical fruits on the rise, this type of high-value agriculture represents a strong comparative advantage for tropical countries. CIAT recognizes that targeted R&D in this area has enormous potential to boost small-farmer competitiveness while promoting healthy agroecosystems.

To help partners in the public and private sectors promote the production, processing, and marketing of tropical fruits in rural communities, CIAT scientists will develop an interactive Web-based information system that indicates what tropical fruit species can be grown successfully in particular locations, based on agroecological similarities. They will also identify and help develop tropical fruit-based business opportunities.

The Tropical Fruits Project will be housed within the Agronatura Science Park at CIAT headquarters in Cali, Colombia. We have created the science park on the premise that research linked to commercial opportunities can generate new benefits for poor farmers. Agronatura currently hosts 18 research organizations, which share the Center's facilities and work with our scientists in joint projects.

Climate change

Global warming is now an accepted scientific fact, and climate change models are giving us an increasingly detailed picture of what is in store. The issue is of particular concern to CIAT, since crop yield reductions are now being predicted for most of the tropics and subtropics where the capacity to rapidly adapt is weakest.

Our new climate change project builds on and integrates earlier CIAT research on this topic. It centers on three themes:

- The use of geographic information systems and other modeling tools to predict the effects of climate change on agriculture

- The design of coping strategies for farmers and agricultural policy makers
- Research on the mechanisms by which agriculture either contributes to atmospheric warming (for example, through the release of methane by livestock) or slows it down (as when improved tropical pastures sequester large amounts of carbon in the soil)

This CIAT work will feed into any future multi-institutional initiative on climate change undertaken by the CGIAR.

From Risk to Resilience

In North and South alike, agriculture is a perennial gamble. Farmers have little influence—and sometimes none at all—over the biophysical factors involved in plant growth and the economic conditions that dictate profit or loss. Among the most elusive variables are weather, pest and disease pressures, and commodity prices.

Poor people in the tropics make up the vast majority of the world's farmers. They are also the ones most exposed and vulnerable to threats. Yet there are many entry points through which they can gain some control over an otherwise risky livelihood. Adopting new crop varieties that resist stresses, improving family nutrition, and organizing the community for sustained local rural innovation are among the options.

In the following pages, we examine some of the key constraints and risks faced by developing country farmers. We then highlight a few examples of how CIAT's research is helping to build rural resilience in a world full of unexpected threats and opportunities.

Coping with Risk

In most industrial economies, support for farmers in their age-old task of coping with risk is just a phone call or Internet search away. Access to timely technical information goes a long way to reducing their vulnerability to the unexpected. Acquiring the latest improved plant varieties, livestock breeds, and chemical inputs also helps. But when such measures fail, there is always crop insurance to fall back on.

Risk factors

Small-scale farmers in the tropics do not have nearly as many aces up their sleeve. The art of taking calculated risks is more complex for them and the consequences of being wrong are more brutal. Indeed, total crop failure and seasonal hunger are all too common.

To begin with, small farmers in developing countries usually cannot afford the chemical inputs that their counterparts in the North routinely administer to protect investments. While fertilizer application, for example, varies widely across countries and regions, a few numbers from the UN Food and Agriculture Organization (FAO) illustrate the point clearly. In 1999 industrialized Italy, with 58 million people, consumed 1.8 million metric tons of fertilizers. In contrast, the 41 sub-Saharan African countries for which figures are available together used only 75 percent of that amount. Yet their combined population is 10 times greater than Italy's, and their soil fertility problems are intrinsically worse.

Second, small holdings in the tropics are often located on hilly, marginal land whose soil quality, slope, and elevation vary dramatically even between plots on the same farm. Soil erosion and even landslides are a constant hazard.

Third, rural communities in the tropics rarely have access to the full array of sophisticated public and private services that farmers in industrialized countries take for granted. Resources for mitigating risk and coping with explicit threats include social safety nets, public and private research, extension agencies, weather offices, crop insurance, marketing boards, and lending agencies.

Many such services are, in theory, available to producers in tropical countries. But the sheer numbers of farmers to be served from severely limited resources precludes widescale, equitable coverage. FAO estimates the agricultural population of the developed countries at 100 million, or 7.6 percent of their total population (2000 figure). For the developing world, the figure is 2.47 billion, or more than half its total population. So, for every person in the developed world who needs agricultural support services, there are some 25 such clients in developing countries.

That is half the story. The other major element is public fiscal capacity to provide key agricultural services like research. A recent report by the International Food Policy Research Institute (IFPRI) reveals the enormous fiscal gap between the developing and developed countries. During the 3-year period centering on 1995, the annual average expenditure on public research per economically active person in the agricultural sector of the developing world was $8.50 (1993 US dollars). For the developed countries, the figure was $594.10.

One final factor, frequently glossed over in discussion of risk management, is human health. Rural people in the tropics are typically exposed to a dangerous mix of infectious and vector-borne diseases, occupational hazards, and poor nutrition. Malaria, schistosomiasis, sleeping sickness, and diarrheal diseases are afflictions that canola farmers in Canada or vineyard owners in France rarely give a thought to. And, for pharmaceutical companies, they occupy low-level slots on the drug-development agenda. Yet these diseases remain chronically serious in the tropics, particularly Africa. AIDS, pesticide poisoning, iron-deficiency anemia, and mycotoxin contamination of food likewise take a heavy toll in developing countries, reducing the resilience of farm families.

Information as power

While a few such generalizations about the vulnerability of rural people in the tropics are possible, risks vary markedly with time and location. As well, human responses to risks and threats differ according to the level at which they are taken: global, regional, national, or local. As CIAT environmental scientist Manuel Winograd notes, this variability of risk and response demands a concerted research effort if developing countries are to systematically and successfully cope with their vulnerabilities. As a starting point, he says, they need reliable methods for collecting, organizing, and using information to map and assess risks.

"The absence of planning as to how land should be used and where human populations and infrastructure should be located, along with failure to apply precautionary principles, are the main causes of increased risk and vulnerability," says Winograd. "Policies, strategies, and actions are oriented more toward dealing with the consequences of crises than to preventing them."

In recent years CIAT has designed many information tools to help rural communities and public officials deal with issues like land use planning, biodiversity conservation, soil management, and natural disaster mitigation. While some are simple text-based decision guides, others are CD-ROM-based software packages requiring substantial training and data sets to operate. Such knowledge-intensive products, usually aimed at development advisers, rarely have as direct an impact on natural resource management at the farmer level as our germplasm has had on agricultural production. Yet information is power, and demand for it is growing remarkably fast.

Seed-based germplasm is "biological information packaged in a form suitable for broad-based transmission to farmers," says Simon Cook, manager of CIAT's Land Use Project. "How can we mimic this process for natural resource management technology? Maps? Documents? Guides? Web sites? We need to find ways to distribute this information to users, who are generally community leaders, development professionals, or government officials. While the insights contained in new information tools may be incredibly useful, farmers cannot adopt them directly as they can improved varieties. What we're searching for is the NRM equivalent of the seed."

In the meantime, CIAT continues to work on a variety of ways to help small tropical producers cope with risk. As two of the following articles illustrate, these include progress toward "solutions-in-a-seed," specifically drought tolerance in beans and enhanced micronutrient content of staple crops. The other two articles look at the use of computer models to estimate the likely impact of climate change on crops and the building of community resilience in Bolivia through farmer participatory research.

Seeds of Health

Combating micronutrient malnutrition through crop biofortification

A new research program to boost the vitamin and mineral content of the world's staple foods is expected to improve the health of millions of poor people in tropical countries. Micronutrient malnutrition, especially lack of iron, zinc, and vitamin A, currently afflicts more than half the world's population. So the potential benefits of this major international R&D undertaking are enormous.

The transdisciplinary effort to "biofortify" crops is a major intercenter collaborative effort and a candidate for the Challenge Programs to be launched by the CGIAR. The program combines plant genomics and breeding with human nutrition science, social behavior studies, and policy analysis. It draws on the substantial experience gained over the past 7 years by the CGIAR's Micronutrients Project, results of which indicate that biofortification is highly feasible for most crops.

The program is intended to complement more conventional measures, such as distribution of vitamin and mineral supplements and commercial fortification of processed foods. Indeed, agricultural and health experts widely recognize that there is no single magic bullet that will wipe out micronutrient malnutrition. Multiple, interlocking strategies are needed.

The priority crops of the new program are common beans, cassava, maize, rice, sweet potatoes, and wheat. By the end of the project, micronutrient levels in these crops are expected to be at least 80 percent greater than current levels. Researchers will also conduct prebreeding studies to build the necessary knowledge base for biofortifying bananas, barley, cowpeas, groundnuts, lentils, millet, pigeon peas, plantains, potatoes, sorghum, and yams.

The program is coordinated jointly by CIAT and the International Food Policy Research Institute (IFPRI) in Washington, D.C. CIAT plays two roles. First, it provides overall coordination of the breeding and related biotechnology work carried out by a consortium of seven Future Harvest centers in collaboration with selected national research programs in developing countries. And second, CIAT scientists conduct micronutrient research on two crops: beans and cassava, the latter in partnership with the International Institute of Tropical Agriculture (IITA) in Nigeria. IFPRI coordinates the human nutrition and policy research components, while Michigan State University in the USA will provide leadership in nutritional genomics research in collaboration with other advanced research institutes in Africa, Asia, Latin America, and North America.

As illustrated in the rest of this article, CIAT has been working hard to integrate its long-standing expertise in plant breeding with that in molecular biology, as a way to tap the genetically based micronutrient potential of beans and cassava.

Breeding iron-clad beans

Iron deficiency anemia afflicts an estimated 1.5 billion people in developing countries, most of them women, reducing mental ability, creating severe complications at childbirth, and lowering physical capacity. Zinc deficiency, though less well understood, is also known to be widespread in the tropics and is a major threat to children's growth and health.

In analyzing the content of these minerals in common bean, CIAT scientists have examined new breeding populations as well as a much wider collection of nearly 2,000 genotypes. In addition, our research collaborators at the University of Nairobi analyzed the mineral content of a set of 70 commercial and farmer-bred bean varieties from six African countries.

The results have provided CIAT and other scientists with a substantial inventory of mineral-rich bean cultivars. Scientists working jointly with NGOs will soon test some of these high-iron beans in a nutritional efficacy trial involving Kenyan and Ugandan communities at high risk of iron-deficiency anemia. The beans will be combined with vitamin A-enriched sweet potatoes developed by the International Potato Center (CIP), allowing researchers to examine the synergistic effects of the two micronutrients in a biofortified diet.

This work in Africa is part of a 3-year project funded by the United States Agency for International Development (USAID), which has taken a lead role in crop biofortification. A component of the CGIAR Challenge Program on biofortification, the work brings together several African research groups and Cornell University.

CIAT research has shown that beans possess enough genetic variability—the scientific elbow room so valued by breeders—to make further improvements in iron and zinc content. It has been estimated that breeding could comfortably improve iron content by about 80 percent and zinc by 40 percent.

To exploit the genetic potential of beans, CIAT scientists have produced a series of potentially mineral-rich bean populations for chemical analysis and further improvement. Two recognized sources of high iron and zinc content were recruited in the “backcrossing” experiments through which this germplasm was developed. One was a wild Mexican bean, the other a cultivated variety, known respectively in seed bank parlance as accessions G 10022 and G 14519. These were crossed with several other popular varieties, which served as “recurrent” parents. (In recurrent backcrossing, hybrid progeny are repeatedly crossed with one of the original parents to weed out undesirable traits over several generations.)

Chemical analysis of these materials revealed that plants with high iron levels also tended to have a lot of zinc. This suggests that the accumulation of both minerals in beans is to some extent controlled by the same sets of interacting minor genes, known as quantitative trait loci, or QTLs. Thus, breeders may be able to select for iron and zinc simultaneously.

Molecular mapping of micronutrients

Parallel CIAT work based on molecular marker technology supports that view. The molecular mapping work for micronutrient content focused on two bean populations bred for high iron and zinc concentrations. One was a cross between two Andean bean types, the other between two Mesoamerican types. CIAT bean geneticist Matthew Blair and colleagues developed a genetic map for each population, one containing 119 molecular markers and the other 98 markers.

These maps enabled the researchers to identify a number of QTLs linked to the accumulation of iron and zinc. The most significant QTLs accounted for up to 33 percent of the variance in iron content and 37 percent for zinc. While some of the QTLs were specific to either iron or zinc, others were positive for both minerals. These double-duty QTLs were found on five chromosomes in the Andean population and on three chromosomes in the Mesoamerican beans.

The next step for Blair and his colleagues is to zero in on certain parts of the genome to find out whether the genes for higher mineral content occur at the same locations in other selected bean populations.

“We now need to translate the results of our QTL studies into a practical marker-assisted selection scheme,” says Blair. To this end he and his colleagues plan to integrate the mapped locations of the QTLs observed for micronutrient content with known locations of QTLs responsible for other traits. Then, a carefully chosen set of microsatellites (a particularly advantageous type of molecular marker) can be used in marker-assisted selection. This will speed up breeding, allowing CIAT’s bean improvement team to select simultaneously for high mineral content and other useful traits, like disease resistance and drought tolerance.

Vitamin A from cassava

The World Health Organization estimates that, worldwide, between 100 and 140 million children suffer from vitamin A deficiency. Every year it causes 250,000 to 500,000 children to go blind, and about half of them die within a year.

Animal products, mothers’ milk, and many edible plants are rich sources of vitamin A. In plants carotenes, especially beta-carotene, serve as chemical building blocks, or “precursors,” of vitamin A. These pigments are abundant in dark-green leafy vegetables and in yellow or orange fruits and root crops, including some types of cassava.

Cassava roots provide lots of calories to consumers in the tropics, but they do not contain enough carotene to supply the minimum amount of vitamin A needed for good health. While the leaves are up to 100 times richer in carotenes than the roots, and in some cultures are eaten as a fresh vegetable, they account for only a tiny fraction of total cassava consumption.

CIAT research has shown, nevertheless, that cassava possesses significant genetic variation for micronutrient content, both of carotenes and minerals. Recent work in this area has been funded by Danish International Development Assistance (Danida). We are confident that, as in the case of beans, we can exploit this natural advantage through traditional germplasm screening, marker-assisted selection, and other methods.

The opportunities and challenges involved in biofortifying cassava are somewhat different, though, from those encountered in bean improvement. To begin with, the long reproductive cycle of this crop makes for slow progress in crossing and selection. Breeding is further complicated by the "heterozygous" nature of cassava. This refers to the fact that in a matching pair of cassava chromosomes, a given gene on one chromosome is not identical to the corresponding gene on the other chromosome. As a result, it is quite difficult to use standard crossing methods to reorder genes in such a way that specific, valued plant traits are systematically passed from one generation to the next. Even so, an increasing measure of control is being gained through the use of molecular marker technology.

Fishing for carotene genes

Genetic transformation is a faster way to produce beta-carotene-rich cassava, and CIAT is currently investigating this option. In this type of plant engineering, beta-carotene genes from one cassava genotype would be cloned and inserted into another cassava genotype.

To do this we first need to improve our understanding of the "carotene pathway," the biochemical process by which cassava plants synthesize and regulate root beta-carotene. CIAT biotechnologists have therefore been studying the cassava genes responsible for the four enzymes that manufacture beta-carotene. These enzymes are widely found in other organisms like flowers and bacteria, and the DNA sequences of the genes that encode for them are public knowledge.

During 2001 we used those sequences to design PCR primers. (Primers are short fragments of DNA that complement the chemical structure of target genes and lock onto them—a bit like the action of a zipper.) This allowed us to successfully amplify the four target genes from the DNA of two cassava samples, one with high carotene content, the other low in carotene. Some amplified DNA fragments have now been cloned for comparison and further analysis. Thus, the stage is set to "fish out" the enzyme-related genes needed to transform cassava into a better source of vitamin A.

CIAT's analytical work has correlated carotene content with a difficulty faced by all cassava farmers: postproduction physiological deterioration, or PPD. "This oxidation process is a major bottleneck in cassava production and processing," says Hernán Ceballos, manager of CIAT's Cassava Project. Although cassava roots keep well when left attached to the plant in the soil, they quickly rot when harvested and exposed to the air.

Some CIAT results suggest that high carotene content is linked to lower rates of root deterioration. Four cassava genotypes have been identified that show both high root carotene and low rates of deterioration. "These findings are very important," says Ceballos. "It means we can use the low PPD rate of yellow, vitamin-A-rich cassava as a selling point to farmers—as long as we also ensure the cassava has a good agronomic background."

Beans with a "Hope in Hell"

Scientific perseverance yields elite beans that stand up to drought

After nearly a quarter century of research, CIAT scientists have succeeded in breeding drought-tolerant beans that also incorporate other traits important to farmers. The work is now in the varietal development stage.

The achievement is significant because drought is a widespread threat to agriculture and a common cause of crop failure and hunger. It is thought to affect about 60 percent of global bean production. In Latin America, a major bean-growing region, an estimated 3 million hectares of the crop suffer from moderate to severe drought most years.

The new beans yield 600 to 750 kilograms per hectare under severe drought. This is roughly double the maximum yield that Latin American farmers currently get from commercial varieties under the same conditions.

Led by breeder Steve Beebe, CIAT's bean improvement team used several sources of drought tolerance to produce the promising new lines. These included several highland Mexican beans of the Durango race and a southern Colombian farmer variety of Central American origin. San Cristóbal, a bean from the Dominican Republic that was first identified in the early 1980s as being a source of stable drought resistance, was also used.

To see how well the drought tolerance is expressed across different environments, Beebe and his colleagues assembled a "nursery" of 36 genotypes, the best of the breeding lines created from the drought-tolerant parents. These were distributed in 2001 to researchers in Colombia, Cuba, Haiti, Honduras, Guatemala, Kenya, Mexico, and Nicaragua for testing. The first block of results showed good correspondence between drought tolerance at CIAT headquarters in Colombia and that recorded by the Pan-American School of Agriculture in Zamorano, Honduras.

The physiology of tolerance

Developing drought-tolerant beans has been a long-term, complex challenge. This is mainly because drought tolerance in beans and other plants is a genetically complex trait. It is controlled by several physiological mechanisms, which in turn are orchestrated by the interactions of many genes.

Greater understanding of the role played by deep-root systems in protecting beans from drought was a major contribution of CIAT plant physiologist Jeff White in the 1980s. More recently, a second mechanism has been identified: the ability of some types of beans to efficiently transport carbohydrates (produced by photosynthesis) from leaves to the edible grain even under the stress of drought. Many of the details of this process, observed in a southern Colombian landrace (G 21212), are being worked out by CIAT plant physiologist Idupulapati Rao, in collaboration with Beebe.

"Nobody at the end of the 1970s believed that common bean had a hope in hell of showing any drought resistance," says CIAT agricultural geographer Peter Jones. "It went against all physiological principles. We were recommended to drop the problem quite a few times along the way. If we had listened to that advice, nothing would have happened. It hasn't cost a fortune, just plain old slogging away."

Jones and other CIAT scientists note that such continuity in international crop improvement efforts is crucial to the development of practical technologies for farmers. The point, says Jones, was reinforced recently by a Central American scientist visiting the drought-tolerant bean nursery at CIAT. "As we were leaving the field, he said, 'Thank God for CIAT's breeding work. There's not a national program in Latin America that could have kept this research going for a quarter of a century'."

From floods to drought

CIAT's seed-based solution to what many earlier believed was an intractable obstacle to higher bean production is particularly timely and relevant for Central America. Just 3 years ago, Hurricane Mitch killed thousands of people in Honduras and Nicaragua, flattened homes, and deluged farm fields, destroying bean and other crops in the process. During the following 2 years, rural people again lived the nightmare of food and seed scarcity, but because of drought linked to the El Niño/La Niña cycles. CIAT's new bean lines, into which other good agronomic traits are now being bred, will provide long-lasting benefits to this drought-prone, bean-producing region of Latin America.

We are also collaborating with several NGOs and research organizations to distribute seed of improved bean varieties in Haiti. This is part of a major relief project to help this island nation recover from the September 1998 devastation of Hurricane Georges. Over the next few months, the most advanced drought-tolerant lines will be sent there for testing.

On a much wider scale, atmospheric warming is expected to increase the intensity and frequency of drought and other severe weather events in much of the tropics in the coming decades. Millions of people in Latin America and central, eastern, and southern Africa depend heavily on beans as a daily source of dietary energy, protein, and micronutrients, as well as income through sales. The future resilience of their rural livelihoods will thus depend significantly on reliable access to drought-tolerant bean seeds made available through CIAT's work.

Combining strengths

In 2001, CIAT's bean project took another major step forward when it began crossing its drought-tolerant bean lines with a selection of other CIAT beans tolerant of low soil fertility and resistant to major diseases. One of these diseases, the bean golden yellow mosaic virus (BGYMV), is a serious drawback for Central American bean farmers. Furthermore, it is directly linked to drought because the whiteflies that transmit BGYMV thrive in hot, dry conditions.

"We've moved from a trait development phase to a varietal development phase," says Beebe, stressing how important it is to now combine as many genetic advantages as possible in the new germplasm.

This multiple-trait breeding work, made more efficient by the use of CIAT-designed molecular markers linked to specific types of disease resistance, focuses on the small black-seeded and red-seeded beans so popular in Central America. About 10 percent of the second-generation plant populations from multiple crosses, plus a selection of six simple crosses, have proved highly promising. These have been bred to the fourth generation, and the resulting 200 elite bean populations are now being shared with national research programs and other collaborators in Central America. Parallel work is targeted on African bean-growing areas.

Tracking the Impact of Global Warming

Maize yields on two continents will dip, but local effects will vary widely

Climate change will cause overall annual maize production in Africa and Latin America to drop about 10 percent by 2055 unless remedial measures are taken. That's the prediction of two scientists with CIAT and the International Livestock Research Institute (ILRI).

"The simulation results are what we would expect if farmers continue to plant the same varieties in the same areas," explains CIAT agricultural geographer Peter Jones. Future changes in crop management and the use of better-adapted varieties should lessen the blow to maize producers.

Over many years, Jones and ILRI colleague Philip Thornton collaborated on a method for simulating site-specific daily weather based on data collected by thousands of weather stations around the world. Their aim was to sharpen the ability of standard crop models to predict the behavior of food and forage crops under different climatic and crop management conditions. The fruit of their research effort, a computer tool called MarkSim, was first tested in 2000 and will soon be released by CIAT on CD-ROM.

The researchers went a step further by using MarkSim to predict the effects of climate change on crops. They combined MarkSim and a well-known crop model, Ceres-Maize, with a climate-change model called HadCM2, which maps probable future temperatures around the world. Their initial simulation test, described in last year's *CIAT in Perspective*, examined future changes in yields of a popular maize variety at specific sites in southeastern Africa. More recently, Jones and Thornton expanded the analysis to cover all of Africa and Central and South America. They also increased the number of maize varieties to four, to better simulate smallholders' cropping decisions under different soil and climatic conditions.

Zeroing in on local effects

The latest simulations suggest that the agricultural impact of rising temperatures and shifting rainfall patterns in the tropics and subtropics will vary widely from one agroecosystem to another and between countries. For example, in wet highland tropical environments of Africa and Latin America, maize yields could increase by 4 to 12 percent over yields simulated for 1990 (the baseline year). Dry lowland tropical areas, in contrast, could see reductions of about 25 percent. "It's the local effects that are going to hit farmers hard," says Jones.

In the dry lowlands, temperatures will rise above the optimum for maize, and rainfall may decrease. Large parts of Northeast Brazil and its savannas (the Cerrados) fall into this category. "The areas where yields will increase are very limited," says Jones, "and comprise only some well-watered highland areas and a coastal region in southern Brazil and Uruguay."

Farmers in three of Africa's major maize-growing countries—Nigeria, South Africa, and Tanzania—would experience maize yield losses in the neighborhood of 15 to 19 percent under this business-as-usual scenario. Yields in Côte d'Ivoire and Ethiopia, however, would remain more or less stable to midcentury. In Brazil, South America's leading maize producer, yields would drop 25 percent. But in Mexico, the second largest producer, the reduction would be a little less than one-third of that. Only in Chile and in Ecuador are yields expected to hold their own or increase due to climate change.

Research on global climate change needs to continue zeroing in on local effects, according to Jones. This will make it possible to arm the poorest and most vulnerable people, those who depend on small-scale agriculture, with site-specific coping strategies. At the same time, scientists need to begin analyzing the impact on whole farming systems, not just single crops in isolation. Future CIAT work will therefore expand the application of MarkSim and related tools to other staple crops and production systems.

Urgency of adaptation

The CIAT-ILRI maize-modeling work is just one component of a wider international effort to better understand the interactions between tropical agriculture and climate change. CIAT is an active member of the Inter-Center Working Group on Climate Change of the CGIAR. The Group is currently formulating a multidisciplinary research agenda that will form the centerpiece of a major proposal for consideration under the new CGIAR Challenge Programs. In early 2002, CIAT also integrated its various climate change activities into a coherent, high-priority effort. This will allow for better scientific coordination both within CIAT and with our institutional partners.

Research on climate change is important for two reasons. First, it will help farmers and policy makers to cope with the impending negative effects of global warming. Second, it will contribute to the development of land-use patterns and farming technologies—so-called mitigation strategies—that help slow the buildup of greenhouse gases in the atmosphere.

"People in the temperate zones have ambivalent feelings about climate change," says Jones. "Yes, it will bring some uncertainty to their lives. But it also means an increase in temperature of two or three degrees, and for many people that would be rather nice. But when you think about the tropics, it's a completely different story. For some tropical crops, there will be nowhere to go."

Much of the world's rice, for example, is being grown in areas that are already at the temperature tolerance of this staple cereal crop. Global warming could seriously jeopardize flowering and result in major crop failures.

"It's not a situation where we can sit back and say, 'we'll only do something concrete when climate change really starts to happen'," Jones stresses. "A ton-per-hectare yield loss when you're only getting 1.5 tons of maize to begin with will be catastrophic! That's not to say we can't do something about it. But we have to act now. We've also got to get policy makers to realize there could be major upheavals in agriculture."

His message of urgency echoes that of the most authoritative international body on the topic, the Intergovernmental Panel on Climate Change (IPCC). In its Third Assessment Report (TAR), published in 2001, the panel says that, in the absence of mitigation measures, the world's average surface temperature will likely rise by 1.4 to 5.8 degrees C by the end of this century. That would be the fastest rate of change in at least the past 10,000 years. The effects of global warming, it says, are already being seen on physical and biological systems: shrinking glaciers, earlier egg-laying by birds, and poleward migration of some plants and animals.

The IPCC foresees significant and irreversible damage to natural systems such as coral reefs and polar ecosystems and greater risk of extinction of vulnerable plant and animal species. Water stress is expected to worsen in many arid and semiarid areas. In the tropics and subtropics, crop yields are expected to fall even with small temperature increases.

As University College researcher Joanna Depledge recently noted in a review of the IPCC report: "A key recurrent message is that developing countries will be hardest hit by climate change, as they are more vulnerable to its adverse impacts and have less capacity to adapt."

Permanent Participation
Institutionalizing farmer research committees in Bolivia

Farmers in the tropics are tireless inventors and skilled experimenters—with crops, trees, livestock, soil, water, fertilizers, and farm equipment. This necessity of rural life represents a valuable social resource that for many years was unfortunately overlooked or underestimated by R&D organizations.

Recognition that local knowledge systems, backed by formal science, can be a powerful tool for socioeconomic progress is at the root of a bold experiment in participatory research that CIAT launched 11 years ago in Colombia. Our system of local agricultural research committees, or CIALs (the Spanish acronym), has since spread to seven other Latin American countries. As a vehicle for rural empowerment, it has been embraced by hundreds of farming communities, who have helped CIAT refine the system. But it is also being adopted as an organizational model by R&D organizations that support farmers.

"Although our CIAL is a small organization, it's very important to us," says Bolivian potato farmer Roberto Merino Montaño, a member of the *Primera Candelaria* CIAL, based in the township of Colomi. "Technicians come and go, but we're always here. Right now our mentality is to get ahead, to enter the markets."

Of the more than 250 farmer-research committees currently operating in Latin America, about 10 percent are in Bolivia. The quest for a better rural livelihood by Merino and his fellow farmer-researchers—in this case via farm-based potato experiments that will help the rural community tap new market opportunities—typifies the aspirations of millions of small farmers in Latin America.

A demanding job

In brief, a CIAL is an agricultural research service owned by and accountable to the community, usually at the village level. Local citizens elect a small group of farmers known for their ability and interest in experimentation and their community spirit. Through public meetings, the community diagnoses the priority problem or issue to be tackled. The CIAL then carries out the experiments to establish the best technical options for farmers. Technicians from a public agency or NGO advise the farmers on experiment design and results analysis. In some cases farmers trained as paraprofessional researchers serve this function. Research results are systematically reported back to the community by CIAL members.

Being an active member of a CIAL is a demanding job that cannot help but compete with farm, family, and other responsibilities. Merino, for example, has to travel regularly in rural areas to farmer field days and other events. At the same time, he is enrolled in a distance education program at the Universidad Católica Boliviana to become a rural teacher. To make ends meet, Merino works 7 days a week. Besides taking care of his own potato plots, he works on neighboring farms to earn extra income of about US$3 a day.

While the day-to-day demands of being both a farmer and community activist are heavy, Merino is clearly inspired by the potential of his CIAL to make a difference in the community. "We're conducting this trial because native potato varieties face a serious risk of extinction in this area. In the past seed was planted on land that had been fallow for 20 years, land that was rested and fertile. Today we cannot leave land so long without planting because of the growing population. Many people occupy the same land, and to leave the land to rest is a luxury we can't afford."

While just a few decades ago farms in the area averaged about 10 hectares, today each family has only a tiny fraction of that as a result of farms being divided up among children from one generation to the next. For Bolivia's overall potato-growing population of some 200,000 families, the average holding is currently about two-thirds of a hectare. Thus, finding more productive potato varieties that also have strong consumer appeal is critical to the livelihoods of these small farmers.

"We're now testing 35 potato varieties on land that has been continually sown," says Merino. On some of the new potato plots, farmers have recently harvested quinoa and barley, for example. As part of their research, the CIAL members assess production conditions as well as the flavor and cooking time of the harvested tubers.

"We've been experimenting with these varieties for 2 years and have had very good results with several of them." Farmers like the variety *pinta boca* (mouth paint), so named because when you eat this potato, it leaves your mouth a violet color. Another variety is the reddish colored *puca candelero*. In Quechua, *puca* means "red," and it is called *candelero* (candlestick) because of its shape.

Moving to the next level

With the effectiveness of the CIAL method now well established, CIAT has turned its attention in recent years to second-generation issues. These "institutionalization" aspects include the financial and social sustainability of existing CIALs, mechanisms for scaling up the method to achieve wider impact in Latin America and beyond, and participatory methods of monitoring and evaluation. This last component involves design and use of multiple feedback loops, among farmer-researchers, community members, technical advisors, municipal and other government planners, and CIAT.

But, as Jacqueline Ashby, director of CIAT's new Rural Innovation Institute and chief architect of the CIAL concept, points out, each country is different and solutions will therefore vary. In some instances, second-order organizations—associations of farmer committees at the provincial or national level, for example—will be the main vehicle for sustaining the CIAL approach and ensuring farmers' voices are heard by authorities. This is the pattern emerging in Colombia and Honduras. In other countries, such as Bolivia, new municipal structures can serve as the institutional base. In all cases the role of public research institutes, universities, and NGOs will continue to be critical in providing scientific, organizational, and financial advice to farmer-researchers.

As in many developing nations, the government of Bolivia has restructured its public agricultural research system in recent years. The current watchwords are demand-driven services and fiscal responsibility. To these ends, semiautonomous organizations (*fundaciones*) have been set up to respond to producer, processor, and consumer needs through contracted R&D. CIALs are among the various research-service providers that may submit proposals for funding, mainly in the area of adaptive research.

Combining forces

One such organization is Fundación PROINPA, the Foundation for Promotion and Investigation of Andean Products. Originally launched in 1989 as the potato research program of Bolivia's national agricultural research institute, it was reconstituted in 1998 as a national development center for Andean crops.

Over the years, PROINPA has helped Bolivian farmers more than double potato yields, from 4 to 9 tons per hectare. It has also been a key CIAT partner and promoter of the CIAL methodology in Bolivia. It provides technical and other support to 10 of the country's 23 CIALs, including Roberto Merino's group, *Primera Candelaria*.

Under new national legislation, the so-called Law of People's Participation and the Law of Dialog, municipalities are charged with responding to local development demands to improve people's living conditions. Grassroots organizations called *sindicatos*, into which CIALs will be integrated, are being set up to represent community concerns. These changes provide all Bolivians with a government-sanctioned window of opportunity for rural advancement. They will allow the practical inventiveness of CIALs and the scientific expertise of organizations like PROINPA to be meshed with the development projects of municipal governments throughout the country.

Perspectives on Research Impact

Assessing the risks of transgenic crops

Besides evaluating past and future research, CIAT's Impact Assessment Unit also monitors trends influencing agricultural science. In 2001, Center economist and research director Douglas Pachico compared three regulatory structures set up to assess the risks of genetically modified organisms (GMOs), including transgenic crops.

By 2000, GM crops occupied some 45 million hectares of farmland worldwide. Transgenic soybean, cotton, canola, and maize account for most of the area. Top producers are the USA, Argentina, and Canada, with substantial areas also planted in China, Australia, and South Africa. All populated continents except Europe now have significant sowings of GM crops.

Enormous benefits from GM technology have been predicted for both industrialized and developing nations. There is, nevertheless, growing international concern over the environmental and human health risks posed by transgenic crops. Gene flow into wild relatives is a major worry for the environment. So is the possibility of transgenic plants becoming superweeds.

CIAT's recent comparative review examined the environmental risk assessment principles and regulations of the Biosafety Protocol of the Convention on Biological Diversity, as well as those of the USA and European Union.

The Biosafety Protocol is an international agreement reached in 2000 by over 130 governments. It focuses on the cross-border movement of GMOs destined for release into the environment and regulates the mutual rights and responsibilities of importers and exporters.

A guiding principle of the Biosafety Protocol is the precautionary approach set out in the 1992 Rio Declaration. In practice this means the burden of proof is on the exporter to demonstrate scientifically that the GMOs will not have unacceptable or unmanageable adverse effects.

The Protocol lays out a procedure of advance notification and informed consent. Exporters supply the biosafety regulatory authorities of importing countries with the scientific information needed to approve or reject a request to import. The Protocol does not require the exporter to demonstrate complete absence of risk, and it allows for socioeconomic benefits to be considered in the regulatory decision. What constitutes an acceptable or manageable risk is left to the judgment of importing countries.

The European Union's directive on deliberate release of GMOs into the environment differs from the Biosafety Protocol in several respects. While it too adopts the precautionary approach, it is much more specific about the scientific questions to be addressed in the risk assessment. In addition, it covers issues such as product labeling, postrelease monitoring of GMOs, and risk management strategies.

Unlike the Protocol, the European framework does not make provision for including the potential socioeconomic benefits in decision-making. It focuses squarely on avoiding increased risk to human health and the environment.

The USA is the largest producer of GM crops. About 50 crop varieties have gone through that country's regulatory system over the past decade. Three government bodies share responsibility for GMO assessment and regulation. Separate approval is needed from each before a GM crop can be commercialized.

As in Europe the US system spells out the specific scientific information and testing required to ensure there is no significant risk to people, other animals and plants, and the environment.

Assessments cover many factors such as potential for gene transfer to wild relatives and for weediness; allergenicity and toxicity of GM foods; and impact on other organisms.

While the first generation of transgenic crops in the USA and elsewhere has benefited producers more than consumers, future gene combinations are expected to take better account of consumer needs like nutritional content. Boosting vitamin A in cassava, a key food staple of the poor in many tropical countries, is one application of GM technology now being investigated by CIAT.

We have also developed transgenic rice that resists rice hoja blanca virus (RHBV), a major hurdle to rice production in Latin America. Experimental genotypes are now being field tested under strict biosafety conditions. Our planning of future transgenic research needs to take into account the costs and benefits of such biosafety procedures and risk assessments.

"CIAT recognizes that there are environmental risks involved in transgenic crops," says Douglas Pachico. "We cannot allow a technically feasible transgenic solution to be deployed if it creates other problems. We need to take a rational look at those risks." In some instances, he says, the costs of risk assessment and other regulatory compliance, as well as those involved in gaining access to patented technology, "may be so high, and the process may take such a long time, that it isn't worth pursuing the transgenic research."

As CIAT seeks technological options for alleviating rural poverty, we must keep our finger on the pulse of the evolving regulatory climate. Reviewing GM risk assessment measures is but one element in an ongoing effort to cultivate the institutional foresight demanded by successful, cost-effective science.

Costs and benefits of farmer participation

Participatory research methods and gender analysis now figure prominently in the work of the Future Harvest centers funded by the CGIAR. Center resources devoted to these approaches amounted to US$66.2 million in 2000 and the equivalent of 145 full-time staff.

"This is a sizable body of effort, certainly comparable to that of an individual center," says Nina Lilja, an economist with the CGIAR's Participatory Research and Gender Analysis (PRGA)

Program. Recent and rapid adoption of participatory approaches has prompted the PRGA Program, which CIAT hosts, to begin analyzing their benefits and costs.

With funding from Germany's Federal Ministry of Cooperation and Economic Development (BMZ), Lilja and two CIAT colleagues, Nancy Johnson and Jacqueline Ashby, recently examined the impact of farmer participation in natural resource management research. They chose three completed projects as case studies. Two projects, during the 1990s, were led by Future Harvest centers: the International Potato Center (CIP) and the International Crops Research Institute for the Semi-Arid Tropics (ICRISAT). The third was a project by the international NGO, World Neighbors, that spanned the 1980s.

CIP's project centered on the design of integrated crop management (ICM) methods for sweet potato production in Indonesia. Farmers actively participated in all stages of the project, including the development of curricula for farmer field schools. ICRISAT's project in Malawi tested legume-based technologies for managing soil fertility. "Mother" experiments designed and executed by researchers were replicated on-farm as "baby" experiments by participating villagers. The project supported by World Neighbors in Honduras promoted soil conservation practices in 41 communities.

A key finding of the impact analysis was that, while participatory methods do in fact result in more suitable technologies and greater adoption by farmers, they also give rise to learning and change. Among the benefits are the new skills and knowledge gained by individual farmers (so-called human capital) and the emergence of organizational capacity for innovation and action at the community level (social capital). In addition, partner research organizations benefit from collaboration with farmers. Insights and participant feedback sometimes lead these institutions to reset research priorities and improve R&D strategies.

"There are benefits to participatory research over and above the actual technology options eventually offered to farmers," says study coauthor and PRGA Program coordinator Jacqueline Ashby. "Local participation provides building blocks for rural people to improve their lives—by being able to articulate their needs, organize themselves, and apply what they've learned to nonagricultural activities."

The researchers distinguished between two types of participation in the case-study projects: functional/consultative and empowering/collaborative. With functional participation formally trained researchers interact with farmers to better understand their problems, priorities, and preferences. But the researchers still make all key decisions regarding technology development. The project in Malawi falls into this category.

The empowering form of participation goes well beyond consultation. Farmers make decisions about the project focus, objectives, and design, and they are deeply involved in research execution. Researchers work hand in hand with farmers to develop individual and community capacity for local experimentation and innovation. Both the Honduran and Indonesian projects promoted this type of participation to varying degrees.

In all three projects, farmer input influenced the technology development process and provided useful feedback to the R&D institutions leading the projects. The effect on the direction of technology development was greatest when farmer participation came early on in the research. In two of the three projects—those in the empowering/collaborative category—user participation was linked to increased technology adoption. In the Honduran project, adoption rates in participating villages ranged from 50 to 100 percent, with an average of 60 percent. In the case of Indonesia, production data indicate that farmer exposure to the new ICM technologies resulted in higher per-hectare income from sweet potatoes.

Significant human capital improvements were seen in the Indonesian and Honduran projects. The consultative approach to participation used by ICRISAT in Malawi generated fewer agronomic and economic research results, but there were some observable increases in participants' individual skills. Moreover, researchers became more adept at adjusting their methods to elicit input from farmers.

As for the costs paid by research organizations, the study found that participatory approaches increased expenditures for communications and workshops, field work by researchers, and researcher training in participatory methods. However, farmers' own costs of participation tended to replace and sometimes reduce researcher-related costs. Furthermore, expenditures on researcher training are essentially start-up costs. As participatory methods become institutionalized and individual scientists gain experience with participatory methods, these costs should decline.

The World Neighbors project was the only case study for which it was possible to roughly estimate cost-effectiveness. For each hectare of land to which farmers applied soil conservation practices, the project cost was US$208. Similar projects that did not use the "empowering participation" strategy had much higher costs, ranging from $845 to $6,000.

Sharing bean genes in Latin America

The smooth flow of seeds and other plant genetic resources across national borders has long been seen as vital to the design of better food crops and to the fight against rural poverty around the world. A recent CIAT analysis of the genetic origins and benefits of improved bean varieties that were derived in whole or in part from material in our germplasm bank lends credence to that conventional wisdom.

Reported in January 2002, the study lays out the patterns and economic impact of Latin America's longstanding international exchanges of bean genes. Its authors conclude that nearly three-quarters of the more than US$1 billion in regional benefits gained from planting improved CIAT-related varieties of common bean between 1970 and 1998 can be attributed to foreign genetic material.

CIAT agronomist Oswaldo Voysest analyzed the pedigrees of hundreds of commercial varieties released in Latin America over the past few decades. This allowed him to weight various countries' genetic contributions to the new varieties. CIAT economists and core searchers Nancy Johnson and Douglas Pachico then used price and production figures to estimate and analyze the economic benefits of these germplasm flows, country by country.

For 11 of the 18 countries in the study, more than 70 percent of the genes present in released bean varieties originated in other countries. Colombia was the biggest contributor to the international flow, followed by Mexico, Costa Rica, and El Salvador. Not surprisingly, the greatest beneficiaries were Brazil and Argentina. These large countries have long been major bean producers and their breeders rely heavily on foreign germplasm. Colombia and the Dominican Republic were the only countries where local sources accounted for more than half the genes making up released varieties.

"Clearly, everyone is both borrowing and lending germplasm for mutual benefit," says Johnson who led the study. "Patterns of country interdependence in sharing bean genes are rather similar to those for maize, rice, and wheat."

The emerging, often thorny issue of intellectual property rights over plant genes was one of several factors that led CIAT to conduct the study. On the one hand, international agreements like the Convention on Biological Diversity explicitly recognize national ownership of these resources. They call for greater fairness in the exchange and use of genetic materials, a domain that until recently was largely unregulated except for measures to prevent the spread of disease. On the other hand, the prospect of countries attempting unilaterally to profit from plant gene sales presents clear dangers. As the CIAT authors note in their 2002 study report, such behavior could end up restricting the international flow of germplasm.

The study findings echo those of earlier CIAT research which analyzed the potential benefits of introducing an international system of germplasm royalties. Under such a scheme, user countries would pay source countries a fee, proportional to the latter's genetic contribution to the commercial variety being planted. The analysis concluded that, overall, the economic gains from planting better crop varieties would far outweigh those from any royalty scheme, even at the generous rate of 10 percent of local seed prices. Thus, if any future royalty scheme is to have a positive net effect—namely, a combination of just payment for germplasm and continued improvements in agricultural productivity—it must be designed to promote, not hinder, gene sharing.

Research and Development Highlights

A market-oriented strategy for bean improvement in Africa

CIAT and partner organizations are making rapid progress in combining popular African varieties of common bean with advanced breeding materials that yield well, resist diseases and insect pests, and stand up to physical stresses like drought and poor soil fertility. This large-scale crossing work, begun in 2000, is a key component of a new market-driven bean improvement strategy for eastern, central, and southern Africa.

The common bean is a major source of protein, fiber, and micronutrients in the African diet. In the Great Lakes region of East Africa, for example, bean consumption is 66 kilograms per person per year, one of the highest levels in the world. With a protein content of about 22 percent, beans are a natural complement to carbohydrate-rich staples like bananas, maize, and sorghum, which African farmers often intercrop with beans.

Common bean possesses enormous genetic variation. Over the centuries, this diversity within the species has been exploited by farmers, and more recently by formal plant breeders, to produce a vast array of bean-seed colors, shapes, sizes, tastes, and cooking qualities. However, many popular bean types do not yield well, particularly under pressure of diseases, such as angular leafspot, root rots, and other stresses.

Our collaborators in the refocused regional program are the University of Nairobi and two research associations: the Eastern and Central Africa Bean Research Network (ECABREN) and the Southern Africa Bean Research Network (SABRN). The two networks, comprising national research programs, universities, and NGOs, together form the Pan-African Bean Research Alliance (PABRA). Funding is provided by the Canadian International Development Agency (CIDA), the Swiss Agency for Development and Cooperation (SDC), the US Agency for International Development (USAID), and the UK's Department for International Development (DFID).

The coordinators of national bean programs in Africa surveyed markets in 2000 to determine the main types of beans being grown and sold in their countries and the key constraints on production. The results helped them select the seven most important market classes of beans for accelerated improvement. Since African farmers and other bean consumers are very particular about seed color, that trait provides a practical means of dividing beans into distinct market classes.

In most of Africa's bean-growing regions, red beans win hands down, accounting for about half the sown area. These include the red mottled beans, small red beans, and large red kidney beans. The next most important grouping, accounting for 16 percent of land devoted to bean cultivation, is white beans, consisting of small navy beans, especially for export and local canning industries, and large white kidney beans.

Under the new bean improvement strategy, focusing on major market classes of beans, plant breeders are developing resistance to multiple production constraints at the same time. In the case of eastern and central Africa, the breeding work is shared among ECABREN members, with strong support from CIAT and the University of Nairobi.

For each of several market classes and subclasses identified, the regional program assembled a working collection of germplasm for crossing. Consisting of both local commercial varieties and promising breeding lines under development, these collections come from two main sources: CIAT and national bean programs. Since bean preferences vary widely among African countries and markets, breeding and evaluation for each priority market class is led by a national team that has a particular need for, or experience with, that type of bean. Test sites were selected to represent the major bean-growing environments for each market class. Small groups of local bean growers participate in on-farm tests.

CIAT researchers have made crosses for several market classes, and these have been evaluated for yield and resistance to disease and other stresses at various locations. For example, in Kenya more than 300 crosses were successfully made to improve eastern Africa's most widely grown and marketed variety of large red kidney bean, Canadian Wonder. This variety, despite its popularity, gives low yields and is susceptible to angular leafspot disease, anthracnose, and root rots. Various sources of resistance and of higher yield were used as parents in the crosses. Selections from the crosses were evaluated in Kenya, Tanzania (the lead program), and the Democratic Republic of Congo.

Molecular markers in the war on cassava mosaic disease

A single, dominant gene that makes some Nigerian cassava varieties highly resistant to cassava mosaic disease (CMD) is being harnessed to confer that trait on elite varieties destined for Africa, India, and Latin America. Tests by CIAT during 2001 also confirmed that the *CMD2* gene is effective against an aggressive form of CMD that resulted in crop failure and famine in parts of Uganda in the 1990s. The Ugandan variant of CMD virus continues to spread in central and eastern Africa.

CIAT geneticist Martin Fregene and colleagues have identified several molecular markers associated with CMD resistance. The cassava in their study was provided by the International Institute of Tropical Agriculture (IITA) in Nigeria. Some of the markers identified are simple-sequence repeats (SSRs). These give scientists a reliable, fast, and inexpensive way to screen for valuable genes without observing the corresponding phenotype—a technique know as marker-assisted selection (MAS).

One marker associated with the *CMD2* gene accounts for more than 80 percent of the phenotypic variance in CMD resistance observed in the plants with which the study was conducted. The gene is called *CMD2* because it is the second resistance gene found so far. IITA breeder Alfred Dixon was the first to observe that several local landraces, or farmer varieties—designated the TME series by IITA—showed good resistance to CMD.

The first source of resistance, discovered 3 decades ago, is the wild cassava species *Manihot glaziovii*. It was crossed with cultivated cassava, providing the basis for IITA's initial lines of CMD-resistant cassava, the TMS series developed in the 1970s. Although these breeding lines have a good measure of resistance, TMS plants under heavy CMD pressure often develop disease symptoms.

Under an IITA-CIAT project launched in 1996 with Rockefeller Foundation funding, four crosses were developed for tagging genes that control resistance to CMD. One of the crosses was made at CIAT by hybridizing the TMS source of resistance with a susceptible Latin American variety. The other three were made at IITA, with two using the TME varieties as the resistance source. In 1999 Fregene and CIAT virologist Lee Calvert, who were collaborating with Alfred Dixon, visited IITA's Onne experiment station in southern Nigeria to field-evaluate the progeny of the CIAT cross incorporating TMS-type resistance. The plants were growing adjacent to Dixon's TME experiment.

Fregene and Calvert were disappointed by the uniform appearance of their own plants. "If there are no differences, then there's no genetics," Fregene thought to himself. "Then, I looked across the fence to the IITA plot. And bingo, there it was! A lot of variation. One row was in bad shape, the next row in really good condition. The 50/50 division fit the model of a dominant gene for CMD resistance."

Fregene obtained DNA samples from the IITA plants so he could screen them with markers from the CIAT molecular genetic map of cassava. The result was the identification of the *CMD2* gene. At the same time, virus-free in vitro plantlets were shipped to CIAT in Colombia. These have since been grown out to produce seed for breeding. Henceforth, only plantlets bearing the *CMD2* markers will be transferred to CIAT's breeding program.

CMD is found mainly in Africa but also in parts of India. Viral strains vary from one cassava-growing region to another. In South America, where the root crop originated, CMD is not yet a problem. However, since the whitefly that transmits the virus is rapidly spreading in many countries, scientists fear the disease could soon appear in Latin America and parts of Asia. Thus, CIAT is now including CMD resistance in new lines of Latin American cassava as a precaution, made possible by the SSR markers.

Brave new dairying venture transforms upland villages in the Philippines

It's a brave farmer that would hunker down every morning to hand milk a buffalo. The very name conjures up a reputation for awesome strength and unpredictable temperament. But the buffaloes referred to here are not the lumbering beasts of burden that are a ubiquitous part of the Southeast Asian countryside. They are bred in India and Pakistan for their ability to produce milk, and they come with an even worse reputation for capricious behavior than their hulking relatives. They are, nevertheless, the focal point of one of the most unlikely dairying ventures in the most unexpected of places.

Former subsistence farmers in Mindanao have formed a rapidly expanding cooperative that supplies buffalo milk to an eager local market. The venture was sparked by the Forage for Smallholders Project (FSP), launched 6 years ago with support from the Australian Agency for International Development (AusAID). The project is now in its second phase, under CIAT coordination and with funding from the Asian Development Bank (ADB). The FSP aims to provide resource-poor upland farmers in seven countries of Southeast Asia with a range of grass and tree species that can be grown as crops to provide fodder for livestock while protecting the soil.

One noteworthy aspect of the FSP is the involvement of farmers themselves in the research process. Scientists offer groups of farmers a range of forage species that are suited to tropical conditions and are nutritious for farm animals. The grasses and trees are planted and managed with expert advice, but the manner in which they are used is up to the farmers themselves. The consequences have been both successful and surprising.

The village of Pagalungan clings to a wooded ridge in the mountainous countryside west of the southern Philippines city of Cagayan de Oro. For generations its farmers eked a gritty existence from sloping fields laid naked by loggers and subsequently cropped to exhaustion. Their crops of maize, mungbeans, and coconuts provided a bare existence, but their cattle and buffaloes failed to survive the local shortage of fodder. Every day farmers had to either lead them long distances over precipitous paths to rough pasture or cover the same distance to cut fodder and carry it home. Despite such efforts the quality of the feed was too poor to keep the animals in good health.

That all changed a few years ago when a local veterinary officer, Perla Asis, entered into collaboration with the FSP. She persuaded about 25 local farmers to plant exotic forage species around their houses. The grim pallor of poverty has since lifted from Pagalungan. There are new houses built of concrete, with fibro-cement roofs. The children are vigorous and bright-eyed. A few hundred feet below the village, the grassy banks of a swift stony river are dotted with carabao.

At first, the farmers of Pagalungan were unconvinced of the wisdom of planting what they saw as exotic weeds. But they persevered with the first batch of about 15 different grasses and legumes and quickly recognized the benefits. With the help of CIAT researchers and local collaborators, the range of forage species grown at Pagalungan has risen to more than 30.

The number of farmers cultivating the forage species has grown as quickly as planting materials have become available. In 1998 a group of 22 farmers formed the Pagalungan Tribal Settlers' Multipurpose Cooperative. At last count the membership had grown to 60 and was expanding rapidly.

Each of the dairy buffaloes gives 1 to 4 liters of milk every morning, and at Pagalungan this currently amounts to about 40 liters a day. The farmers are paid about US40 cents per liter for milk that they claim is richer and more nutritious than milk from dairy cattle. As well, they make big lump sums from the occasional sale of unwanted animals, and there is a big demand for planting material from their forage crops. So virtually every Pagalungan farmer is involved in the new forage trade.

Gaining ground on pasture spittlebugs

Recent CIAT research opens up new opportunities for controlling spittlebugs, the most destructive pests of Latin America's forage grasses. Our strategy for integrated pest management (IPM) combines three lines of attack: host-plant resistance, biological control, and pasture-and-livestock management.

Recent screening of our hybrid *Brachiaria* grasses, for example, has revealed 15 genotypes with good resistance to at least three spittlebug species. And the construction of a molecular genetic map of *Brachiaria* over the past few years has allowed us to identify two genetic sites (quantitative trait loci, or QTLs) linked to spittlebug resistance. This is a key step toward using marker-assisted selection to improve the efficiency of our forage grass breeding.

Spittlebugs have become a grave problem in pastures in Colombia's Caribbean coastal area over the past decade, and recently a species from Central America, *Prosapia simulans*, has taken a heavy toll on pastures in southwestern Colombia. In this country alone, the economic losses caused by spittlebugs through reduced beef and milk production amount to at least US$40 million annually, according to CIAT livestock specialist Federico Holmann. But the damage extends to a much wider area of beef/dairy cattle and sugarcane production across Central and South America.

"The problem has actually been around for a very long time," explains Daniel Peck, insect ecologist and senior research fellow who leads CIAT's work on spittlebug bioecology. "In the latter part of the 19th century, it almost destroyed the sugarcane industry in Trinidad." Spittlebugs, he says, also developed an appetite for *Brachiaria*. Over several centuries these naturalized grasses, of African origin, have generally adapted well to the Latin American environment. Today they are planted on millions of hectares of pastureland, especially in Brazil.

Spittlebugs get their English name from the frothy, saliva-like mass with which insect nymphs surround themselves as they suck sap from grass plants. Leaves and stems quickly dry out. And as the pasture infestation progresses year to year, weeds begin to fill the ecological vacuum.

"Pasture degradation is caused by mismanagement, lack of fertilizer application, and spittlebugs," says Carlos Lascano, manager of CIAT's Tropical Forages Project. "Farmers have to take cattle out of pasture, and that's a big economic loss. The number of animals per hectare is smaller, so farmers end up converting more forest to pasture to compensate."

To date, limited host-plant resistance to spittlebugs—such as that found in Marandú, a popular commercial variety of *B. brizantha*—has been the only weapon available to livestock producers. But Marandú is ill-adapted to the acidic, infertile soils typical of Latin American savannas. CIAT's new hybrids, however, do not have this problem, and some of them combine resistance to several spittlebug species with other agronomic advantages, like robust productivity and high nutritional value for cattle.

From the standpoint of both their biology and ecology, spittlebugs present scientists with an extremely diverse target. Within the family Cercopidae, there are dozens of spittlebug species distributed across 11 genera that attack grasses. What's more, the pest's behavior varies widely with climate, local habitat, and host plant. With so many factors influencing the timing, pattern, and intensity of pasture infestations, control methods need to be tailored to each situation. At the same time, CIAT breeders need to know which mix of spittlebug species to focus on in their efforts to improve resistance in *Brachiaria* hybrids.

Over the past 5 years, CIAT entomologists have been systematically building the necessary knowledge base and sharing it with national researchers through workshops. They have identified five contrasting ecoregions within Colombia, CIAT's host country, to serve as living laboratories. The chosen sites are representative of the different kinds of pastureland and rainfall patterns found in Central and South America. This ecoregional approach has allowed the team to profile the distribution of spittlebug species, their life cycles, population dynamics, and feeding behavior.

So far, Peck and his colleagues have examined nine previously unstudied species, observing their behavior—even mating "songs"—in detail. The resulting profiles are vital to predicting pest outbreaks, designing cost-effective control methods, and timing their use.

In the area of biocontrol, a key advance has been the collection of 77 strains of fungi from various spittlebug species. These parasitic organisms, known as entomopathogens, are natural enemies of the insect. Their suitability as biocontrol agents is now being evaluated. To maintain and propagate the fungi, CIAT has established a live collection (a "ceparium"), which also houses fungal isolates of potential use against cassava pests.

After developing methodologies to screen this collection for effectiveness against different life stages of spittlebugs, researchers confirmed that virulence varied significantly among spittlebug species. Field tests in contrasting ecoregions are now under way to determine just how entomopathogens might be effectively deployed under typical pasture conditions.

Brachiaria grass is a perennial and therefore a long-term crop. Replanting vast tracts of pastureland with new spittlebug-resistant varieties adapted to local soil and climate conditions will therefore be a long and expensive process. In the meantime our enhanced understanding of the bioecology of spittlebugs is supporting the development of new biocontrol options, pasture-management methods, and ways to best tailor these to the diverse ecoregions where this pest occurs. The solution will undoubtedly involve a complementary mix of these with enhanced host-plant resistance.

Tapping the wild side of rice

All traits considered, most wild plants are decidedly inferior to their bred counterparts. For example, *Oryza rufipogon*, a wild rice from Malaysia, has tiny, unappetizing seeds with dark hulls that shatter easily. It's the last thing rice farmers would want to sow in their fields.

Yet hybrids developed by CIAT over the past few years through repeated crossing of this wild plant with elite commercial rice continue to outyield the latter. "We've been able to show that wild rice species possess genes of great agronomic importance," says CIAT rice breeder César Martínez. "And we've been able to transfer some of them to cultivars."

CIAT has also been working with an African wild rice, *O. glaberrima*, which in many areas of West Africa is cultivated by farmers. It tolerates water stress, competes well with weeds, and resists rice blast and crinkling disease. As with *O. rufipogon*, CIAT breeders have crossed *O. glaberrima* with elite rice for evaluation.

Drawing on wild species like *O. rufipogon* and *O. glaberrima* is just one of several strategies CIAT is now using to enrich the rice gene pool at the disposal of rice breeders in Latin America. "The genetic base of rice in this region is very narrow," says virologist Lee Calvert, who leads CIAT's Rice Project. Certain varieties, like Fedearroz 50, have become extremely popular across the region, he adds.

The potential of wild and weedy species to boost the yields of related crops was first recognized in 1981. But such superior traits, often controlled by multiple genes called quantitative trait loci (QTLs), could not be directly seen in the scientific twilight of the wild plants' physical appearance and behavior. The lights were finally turned on in 1996 by researchers at Cornell University in the USA. They showed how molecular markers and genetic maps could be used to exploit wild-tomato genes for the benefit of commercial processing tomatoes. They went on to design a novel strategy called "advanced backcrossing QTL analysis," which CIAT now uses for rice improvement.

Our current research, in collaboration with Cornell, is funded by the US Department of Agriculture (USDA), the Rockefeller Foundation, and Colombia's Ministry of Agriculture and Rural Development. It is part of a larger, long-term international project in partnership with other Future Harvest centers and researchers in several Asian rice-producing countries.

Since the mid-1990s, we have been using conventional crossing of wild rice species with elite cultivars, in tandem with molecular marker technology, to transfer wild genes and track their inheritance. The research has allowed CIAT to simultaneously broaden the gene pool and improve elite rice varieties in Latin America for further development by national programs.

To date, a range of traits—not just disease resistance and yield but also nutritional value, grain quality, and cooking qualities—have been examined. However, the most advanced work focuses on yield and yield-related components like grain weight per plant.

Over several years we developed two experimental hybrid populations to examine the potential of *O. rufipogon* for enhancing cultivated rice (*O. sativa*). One population was bred for the rainfed uplands, the other for irrigated conditions. Upland fields account for 45 percent of Latin America's total rice area. About one-third of the upland rice is cultivated manually, usually by poor farmers.

Results of field trials, focusing on yield and related factors in the rice hybrids, were highly encouraging. For each study population, the hybrids outperformed the cultivated parent for most or all traits. What's more, molecular marker analysis showed strong and positive genetic contributions from the wild parent. The CIAT researchers also compared their list of contributing QTLs and their locations on chromosomes with findings from earlier studies by collaborators in China, South Korea, and other Asian countries.

Introgression of wild genes into elite lines is a strategy being pursued by all three Future Harvest centers with a rice mandate: the International Rice Research Institute (IRRI), the West Africa Rice Development Association (WARDA) and CIAT. Lee Calvert is enthusiastic about future advances through collaboration among the three centers and with other partners.

Wild species, Calvert stresses, can be used to improve rice root systems so that they tolerate drought better. This is especially important to poor farmers on small plots who don't have the necessary infrastructure to manage water. Nearly 90 percent of rice producers in Latin America are small farmers with 3 hectares or less, he notes. "We'll be focusing on traits like drought tolerance because the smaller, upland rice farmers need them."

Rebuilding El Salvador's granary through integrated management of whiteflies

With views of the Pacific Ocean, elegant mountain ridges, and irrigated fields, all punctuated by the silhouette of the Santa Ana volcano, western El Salvador presents a handsome landscape to its many visitors, among them CIAT's Francisco Morales. But as the plant virologist points out, the region's Valley of Zapotitán—the "granary" for the nearby national capital of San Salvador—is a land under siege by tiny invaders.

Morales, who coordinates the Tropical Whitefly Integrated Pest Management (TWF-IPM) Project, refers to the valley as one of Latin America's "hot spots." In recent years outbreaks of whiteflies and whitefly-transmitted begomoviruses have devastated fields of dry and snap beans, tomatoes, sweet and chili peppers, cucurbits, and other crops. Damage occurs mostly during the long dry season, when whitefly populations reach a peak.

Heavy and frequent pesticide application, says Morales, is self-defeating, because whiteflies develop resistance and the chemicals destroy their natural enemies. It is also a strategy that local producers can ill afford. In the Valley of Zapotitán, where 80 percent of farms are less than 3 hectares, many families are extremely poor.

One small-scale farmer Morales spoke with described the vicious circle he faces in growing snap beans: "I apply a mixture of methomyl, methamidophos, and imidacloprid every 3 days until harvest. But the plants turn yellow and produce small, distorted pods anyway." The disease is caused by bean golden yellow mosaic virus (BGYMV), transmitted by the whitefly *Bemisia tabaci*.

In collaboration with CIAT, El Salvador's National Center for Agricultural Technology (CENTA) has launched a project to reverse Zapotitán's trend of declining production. Three divisions of the Ministry of Agriculture, the University of El Salvador, the Latin American Technical University, and five farmer organizations also belong to the partnership.

Local farmers are learning that their frequent applications of synthetic pesticides can be successfully replaced by a combination of cheaper and less environmentally destructive control tactics. In the case of beans, the centerpiece of this integrated approach to pest and disease management is BGYMV-resistant varieties of the red-seeded type preferred in El Salvador and other Central American countries. "We've put 3 years into diagnostic work," says Morales. "We now know what control methods might work well in our pilot sites."

The work in El Salvador was funded initially by Danish International Development Assistance (Danida), the United States Department of Agriculture-Agricultural Research Service (USDA-ARS), and the United States Agency for International Development (USAID). Under a second phase of the Tropical Whitefly Project, this work is supported by the UK's Department for International Development (DFID) and the CGIAR's Participatory Research and Gender Analysis (PRGA) Program.

Beginning in 1971, irrigation systems were built in Zapotitán, and today they serve 60 percent of the valley's 3,000 hectares of prime agricultural land. Despite these development efforts, though, production of beans, tomatoes, and peppers has plummeted over the past decade. Horticultural crops have given way to less profitable sugarcane and maize. The shift has caused large seasonal fluctuations in local produce prices. In San Salvador's markets, for example, tomatoes recently sold for US$7.25 a box in November and for more than triple that in April.

Under the IPM project, Salvadoran researchers and farmers are testing a full package of pest-and-disease control tactics. The target crops are beans, tomatoes, peppers, and *loroco*, a local plant whose flower buds are eaten fresh, often on pizza, or used in aromatic sauces.

IPM components include the virus-resistant bean varieties, physical barriers to insects, minimal use of commercial synthetic insecticides, and substitution of less toxic products for whitefly management. Physical barriers include microtunnels—wire or plastic frames covered with netting. Now being tested as a way to protect tomatoes and peppers during their early growth stage, this option was shown to be successful at another hot spot site in Yucatan, Mexico, and in El Salvador it doubled the national average yield for tomatoes this year.

Loroco presents both economic opportunities and special pest-control challenges for Salvadoran producers. It is grown mostly by women as a backyard crop, both for home consumption and for extra income. Produce from half a *manzana* (0.35 hectares) can fetch up to US$5,000. But loroco is often attacked by whiteflies, as a direct pest, and by aphids, which also transmit viral diseases.

A vine native to El Salvador, loroco is cultivated using a system of poles and wires similar to those found in vineyards. One pest-control tactic being tried by the project is the use of household detergent to control the whiteflies, which tend to fly at or near ground level. But aphids, says Morales, require a different strategy because "they fly high like spy planes scanning for targets." His solution was to increase the height of support poles, add another layer of wires above the loroco plants, and cover the grid with palm leaves. This camouflages the crop, thwarting the aphids' reconnaissance behavior. And since loroco is a forest plant, it easily tolerates the resulting shade.

The technologies being offered to farmers have enormous potential for recovering large areas of prime agricultural land that are currently left idle during peak months of whitefly infestation. The challenge now is to adapt the new technologies, using participatory methods, to farmers' cropping systems and market opportunities.

Small agroenterprises get higher prices for black pepper and coffee

Recent applications of CIAT's participatory method for designing integrated agroenterprise projects (IAPs) support an emerging consensus: adding value to products before sale and understanding market chains better significantly boosts small-farmer incomes.

In Peru producers of black pepper who applied the method ended up with price gains ranging from 20 to 100 percent over prices paid to other farmers. And in Honduras a group of coffee farmers negotiated a 16 percent premium. While world prices have continued to fall since then, project participants were recently earning double for a kilogram of coffee what nonparticipants could get.

The IAP methodology is part of a wider CIAT strategy for promoting multiple rural business opportunities in defined geographical regions. This territorial approach has the advantage of building local skills that benefit not just the producers of a specific crop but also the wider community. And by operating within the context of the overall territorial economy rather than a single subsector, says CIAT agroenterprise specialist Mark Lundy, "we can promote a learning environment that links CIAT research with local development experience and demand."

A key assumption underlying CIAT's approach is that growing more food more efficiently, based on new technology, is not by itself enough to improve rural livelihoods. In some cases research-driven productivity increases, in the absence of new policies and other measures, have actually led to market saturation, lower farm-gate prices, and continuing poverty. The CIAT approach is thus participatory and market-driven—one in which farmers decide to produce what they can sell rather than sell what they can produce. The strategy stresses the creation of local capacity to identify and establish competitive enterprises that are environmentally and economically sustainable, add value to products, and generate added benefits for the community. Such spillovers include new jobs and better organizational skills.

The first step is to identify a local partner group interested in business development. This is typically a consortium of producers and NGOs, sometimes with public- and private-sector participation. The group constructs a biophysical, economic, and institutional profile of its territory and identifies market opportunities. Based on analysis of candidate products and commercial opportunities, some are selected for full-blown IAP development.

IAP design involves market chain analysis, with the participation of as many key players as possible: input suppliers, service providers, producers, processors, commercial agents, industrial consumers, wholesalers, retailers, and exporters. Among other things, this allows for identification of bottlenecks in the system—plant diseases or poor transport capacity, for example. In some instances the IAP will include a research component to rectify problems.

A permanent system for gathering market intelligence is also created. Project members or service providers systematically collect price and other information vital to commercial success. In addition, the availability of business support services—such as those that provide credit, technical assistance, and legal advice—is evaluated, gaps identified, and improvements designed.

At Pucallpa in the Peruvian Amazon, the IAP exercise showed farmers that the price they were getting for their black pepper was only a small fraction of the end-consumer price paid in the capital, Lima. Price differences in the market chain ranged from 600 to 1,000 percent. Based on this information, 45 small producers formed a private company, Piper S.A., and set their IAP in motion.

The farmers moved quickly to improve and standardize pepper grading and presentation. This differentiated their product from that of nonparticipants, leading to a 20 percent price premium in local markets. They also negotiated an agreement with an industrial buyer in the city of Huancayo, netting them a 58 percent increase over the local price for one batch of pepper and 30 percent for another. In other cases they were able to sell their product for more than double the local rate.

Imports from Ecuador led to a price drop in October 2001. Nevertheless, the farmers' initial success in improving and repositioning their product helped them set out a clear business vision for the future, says Lundy. They now want to buy a grinder and identify an industrial client in Lima, so they can sell a more finished product at a higher price.

Yorito, Honduras, is the hub of another "territory" in which CIAT is testing its IAP methodology. A group of 12 coffee farmers there negotiated a 16 percent price premium with an exporter, based on guarantees of high quality. Although falling world prices led the exporter to end the deal, another buyer stepped in with a comparable offer in late 2001. Producers participating in the IAP have been receiving double the price paid to nonparticipants.

That positive experience led a group of 45 producers, with the help of a local business development consortium, to begin the lengthy process of having their coffee certified as organically grown. In the meantime they have been negotiating to have their "transition" coffee bought by a cooperative at a premium price.

CIAT is now drawing on these and other Latin American experiences to fine-tune its IAP methodology. It is also examining ways to involve NGOs and private companies in using and adapting the methodology to multiply positive impact beyond the sites where it has so far been tested.

An Overview of CIAT

The International Center for Tropical Agriculture (CIAT) is a not-for-profit organization that conducts socially and environmentally progressive research aimed at reducing hunger and poverty and preserving natural resources in developing countries. CIAT is one of 16 food and environmental research centers working toward these goals around the world in partnership with farmers, scientists, and policy makers. Known as the Future Harvest centers, they are funded mainly by the 58 countries, private foundations, and international organizations that make up the Consultative Group on International Agricultural Research (CGIAR).

CIAT's donors

CIAT currently receives funds through the CGIAR or under specific projects from the countries and organizations listed below. We gratefully acknowledge their commitment and contributions.

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  Australian Agency for International Development (AusAID)
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Belgium
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Brazil
- Brazilian Agricultural Research Enterprise (Embrapa)

Canada
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Colombia
- Colombian Institute for the Development of Science and Technology (COLCIENCIAS)
- Ministry of Agriculture and Rural Development
- National Program for the Transfer of Agricultural Technology (PRONATTA)

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Our mission

To reduce hunger and poverty in the tropics through collaborative research that improves agricultural productivity and natural resource management.

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.

Agrobiodiversity and genetics
Conserving and Using Tropical Genetic Resources
Bean Improvement for the Tropics
Cassava Improvement for the Developing World
Rice Improvement for Latin America and the Caribbean
Multipurpose Tropical Grasses and Legumes
Tropical Fruits, a Delicious Way to Improve Well-being

Ecology and management of pests and diseases
Integrated Pest and Disease Management

Soil ecology and improvement
Overcoming Soil Degradation

Analysis of spatial information
Land Use in Latin America
Confronting Global Climate Change in Tropical Agriculture

Socioeconomic analysis
Impact of Agricultural Research

Rural innovation
Community Management of Watershed Resources in Hillsides
Participatory Research Approaches
Rural Agroenterprise Development
Information and Communications for Rural Communities

Crop and agroecosystem focus

Within the CGIAR, CIAT has a mandate to conduct 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. Increasingly, the Center also helps national programs and farmer groups find solutions to production problems encountered with other crops, such as tropical fruits, by applying research capacities developed through work on the mandate commodities.

In Latin America our integrated research on crops and natural resource management is organized largely on the basis of three agroecosystems: hillsides, forest margins, and savannas.

CIAT scientists also work to improve crops and natural resource management in midaltitude areas of eastern, central, and southern Africa and in upland areas of Southeast Asia.

Institutional links

CIAT builds ties with other institutions through research partnerships based on projects. Our expanding circle of partners includes other Future Harvest centers, national research institutes, universities, NGOs, 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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The Power of Perspective

Though just 6 years old, Lo Ya already bears on her tiny frame the heavy burdens of upland farm life in northern Laos. Her final chore on a recent afternoon was to fetch a load of rice straw for the family's water buffalo from neighbor Kama Zong, assuming, of course, he had some to spare.

Fortunately, Kama was able to oblige, because he feeds his own animals mostly with forage grasses and legumes that he grows in a nearby upland field. The plants were introduced several years ago by Lao researchers under a CIAT-coordinated forage project that has benefited thousands of farm families in seven Southeast Asian countries (see page 28). Kama also plays an active role in local participatory research aimed at finding better ways to maintain soil fertility in forage plots and to integrate these multipurpose plants into upland farming systems.

A lot depends on the outcomes of this work. Upland villages desperately need new sources of animal feed, so farmers can sustainably intensify the production of livestock and thus reinforce this central part of the social safety net.

Solutions That Cross Frontiers

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CIAT is one of 16 food and environmental research centers working toward these goals around the world in partnership with farmers, scientists, and policy makers. Known as the Future Harvest centers, they are funded mainly by the 58 countries, private foundations, and international organizations that make up the Consultative Group on International Agricultural Research (CGIAR).

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