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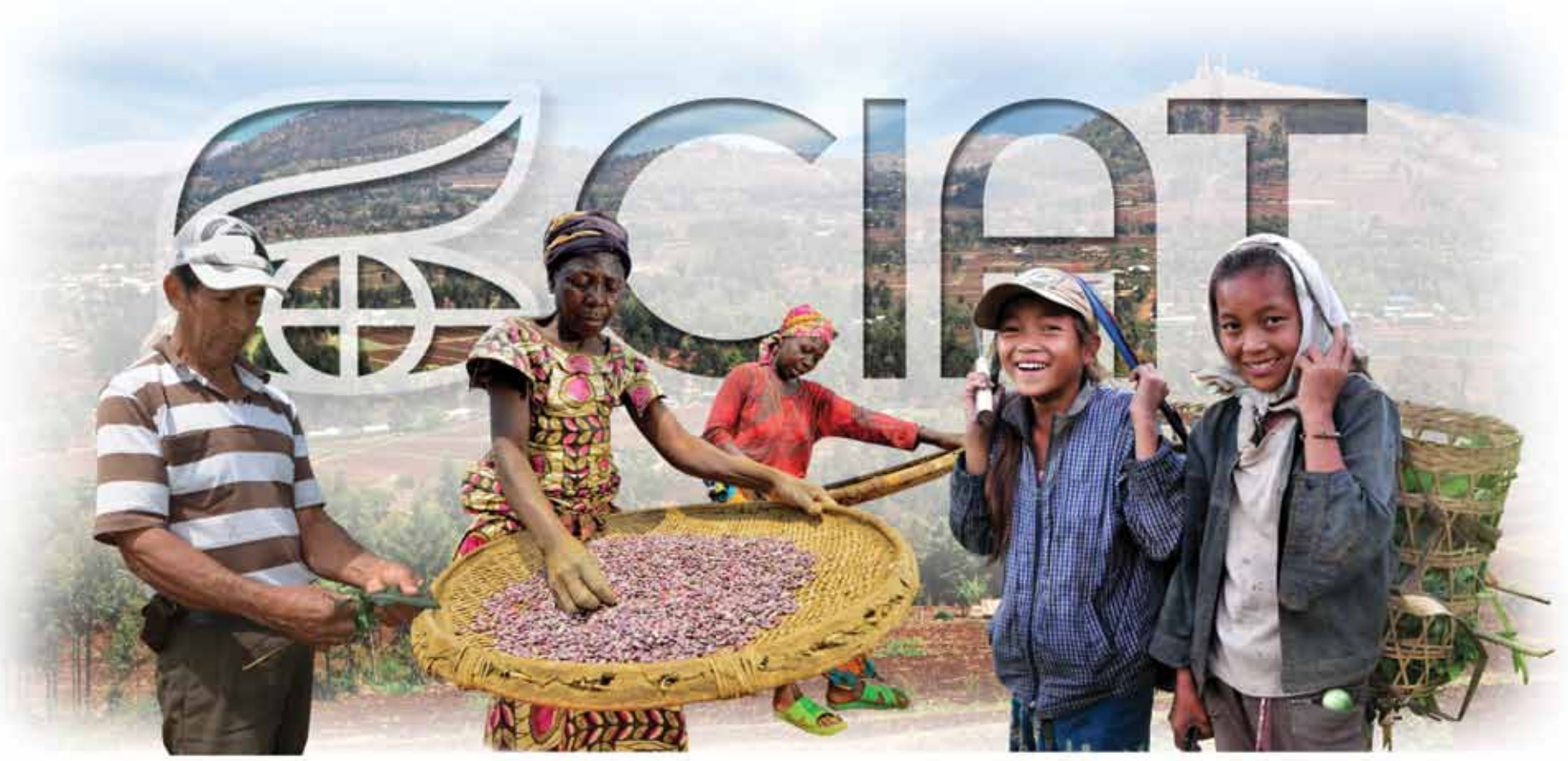
Building an Eco-Efficient Future



CIAT
International Center for Tropical Agriculture
*Since 1967 / **Science to cultivate change***

CIAT Annual Report
2013–2014

Planning for Collective Success

Message from the Board Chair and Director General

Over the last year, CIAT's collaborative research resulted in major achievements, which are delivering tangible benefits for tropical regions today, while also pointing the way to a better tomorrow. This annual report describes some of the most important gains, emphasizing how we and our partners apply advanced knowledge and tools to improve crops, soils, and policies for the good of poor consumers and farmers across the tropics and subtropics.

Leadership from within

Looking to the future, we prepared a new strategy in 2013 (see the summary on pages 4–7), which explains how our growing research team and networks will capitalize on past and current work to help make agriculture more eco-efficient in the years to come.

To meet the central development challenges of our time – hunger and malnutrition, poverty, environmental degradation, and climate change – depends not just on individual achievement but on collective success. To succeed together, we need an approach to institutional leadership that galvanizes commitment, fosters innovation, promotes the development of new capacities, and catalyzes change through strong collaborative ties and networks.

This is the kind of leadership we hope is evident in *CIAT Strategy 2014–2020*. It describes a wide range of innovative approaches through which the Center's research will contribute to the development goals of the CGIAR Consortium – the global science partnership of which CIAT is a member. Our contribution includes four new strategic initiatives (page 6–7) that address emerging challenges and opportunities through pioneering efforts that integrate CIAT's main research areas. These new initiatives have the potential to significantly influence future CGIAR research and expand its development impact.

Ties that bind

CIAT has focused in recent years on cultivating diverse collaborative arrangements, which are essential for building an eco-efficient future. The Center's strategic partnership with the Colombian Ministry of Agriculture and Rural Development, for example, has yielded valuable results, which better enable our host country's research organizations and producer associations to confront climate change (page 39) and achieve sustainable management of its vast savanna region (page 42).

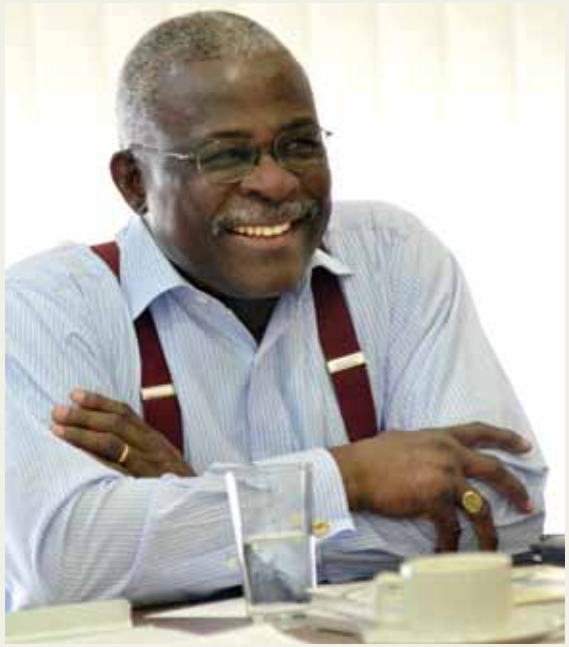
To derive similar benefits from other major partnerships, we signed an agreement to boost scientific exchanges with the Brazilian Agricultural Research Corporation (Embrapa) and also consolidated our cooperation with key institutions in eastern Africa, Peru (page 36), and Vietnam. In addition, CIAT staff engaged with a wide range of universities – especially in the Americas and Europe – aiming to unite our strengths with theirs in a concerted campaign to achieve global food security. Alongside these and other initiatives with national organizations, we also delivered on important commitments to the private sector (page 51) and international development agencies.

Vigorous engagement with our donors (see the complete list on page 50) resulted in support for major new projects. These include research to promote climate-smart farming and restore degraded land in Africa, strengthen agricultural value chains in Southeast Asia and Latin America, and develop climate-resilient beans for smallholder farmers across continents.

Visionary visitors

Three important visits to Center headquarters demonstrated particularly well how strong collaboration better enables us to address the most acute agricultural challenges of developing countries.

One was the Seventh Meeting of CGIAR's Independent Science and Partnership Council (ISPC), held in April 2013, which highlighted CIAT's close alignment with CGIAR's global research agenda. Council members heard progress reports from CGIAR leaders, interacted with the directors of the 16 CGIAR research programs, and learned about CIAT's work, which contributes importantly to 12 of these programs (page 53).



Kanayo Nwanze, President, International Fund for Agricultural Development.

In August, we were honored to receive Kanayo Nwanze, president of the International Fund for Agricultural Development (IFAD). He stressed the critical role of CIAT's research on crops, production systems, and policies in helping "transform subsistence agriculture into a high-performance sector of developing country economies."

The IFAD visit prompted, among other outcomes, a series of exchanges focused on providing new support for agricultural recovery in Haiti. These contacts culminated in the 4-day visit of a 25-member delegation from the country's Ministry of Agriculture, Natural Resources, and Rural Development to CIAT headquarters, where they identified opportunities for collaboration with the Center in technology development and capacity strengthening.

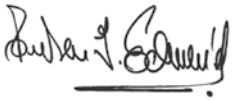
Be part of a global *minga*!

In many parts of Latin America, rural people have kept alive the indigenous tradition of convening community members to achieve a collective purpose – called *minga* in the Andean Region. This practice conveys pretty well the collaborative spirit of CIAT's new strategy, CGIAR science as a whole, and especially the CGIAR Research Program on Climate Change, Agriculture and Food Security (CCAFS), which CIAT leads (see page 8).

The strategy thoroughly commits us to a collective global effort to address major challenges through inclusive partnerships, resulting in tangible benefits for millions of poor people. To help gauge the effectiveness of CIAT's contributions, our strategy sets quantitative targets for strengthening food and nutrition security, creating new market links for smallholder farmers, and making agriculture more environmentally sustainable and climate smart.

We intend for the Center's new strategy to serve as an open invitation for all of our partners and donors to join us in the global *minga* to build an eco-efficient future.

Wanda Collins
Chair, Board of Trustees



Ruben G. Echeverría
Director General

Building an Eco-Efficient Future

CIAT Strategy 2014–2020

In pursuit of wider development impact, CIAT prepared a new strategy in 2013, which we briefly summarize here. Reaffirming eco-efficiency as a guiding principle of our research, the strategy commits us to reaching these targets by or before 2020:

- Enhanced food and nutrition security for more than 15 million poor consumers
- Improved market opportunities for at least 3 million rural poor
- Technologies for environmentally sustainable crop production in the hands of a million farmers
- Climate-smart policies established in 10 countries

Each country and rural community must build its own eco-efficient future. To that end, *CIAT Strategy 2014–2020* (http://ow.ly/ugcuV) offers not a detailed blueprint but a call to action on many fronts across the diverse panorama of tropical agriculture.

The new technologies, methods, and knowledge that we aim to deliver by or before 2020 will help farmers respond to growing pressures from powerful forces impacting on economies and agro-ecologies across the developing world. Foremost among these forces is population growth. Overall, it will slow markedly toward 2050, but populations in many developing countries will expand significantly, especially in cities, making food insecurity an increasingly urban phenomenon.

More intense competition between food and non-food uses of land and water could take a heavy toll on these and other natural resources. Climate change will further magnify agriculture's environmental challenge by diminishing the suitability of many tropical areas for the production of key staple crops.

Regional renovation

Major trends shaping tropical agriculture will unfold differently in each region where CIAT works, requiring carefully crafted responses.

In **Sub-Saharan Africa**, for example, agriculture will face a combination of high population growth, rapidly degrading farmland, and emerging climate change impacts. CIAT's strategic research on crops, soils, and policies will feed into major initiatives aimed at bolstering food and nutrition security, restoring landscapes to ecological health, and fostering economic growth, based on a sustainable and climate-smart agriculture.

For **Asia**, a key challenge will be to ensure that marginalized upland communities gain a greater share of the wealth created by rapid economic development. To this end, CIAT will work to put the cassava and livestock sectors on a more socially equitable and environmentally sound basis, while also helping curb land degradation, create more beneficial market links for farmers, and cope with the impacts of climate change.

Latin America and the Caribbean is a global grain basket and provider of environmental goods, with enormous potential for expanding food exports and putting the management of its natural resources on a sustainable footing. In addition to helping realize these possibilities, CIAT's research will focus on making major agricultural value chains more competitive in response to challenges and opportunities created by trade liberalization.

Upward spirals of sustainable growth

Since its inception in 1967, the Center has created a solid array of strengths in research and partnership. These encompass essentially every aspect of tropical agriculture – including the crop varieties that farmers grow, the production systems they manage, the agricultural landscapes they inhabit, the markets in which they participate, and the policies that influence their options and decisions. Moreover, in recent years, we have carefully engineered CIAT's research areas so as to project our strengths and achieve greater impact through CGIAR's wide array of global research programs (page 53).

CIAT's new strategy defines three objectives, which are central for creating upward spirals of sustainable growth:

1. Make affordable, high-quality food readily available to the rural and urban poor by boosting agricultural productivity and enhancing the nutritional quality of staple crops.
2. Promote rural income growth by making smallholder agriculture more competitive and market oriented through improvements in agricultural value chains.
3. Provide the means to make a more intensive and competitive agriculture both environmentally sustainable and climate smart.

Pillars of strength

The research that CIAT will conduct to achieve its objectives aims to put in place eight interlocking pillars of eco-efficient agriculture, which reinforce the wider CGIAR research agenda.

High-yielding, resilient crops – Improved seeds are a major leverage point for strengthening food security and making agriculture environmentally sustainable. For that reason, the Center will continue to focus a large

Alcides Hincapié, field worker in CIAT's Bean Program.

part of its research effort on the development of new bean, cassava, rice, and tropical forages germplasm that is high yielding and resilient in the face of multiple stresses, taking full advantage of recent advances in gene discovery and genomics.

Crop genetic resources – Crop landraces and wild relatives offer valuable genes for the development of new varieties that are resilient under stress and use resources efficently. CIAT proposes to create a state-of-the-art genebank that will distribute both physical seeds from the collections we safeguard as well as the related digital genetic information that is vital for unlocking their hidden production potential.

More nutritious food – Increasing the micronutrient content of crops by means of a breeding approach called biofortification has shown great promise for helping overcome malnutrition. CIAT will continue to develop and promote biofortified bean and cassava varieties that are agronomically competitive and more nutritious than varieties currently grown.

Sustainable intensification – Improved soil health is critical for optimal expression of crop genetic potential over the long term. To this end, CIAT research will better enable farmers to manage soil biology appropriately, make better choices about soil cover and crops, maintain balanced nutrient supplies, and maximize organic amendments, based on the use of new diagnostic techniques.

Restoration of degraded land – In recent years, major development agencies have taken up the call to rebuild agriculture's natural resource base. CIAT scientists will contribute by generating more and better soil information with national partners, by mapping soil functional properties (such as soil organic carbon), and by evaluating ecosystem health.

Enhanced ecosystem services – Rural landscapes perform a wide array of vital services, which include the provision of water and food supplies, maintenance of soil fertility, biodiversity conservation, and climate change mitigation. CIAT researchers will work closely with policymakers to create new institutional mechanisms, such as benefit sharing, that better protect these services.

Beneficial market links – Against a background of rapid modernization and globalization, smallholder agriculture has enormous potential to act as an engine of inclusive economic growth. CIAT will develop methods and tools, and conduct research on enabling policies that help build sustained and beneficial commercial relations between farmer organizations and buyers in diverse markets.

Climate-smart solutions – In response to the formidable challenge of climate change, CIAT has undertaken a major effort to develop and implement novel methods for generating information that can guide policies and decisions. This work includes the assessment of likely climate change impacts and of specific technological options and policy instruments, with the aim of informing national adaptation and mitigation plans.

Bridges to eco-efficiency

CIAT's new strategy calls for a set of forward-looking strategic initiatives that will boost the development impact of our work and open new avenues for future CGIAR research.

Tropical forages add up to LivestockPlus – Boosting livestock productivity is critical for overcoming malnutrition and poverty in developing countries. But how can we achieve this growth without also accelerating land degradation and raising the livestock sector's already large greenhouse gas emissions?

CIAT scientists are responding to this challenge through an initiative called LivestockPlus. It builds on growing evidence that improved forage-based livestock feeding systems can lower emissions and store large amounts of atmospheric carbon deep in the soil. Through vigorous development and promotion of such systems, the initiative will help realize the environmental benefits of forages on a large

scale, while also exploiting their demonstrated capacity to raise milk and meat production.

Sustainable food systems for an urbanizing world – Rapid urbanization in the developing world is driving profound shifts in human diets, which are worsening nutritional problems while also leading to greater food waste in production and distribution.

To help put evolving food systems on a sustainable path, CIAT will embark on research aimed at gaining a better grasp of both the urban as well as rural dimensions of agricultural value chains. New knowledge resulting from this work will better inform crop improvement strategies as well as efforts to reduce food waste, boost the efficiency of key value chains, and identify new opportunities for value addition.

Minding the yield gaps – Large gaps between farmers' current crop yields and those that are economically and ecologically feasible offer key opportunities for sustainable intensification of agriculture. While recent years have seen much progress in determining where and how large the yield gaps are, not enough is known about their causes to ensure that efforts to reduce them will be effective.

CIAT is well prepared to address this challenge through research aimed at defining biophysical constraints at a high level of spatial resolution, while also gauging the influence of socio-economic factors, such as market access and gender disparities. On this basis, Center scientists and their national partners will use "big data" approaches to develop site-specific recommendations for improved crop management.

Ecosystem health for human well-being – A new development paradigm is emerging, in which better ecosystem services (such as the provision of water, conservation of biodiversity, and climate change mitigation) are viewed both as an environmental imperative and as a key requirement for enhancing livelihoods in rural areas and forests.

Through interdisciplinary research with a wide array of national and civil society partners, CIAT will focus on identifying new opportunities to translate improved ecosystem health into concrete benefits for rural people, including greater dietary diversity and new sources of income.

Big data

CIAT's work in diverse research areas has given rise to a formidable capacity for data collection, management, and analysis, including an ability to integrate different types of data across agricultural disciplines. New science and technology will give "big data" an even more prominent role in CIAT's future research, with a sharp focus on boosting and measuring development impact.

Farmer growing improved forages to intensify livestock production in Vietnam's central highlands.

Climate Smart and Down to Earth

CGIAR Research Program on Climate Change, Agriculture and Food Security (CCAFS)

CIAT is very pleased with the performance of CCAFS over the last year, which saw significant gains at every level – from farmers' fields to national policy arenas. Through strong partnerships and adept use of new tools and information, the program helped bring climate-smart practices within the reach of rural people across the developing world, as reported in the following highlights. Women are playing a central role in this transformation because of the concerted efforts CCAFS has made to mainstream gender perspectives throughout its work.

Big Facts: Where science meets art

What impact will a changing climate have on the food we grow and eat? How do our diets contribute to climate change? And how can we make farming climate smart? To get the facts on intricate links between climate change, agriculture, and food security, see our newly redesigned Big Facts site. It features more than 100 stunning infographics, which illustrate the most recent and accurate information. The open-access site is carefully curated, covering all the big issues and referencing only facts that come from credible sources and are supported by solid evidence.

Unlike other reports or websites, which might reference peer-reviewed articles, the Big Facts site is itself peer reviewed, adding a critical feedback loop and quality check. We welcome you to download and use the infographics in your reports and presentations, and to contact us if you have more up-to-date data.
http://ccafs.cgiar.org/bigfacts2014/

Climate innovations in West Africa

In July 2013, CCAFS scientists and partners travelled to Ghana to participate in Africa Agriculture Science Week, which brought together researchers, policymakers, and farmer representatives to share experiences and solutions relevant to Africa's food security challenge. The event provided an excellent forum for demonstrating how CCAFS is helping make agriculture more resilient in the face of climate change through research, partnerships, and capacity building.

Activities included a well-attended side event titled "Climate-Smart Villages in Africa: Opportunities for Farmers and Communities" and the widely publicized launch of a new report prepared by the International Water Management Institute (IWMI) on climate change in West Africa's Volta River Basin and its implications for farming and food security in the region.
http://ccafs.cgiar.org/round-what-we-did-africa-agriculture-science-week

Local action plus global vision

What happens when global thought leaders on issues like hunger and malnutrition meet with experts working at the frontlines of climate change in developing countries? Just such an encounter, held in April 2013 in Dublin, Ireland, has helped bring lofty theories down to earth and infuse discussions of rights, risks, knowledge,

Al Gore, former vice president of the USA, stressed climate risks for farmers at the Dublin conference on hunger, nutrition, and climate justice.

and empowerment with inspiring examples from around the world.

Organized by CCAFS, Irish Aid, the Mary Robinson Foundation - Climate Justice, and World Food Programme, the event featured thought-provoking discussions with farmers, youth, community organizers, and leading authorities, including Irish President Michael Higgins, former US vice president Al Gore, and Frank Rijsberman, chief executive officer of the CGIAR Consortium. It also drew attention to the work of CCAFS, particularly on climate-smart villages in Kenya and climate services for smallholder farmers in Senegal.
http://ccafs.cgiar.org/blog/report-back-dublin-conference-hunger-nutrition-and-climate-justice

Forests and farms: Better together in the fight against climate change

Agriculture and forestry were hot topics at a major event held alongside the United Nations Climate Change Conference in Poland during November 2013. Building on the experience of five Agriculture Days and six Forest Days, the first Global Landscapes Forum brought together the agriculture and forestry communities under one roof, with one agenda and a shared commitment to addressing global food security in the face of climate change.

The central objective of the Forum, organized by the Center for International Forestry Research (CIFOR) and CCAFS, was to design a new framework for creating sustainable landscapes, which can provide livelihoods for billions of people, while still preserving forests and other ecosystems. The event attracted more than 2,000 participants as well as 2,500 online viewers. Speakers included Marcin Korolec, Poland's environment minister; Rachel Kyte, World Bank vice president and chair of the CGIAR Fund Council; Agnes Kalibata, Rwanda's agriculture minister; and Ville Niinistö, Finland's environment minister.

Spotlight on climate-smart farming

In December 2013, Rachel Kyte, World Bank vice president and chair of the CGIAR Fund Council, visited a climate-smart village in Nyando, Kenya. One farmer's account of how he is adapting his production to climate change while reducing greenhouse gas emissions reinforced the message that climate-smart agriculture can work for smallholder farmers. Kyte carried this message to the Global Landscapes Forum, urging action in Africa and around the world to curb the devastating impacts of climate change.
http://ccafs.cgiar.org/blog/smart-farming-yields-fruit-nyando
http://ccafs.cgiar.org/blog/climate-warrior-urges-collective-action-farmers-now

Tackling climate change drivers in Latin America

CCAFS Latin America focused in 2013 on raising awareness among key institutions of the regional program's potential role as a partner in making agriculture climate smart. The program has outlined a new strategy for tackling drivers of food insecurity and vulnerability to climate change, using approaches such as prioritization toolkits and socio-economic scenarios.

Scaling out South Asia's climate-smart villages

Climate-smart villages are places where researchers and farmers come together to identify solutions (such as climate information services and improved production technologies) that are suited to local conditions. In South Asia, various organizations have recognized the value

of this model and are starting to replicate it. Practical Action Consulting in Nepal, for example, won a grant of US$1.5 million from the International Finance Corporation for this purpose. The project includes more than 15,000 farmers, with CCAFS giving technical support.

South-South exchange on climate information for smallholder farmers

In the Kaffrine region of Senegal, CCAFS and the country's National Meteorological Agency are working to provide seasonal agro-climate forecasts to smallholder farmers. In a novel example of South-South cooperation, CCAFS organized an exchange visit to Senegal for a delegation from Latin America that included researchers, meteorology experts, farmer leaders, and government representatives, with a focus on lessons learned in developing and disseminating climate forecasts.
http://ccafs.cgiar.org/blog/generating-climate-conscience-through-south-south-learning
http://ccafs.cgiar.org/blog/when-colombia-met-senegal-photostory

A South-South exchange visit built productive new ties between Latin America and Senegal.

Livelihood diversification for food-secure households in East Africa

Helping rural households diversify their livelihood options is a promising approach for strengthening food security and raising incomes. To this end, farmers in western Kenya are learning about the benefits of mixing the production of trees, crops, and improved livestock breeds, with support from CCAFS and its local partners.
http://ccafs.cgiar.org/blog/smart-farming-yields-fruit-nyando

Crop diversification in Kenya to raise incomes and strengthen food security.

Policy options to counter climate change

A book series developed by the International Food Policy Research Institute (IFPRI) and various partners, and funded partly by CCAFS explores weather-based scenarios for climate change impacts on agriculture and food security in East, West, and Southern Africa. Targeting national governments and regional agencies, the series also describes a variety of policy options for countering these impacts.
http://ccafs.cgiar.org/research-highlight/based-what-we-know-can-kenya-plan-its-climate-future

Strengthening capacity for climate change research

In 2012, the Climate, Food and Farming (CLIFF) Network awarded its first grants to eight doctoral students working on climate change and agriculture in developing countries. By 2013, the CLIFF network had grown to a total of 27 students investigating diverse issues at five CGIAR centers. The students have published articles in peer-reviewed journals, made valuable contacts, and shared their research results, for example, with farmers in Indonesia, project managers at NGOs like Oxfam International, and local government in China.
http://ccafs.cgiar.org/climate-food-and-farming-network
http://ccafs.cgiar.org/blog/investing-next-generation-climate-and-agriculture-scientists

Future climate scenarios for Southeast Asia

Planning on the basis of future scenarios with policymakers, researchers, and representatives of civil society and the private sector is an important part of CCAFS's work. This is why the program's Scenarios Team, together with the Food and Agriculture Organization of the United

Exploring future scenarios for food security, environments, and livelihoods in Southeast Asia.

Nations (FAO) and the World Conservation Monitoring Centre of the UN Environment Programme organized the workshop "Scenarios for Future Food Security, Environments, and Livelihoods in Southeast Asia" in November 2013. The idea was to explore future changes in the region's climate and socio-economic conditions and their implications for agriculture and food security as well as future policy responses based on various scenarios for 2050.
http://ccafs.cgiar.org/es/blog/decision-makers-debate-climate-threats-southeast-asia

Gender research and impact pathways

A 2-day workshop on gender training and strategies held in Kenya during October 2013 brought together the newly established Network of Gender and Climate Change Scientists from all five of the regions where CCAFS works: East and West Africa, South and Southeast Asia, and Latin America. Focused on best practices in gender and climate change research, the event enabled participants to develop gender-specific impact pathways for each region.
http://ccafs.cgiar.org/blog/challenging-gender-assumptions-within-farming-and-climate-change-research

Farmer empowerment through entertainment in Kenya

Shamba Shape-Up is an East African TV show designed to help farmers increase their crop and livestock production sustainably. The CCAFS Linking Knowledge to Action Team supports the program by providing information on climate change and climate-smart practices that can be communicated to farmers. With an audience of 11 million viewers, the program shows how innovative partnerships can link farmers' concerns with research through social learning.
http://ccafs.cgiar.org/blog/kenyan-farmers-use-climate-entertainment-empowerment

Fun and games with global cropland maps

A new game called Cropland Capture has resulted from collaboration between the CCAFS Data and Tools Team and the Geo-Wiki Project at the International Institute for Applied Systems Analysis. The game helps scientists identify available cropland by examining Google Earth images online or via smartphone. The information that players provide enables the Geo-wiki team to improve their map of global cropland for uses such as identifying major yield gaps.
www.ccafs.cgiar.org/blog/play-new-geo-wiki-game-cropland-capture

Scaling up low-emissions agriculture

In 2013, CCAFS published a gender strategy aimed at ensuring that efforts to mitigate climate change benefit poor women tangibly. Now, it is being applied to analyze three action research projects, in which women and men are testing innovative approaches to low-emissions agriculture. In Bangladesh, for example, university partners are working with agricultural extension to scale out an approach in which farmers use video to learn about vermicomposting and soil carbon storage.
http://ccafs.cgiar.org/new-paper-outlines-gender-strategy-pro-poor-mitigation-research
http://www.prolinnova.net/gender

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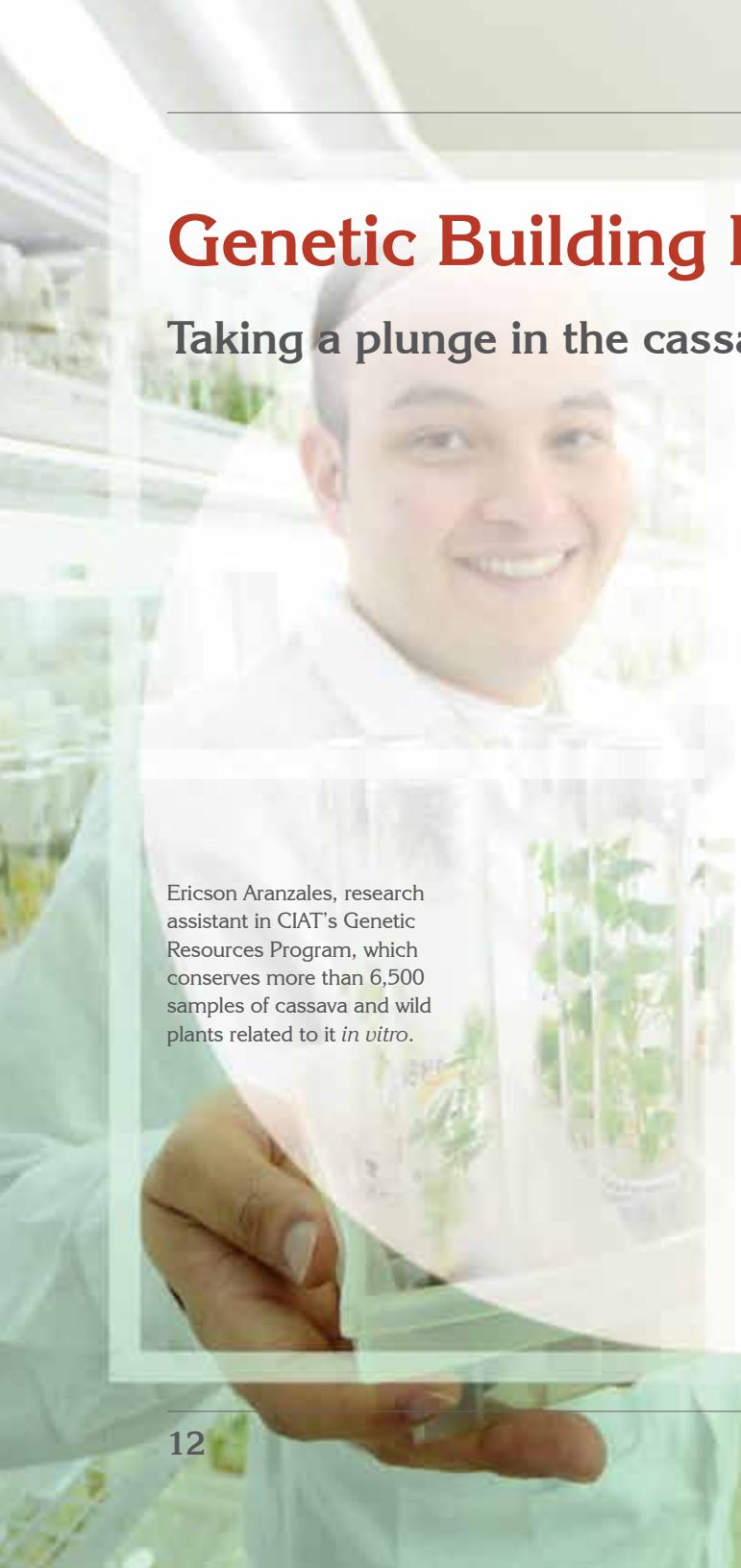
Genetic Building Blocks

Taking a plunge in the cassava genome



Ericson Aranzales, research assistant in CIAT's Genetic Resources Program, which conserves more than 6,500 samples of cassava and wild plants related to it *in vitro*.

CIAT molecular biologists and their partners are "swimming" in a river of data – the result of recent work on genome sequencing of hundreds of cassava varieties. The fact that the scientists are swimming and not drowning in the data is due in no small measure to recent advances in the field of bioinformatics (see page 13).

By early 2014, genome sequencing had been completed for 1,255 cassava varieties. From the immense body of resulting data, CIAT researchers are using advanced bioinformatics tools to derive new insights into the crop's origins, domestication, and diversity. The ultimate aim of this work – part of a larger effort by the CGIAR Research Program on Roots, Tubers and Bananas – is to channel upstream genomics research into genetic improvement, so that it can deliver more benefits downstream for cassava producers and processors.

Controversial origins

Cassava is the fourth most important source of calories in the human diet across the tropics. So, why is its past so important for the scientists whose job is to address current and future challenges, like increased disease and pest pressures?

Starting with the domestication of cassava around 8,000 years ago, human selection for specific traits in different geographical niches gave rise to a wide variety of landraces, which collectively show a distinct population genetic structure, explained CIAT molecular biologist Luis Augusto Becerra. "A better grasp of how and where domestication took place can tell us a lot about the genetic diversity that resulted from this process. Understanding the structure of cassava's diversity in relation to its wild ancestors is vital for using targeted molecular breeding to develop traits that enhance crop resilience."

The origins and evolution of cassava have been hotly debated since at least 40 years ago, when researchers hypothesized that the crop derived from two different wild ancestors in two distinct regions – Mesoamerica and South America. Subsequent work has reached contradictory conclusions, with some researchers suggesting that cassava was first domesticated around the southern rim of the Amazon River Basin and others arguing that it appeared first in Mesoamerica and then spread to South America.

Continued on page 14

Goodbye bottleneck

CIAT's bioinformatics team has devised a new software tool that helps molecular geneticists circumvent a major cost bottleneck in the analysis of genomic data. Such analysis is critical for exploring genetic diversity and putting it to better use through gene discovery or the development of molecular markers that can speed crop improvement.

Until now, even the most adept geneticist has needed to have a skilled specialist at her or his elbow when using new analytical tools to navigate the huge amounts of data generated with advanced sequencing technologies. But apparently, CIAT's bioinformatics experts aren't much concerned about working themselves out of a job.

Their new tool – dubbed the Next-Generation Sequencing Eclipse Plug-in (NGSEP) – offers a fast, accurate, and user-friendly way to analyze data from high-throughput sequencing. In fact, it proved essential for creating the bioinformatics pipeline used to detect differences between sequenced samples and the reference genome in the cassava population genetics study described on page 12.

Moreover, as reported in the journal *Nucleic Acids Research*, NGSEP has shown "superior accuracy and efficiency, compared with currently available packages," when used to analyze sequencing data from research on yeast, rice, and humans. Based on these results, the authors confidently suggest that "NGSEP will become a strong support tool to empower the analysis of sequencing data in a wide range of research projects on different species."

Analyzing data generated through cassava genome sequencing.

Contact:
Jorge Duitama (j.duitama@cgiar.org)
Bioinformatics Specialist, Agrobiodiversity Research Area

New currents in crop improvement

New research at CIAT, using "next-generation RAD sequencing" (the latest approach to large-scale or "high-throughput" genome sequencing), provides strong molecular evidence that cassava was domesticated in central Brazil. It further suggests that varieties from the crop's primeval population then spread north and south.

The results of clustering analysis indicate that this process gave rise to five relatively well-defined subpopulations. Three of them are spread across large areas of South America: the Chaco region, Amazon River Basin, and Brazilian coast. The others are concentrated in smaller areas of two zones: the Andean Region and the Caribbean coast of Mesoamerica.

"Each of the subpopulations we identified harbors genetic diversity for traits developed in places where cassava was adapted to human needs and environmental conditions," said Becerra. "Our challenge now is to identify links between phenotypes possessing useful traits and the underlying genetic structure, so we can make smarter use of cassava's global genetic diversity in crop improvement."

"This new study illustrates extremely well how fast crop improvement at CIAT is moving toward genomics-based precision breeding, in line with the Center's new strategy," said Joe Tohme, director of the Center's Agrobiodiversity Research Area.

For cassava, the shift began in 2012 with a major new initiative to conduct next-generation RAD sequencing for all of the approximately 6,000 varieties conserved in the CIAT genebank. This collection likely represents most of the crop's global genetic diversity. Jointly coordinated by CIAT and the Beijing Genomics Institute, the sequencing initiative garnered support from public and private sources in China and Japan.

A bioinformatics pipeline

Once next-generation RAD sequencing was underway, CIAT researchers next turned their attention to building a "bioinformatics pipeline." This refers to the combination of software tools and procedures required for managing efficiently massive amounts of sequencing data.

Using the pipeline involved, first, the selection of 292 cassava landraces and experimental varieties plus 54 samples of wild species related to the crop. These constitute a geographically representative sample of the 1,255 genotypes from CIAT's cassava collection that have been sequenced so far. Researchers then genetically mapped the whole sample of genotypes to align the sequenced DNA fragments (or "sequence reads") with a cassava "reference genome" – a sort of first-draft genome, which US scientists had completed in 2009.

The next steps included "data filtering" and "SNP and genotype calling," procedures that measure variation among the sequence reads. With the resulting data, CIAT scientists identified large numbers of SNPs (single-nucleotide polymorphisms), which can be used for marker-assisted breeding, gene mapping, and the kind of population genetics analysis described above. The sequencing data also enabled our researchers to identify a core set of the "most informative SNPs," which permit rapid and accurate identification of cassava samples through a process called DNA "fingerprinting" or "barcoding."

"In addition to facilitating crop improvement, the SNPs can help advance our aim of building a digital genomic inventory of CIAT's entire collection of cassava genetic resources," said Tohme. "This is essential for realizing our aim of creating a novel genebank, which shares not only seed but the information that is vital for unlocking its potential.

Contact:

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Molecular Biologist, Agrobiodiversity Research Area

In search of Nike beans

Every 4 years, experts from around the world gather for a meeting of the InterDrought Consortium, which you might think of as a kind of drought Olympics. The metaphor seems especially apt when you consider that Olympia, the site of the original games in ancient Greece, is a pretty dry place.

Instead of competing with one another and giving out medals, though, InterDrought participants talk about challenges and progress in alleviating an age-old scourge of food production, which is getting much worse now as a result of climate change. In the 2013 conference – held at Perth, Australia (another dry place) – Steve Beebe, who captains the CIAT's bean research team, carried the flag for this world-class, nutritionally rich grain legume.

An excellent track record

In their efforts to beat drought, CIAT's bean scientists and their partners have scored a number of major victories in recent years. Two drought-tolerant bean varieties were released recently in Rwanda and three in Malawi (following the release of such a variety in Nicaragua several years ago), while others have been proposed for release in Ethiopia and Kenya.

But at the meeting in Perth, Beebe suggested that recent, hard-won gains are not enough. A definitive triumph over drought in tropical bean crops requires redoubled efforts to deal with the complex interactions between stresses.

"According to recent on-farm experience in Ethiopia and Nicaragua," Beebe said, "low soil fertility diminishes the expression of drought tolerance, so we need to focus on combining tolerance to both these stresses plus other key traits."

An estimated 80% of bean production in Central Africa is subject to soil phosphorus deficiency, while for Eastern Africa, the figure is 65%. That's why African colleagues attending the InterDrought meeting showed a keen interest in Beebe's message. Modeling studies suggest that in Africa and other regions where infertile soils are common (and farmers can't afford to apply much fertilizer), increased drought resulting from climate change will have disastrous effects on bean yields.

Training for the biathlon

Part of what makes the common bean less resilient than other staple foods under tough conditions is what Beebe called its "privileged evolutionary background." The wild ancestor of bean originated in a mid-altitude forest environment of tropical America that is characterized by moderate temperatures and organic soils rich in nutrients.

But by tapping the rich genetic diversity of beans, CIAT scientists have succeeded in identifying and using certain traits in the roots and shoots that contribute to drought tolerance. This accounts for the breeding successes presented at the InterDrought Conference. At the same time, our scientists have developed bean lines that perform well under low soil phosphorus.

Building on these and other recent advances, CIAT researchers have helped devise a strategy for developing tolerance to multiple physical stresses in beans and other grain legumes, like soybean. They are pursuing this strategy through the CGIAR Research Program on Grain Legumes, which offers the opportunity to compare and share successful approaches across crops.

The new strategy combines a variety of innovative techniques. One involves genomics-based breeding, guided by a thorough understanding of adaptive mechanisms and their genetic basis. Another consists of crossing common bean with related species adapted to desert conditions. The scientists aim to win what amounts to a plant genetic biathlon – finding ways to get the upper hand on drought and at the same time low soil phosphorus.

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Rwandan farmer Olive Nakure.

Bean impacts: Making sense of 16%

A recent formal assessment of the impacts of improved bean varieties amply demonstrates the development value of these products, which are developed and promoted through the CIAT-coordinated Pan-Africa Bean Research Alliance (PABRA) with support from the governments of Canada and Switzerland. The assessment forms part of a series of studies on various crops, known as the Diffusion and Impact of Improved Varieties in Africa (DIIVA).

Like all impact reports, the bean study provides a lot of cold, hard statistics – some of them excruciatingly precise – but the gist is essentially this: Years of breeding and dissemination of improved bean varieties have resulted in seemingly small but actually quite significant impacts in combating hunger, especially in Rwanda, where improved bean varieties were linked to a 16% reduction in food insecurity.

Measuring bean impact is not a math test, in which a score of 16% might result in your prompt ejection from class. Being able to pin a 16% reduction in food insecurity to a single variable – improved beans – is actually a sign of a pretty successful intervention. In fact, the study report describes this particular impact as "substantial," meaning that for about 500,000 people, the hunger months – those in which food supplies are lowest – have completely vanished thanks to improved beans.

Somewhere in those statistics is the ear-to-ear grin of farmer Jean Damascene Bizimana and his star-performing climbing beans in Rwanda and the industrious resilience of Olive Nakure, who with the money from her improved beans, invested in a big sewing machine and trained in Uganda for 2 months to learn how to use it. In the field, the cold stats spring to life.

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Rwandan farmer Jean Damascene Bizimana.

Getting to the root of drought tolerance in rice

Vietnamese farmers like Pham Thi Thai urgently need rice varieties with tolerance to drought and other stresses.

Crop scientists have discovered a gene in rice that could significantly improve its tolerance to drought. The *DEEPER ROOTING 1* (*DRO1*) gene makes the roots of rice plants grow downwards instead of outwards, enabling them to reach water held deeper in the soil. This means that even under conditions of extreme water stress, plants with *DRO1* can continue to grow and produce grain.

The findings were published in *Nature Genetics* by an international team[1] that is led by Japan's National Institute of Agrobiological Sciences (NIAS) and includes scientists from CIAT. This work contributes to the CGIAR Research Program on Rice, known as the Global Rice Science Partnership (GRiSP).

A better way to deal with stress

Rice feeds around half of the global population, and production must increase by around 40% in order to meet expected demand in 2050. Yet, each year drought affects some 23 million hectares of rainfed rice in South and Southeast Asia alone. In parts of India, water scarcity can cut rice yields by more than a third, equal to losses of US$800 million annually. Water scarcity is expected to increase as a result of climate change together with increased demand for water for industrial and urban use.

[1] The research team includes scientists from NIAS, CIAT, the Graduate School of Bioagricultural Sciences at Japan's Nagoya University, and the National Institute of Crop Science in Japan.

Scientists crossbred the high-yielding but short-rooted and drought-prone commercial rice variety, IR64, with a deep-rooting upland rice variety from the Philippines, called Kinandang Patong. While IR64 already contains the *DRO1* gene, the plant cannot produce the necessary proteins that enable the gene to function effectively. Through conventional breeding techniques, the scientists combined the high yields of IR64 with the fully functional *DRO1* gene in Kinandang Patong.

The roots of the resulting plants were able to reach more than twice as deep as those of IR64. When tested under simulated conditions of moderate drought, IR64 yields slumped by almost 60%, while the crossbreeds suffered only a 10% yield loss. Under extreme drought, IR64 completely failed, but the new rice plants continued to produce grain – about 30% of the yield of unstressed rice plants growing in normal conditions.

The scientists also found that the *DRO1* gene appears to only change the angle of root growth and slightly increase the length of the root tips rather than the overall root density, meaning energy is not diverted away from the production of grain.

Underground revolution

"It's a very exciting discovery," said Manabu Ishitani, the CIAT molecular biologist who was part of the research team. "We've known for some time that deeper roots can buy farmers extra time during periods of drought, but until now we haven't known which gene in rice is responsible for root architecture or how to control it. Since water availability will soon become the most limiting factor in rice production around the world, improving the crop's water-use efficiency is essential."

Ishitani hopes that deeper roots might also be able to access additional nutrients deep in the soil, enabling farmers to use fertilizer more efficiently.

Masa Iwanaga, president of the Japan International Research Center for Agricultural Science (JIRCAS), welcomed the new findings: "The Green Revolution of the 1960s and 1970s was made possible by the introduction of short-stature, shallow-rooted cereals capable of producing high yields. The *DRO1* gene confers on crops a deeper root system architecture, which will surely mark the start of an 'underground revolution' in crop improvement."

Joe Tohme, director of CIAT's Agrobiodiversity Research Area, said: "The discovery of *DRO1* is a significant breakthrough in research aimed at adapting food crops to water stress, especially as farmers around the world begin to feel the pressure of climate change on water availability. Technologies like this really can help boost production of one of the world's most important crops."

NIAS is evaluating trials of the new rice variety in lowland, rainfed conditions with scientists at the International Rice Research Institute (IRRI) in the Philippines.

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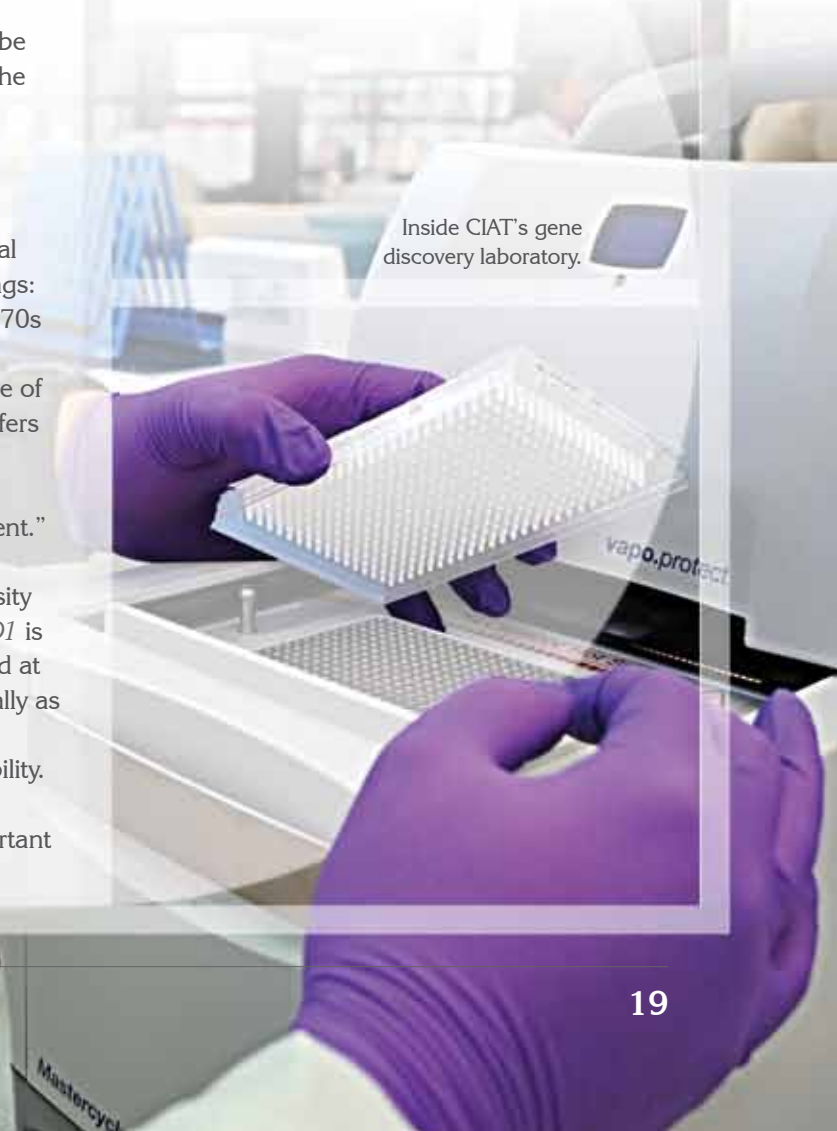
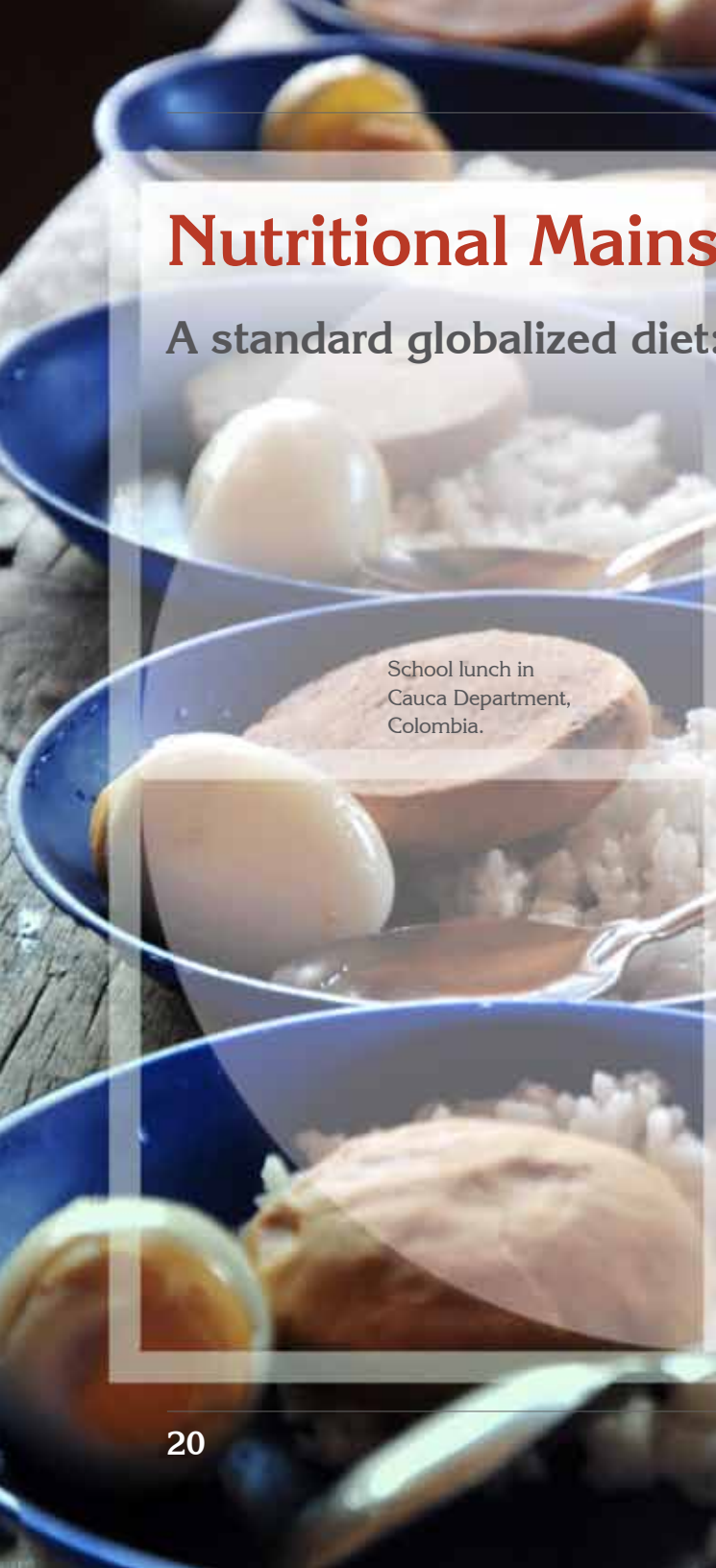


Inside CIAT's gene discovery laboratory.

Nutritional Mainstays

A standard globalized diet: Risks and remedies



School lunch in Cauca Department, Colombia.

A comprehensive new study of global food supplies, carried out by CIAT and several partners, confirms what experts have long suspected: Over the last 5 decades, human diets around the world have grown ever more similar – by a global average of 36% – and the trend shows no signs of abating.

"More people consume more calories, protein, and fat and rely increasingly on a short list of major food crops," said lead author Colin Khoury, who is a specialist in plant genetic resources conservation at CIAT. "Our reliance on these foods, which are critical for combating hunger, obligates us to bolster their nutritional quality, as consumption of other nutritious grains and vegetables declines."

Winners and losers

The new study, published in the *Proceedings of the National Academy of Sciences of the United States of America*, reveals that the crops now predominant in diets around the world include several that were already quite important a half-century ago – such as wheat, rice, maize and potato. But the emerging "standard global food supply" described by the study also consists of energy-dense foods that have risen to global prominence more recently, like soybean, sunflower oil, and palm oil.

In contrast, many crops of considerable regional importance – including cereals like sorghum, millets, and rye, as well as root crops such as sweet potato, cassava, and yam – have lost ground globally. Many other locally significant grain and vegetable crops – for which globally comparable data are not available – have suffered the same fate.

Massive media coverage of the study worldwide contributed to one of its key aims, which was to foster public awareness of the need for healthier diets, based on better decisions about what and how much we eat, and for concerted efforts to reduce the vulnerability of global food supplies through skilled use of plant genetic diversity.

Drivers and dangers

The researchers warn that the increasing homogeneity of global food supplies may accelerate the worldwide rise in obesity, heart disease, and diabetes. These diseases, strongly affected by dietary change, have become major health problems, even in countries that have yet to overcome problems of food availability.

"Another danger of a more homogeneous global food basket is that it makes agriculture more vulnerable to major threats like drought, insect

pests, and diseases, which are likely to become worse in many parts of the world as a result of climate change," said Luigi Guarino, a study co-author and senior scientist at the Global Crop Diversity Trust.

The dietary changes documented in the study are driven by powerful social and economic forces. Rising incomes in developing countries, for example, have enabled more consumers to include larger quantities of animal products, oils, and sugars in their diets. Moreover, urbanization in these countries has encouraged greater consumption of processed and fast foods. Related developments, including trade liberalization, improved commodity transport, multinational food industries, and food safety standardization have further reinforced these trends.

Fostering diversity

Relying on data from the Food and Agriculture Organization of the United Nations (FAO), the study encompassed more than 50 crops and over 150 countries (accounting for 98% of the world's population) during the period 1961–2009. In addition to CIAT and the Global Crop Diversity Trust, it involved researchers from Wageningen University in the Netherlands and the University of British Columbia in Canada.

The authors emphasize various actions that are needed to foster diversity in food production and consumption – two of which CIAT is actively pursuing. As illustrated by other stories in this annual report (see pages 12, 15, 18, and 25), the Center is strengthening efforts to conserve and use plant genetic resources, which are critical for boosting crop resilience, and also helping accelerate the development and dissemination of crop varieties that possess enhanced nutritional quality. The study also calls for research aimed at improving the ability of alternative crops to compete in markets, which is critical for realizing their potential to make agriculture more resilient and human diets more nutritious.

"International agencies have hammered away in recent years with the message that agriculture must produce more food for over 9 billion people by 2050," said co-author Andy Jarvis, director of CIAT's Decision and Policy Analysis Research Area. "Just as important is the message that we need more diverse global food supplies. This is the best way, not only to combat hunger, malnutrition, and over-nutrition, but also to protect agriculture against the impacts of global climate change."

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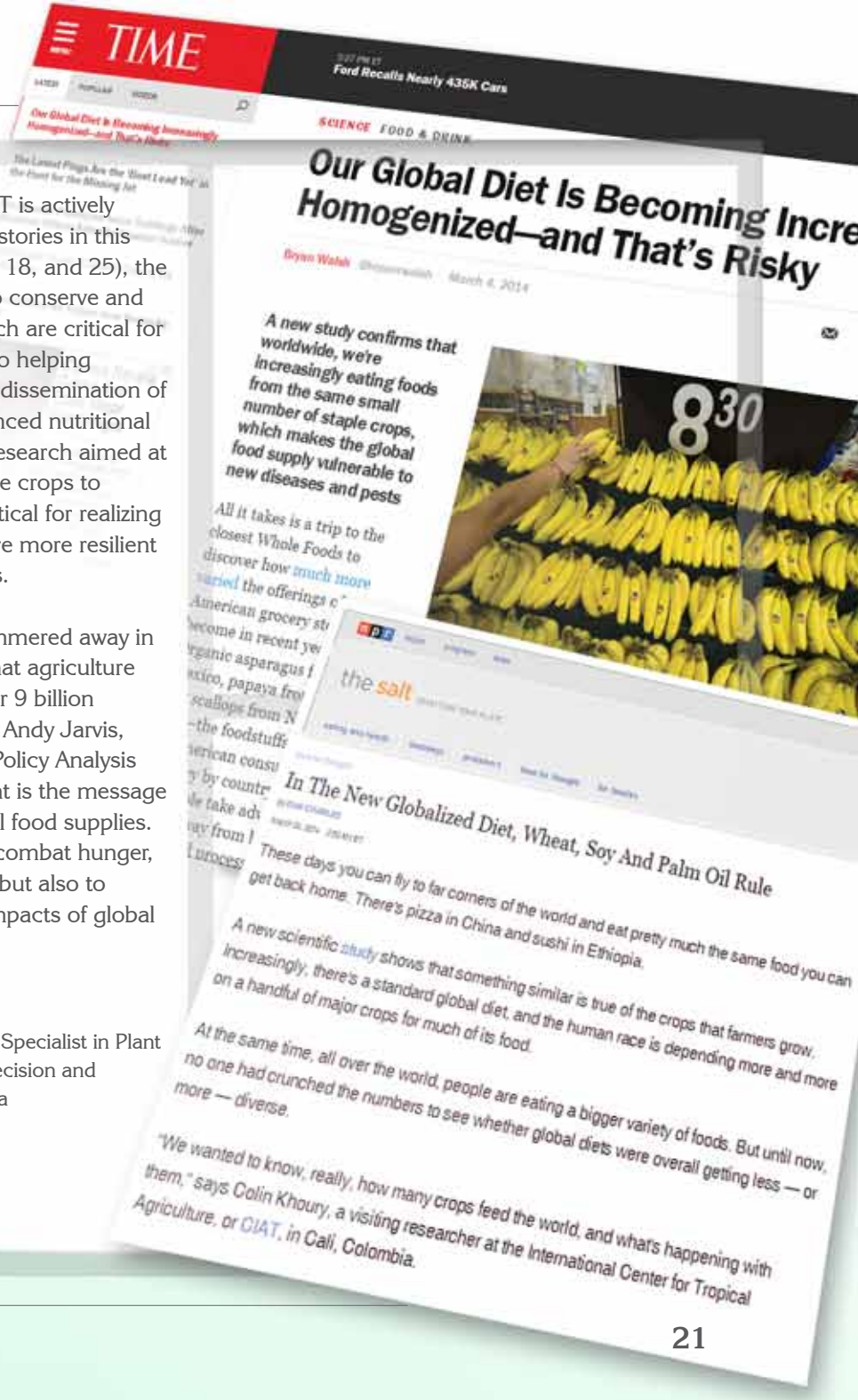

HarvestPlus on the march

HarvestPlus, which develops nutritionally improved or "biofortified" crops (see pages 23 and 25), has been gearing up over the last year for a new phase focused on getting these vitamin- and mineral-rich foods into the diets of 100 million people by 2018. The program, jointly coordinated by CIAT and the International Food Policy Research Institute (IFPRI), is already ahead of schedule, after surpassing its commitment to release and deliver biofortified seeds to more than 500,000 farm households in 2013.

Ramping up this effort is a technical and institutional challenge, involving continued research, large-scale seed delivery, and increased advocacy – all in collaboration with an expanding network of partners. On the technical front, several new varieties entered the pipeline – following the release by 2013 of improved beans, cassava, maize, and sweetpotato in sub-Saharan Africa together with pearl millet, rice, and wheat in South Asia.

"The delivery of new beans in three countries of Central Africa is especially well advanced, because we have very good varieties combining high iron with high productivity and acceptability to consumers – traits that trigger adoption," said Wolfgang Pfeiffer, HarvestPlus deputy director, operations. "But much remains to be done," he added. "We're supporting our national partners, as they develop and apply solutions to a range of technical challenges."

In Rwanda, for example, HarvestPlus staff concentrated this year on promoting the use of animal traction for better crop management, improving fertilizer supplies, and providing training in crop agronomy. They also worked closely with the Rwanda Agriculture Board to strengthen seed multiplication and help farmers use stakes more efficiently (reducing the number needed from 50,000 to 10,000 per hectare) for the production of new climbing beans.

Similar efforts moved forward in other target countries. In Nigeria, for example, HarvestPlus provided training to help roll out a new approach for better production and handling of cassava stem cuttings. Through more efficient stem cutting and packaging, the new approach has greatly accelerated the multiplication of high-vitamin A varieties. In the absence of commercial markets for cassava stem cuttings, the program also began creating an informal network of stem producers and traders.

Collaboration is the key for quickening the pace of this work. At the World Economic Forum held in Davos, Switzerland, during January 2014, HarvestPlus announced a new partnership with World Vision. The program also organized a major global consultation at Kigali, Rwanda, in April with representatives of governments, business, and civil society to determine how biofortification can be mainstreamed in programs, policies, and markets.

HarvestPlus – a major component of the CGIAR Research Program on Agriculture for Nutrition and Health – is funded by more than a dozen donors (see the complete list of CIAT donors on page 50).

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Packing seed of biofortified beans in Democratic Republic of the Congo.

“Gorilla” beans power development in Central Africa

In the Democratic Republic of the Congo (DR Congo), where a third of the population is anemic, beans with higher levels of iron and zinc provide a novel way to address the problem.

“We call them gorilla beans, because they can help make the children strong,” says Antoine Lubobo, a crop delivery specialist for HarvestPlus.

The name gorilla bean refers to five iron- and zinc-rich varieties released in eastern DR Congo from 2008 to 2012. The new “biofortified” beans have been bred by researchers in DR Congo, neighboring Rwanda, and CIAT in Colombia to contain up to double the iron and 70% more zinc than regular beans. HarvestPlus and its partners test and evaluate the beans before they are released.

At a gorilla bean multiplication site in Kashusha, around 100 hired hands work in teams, laying big piles of just-picked pods on tarpaulin sheets and bashing them with poles to release the beans. Then, the beans are passed to winnowers, who sift them on large wicker plates. Finally, they’re tipped into HarvestPlus-branded sacks and sent to market.

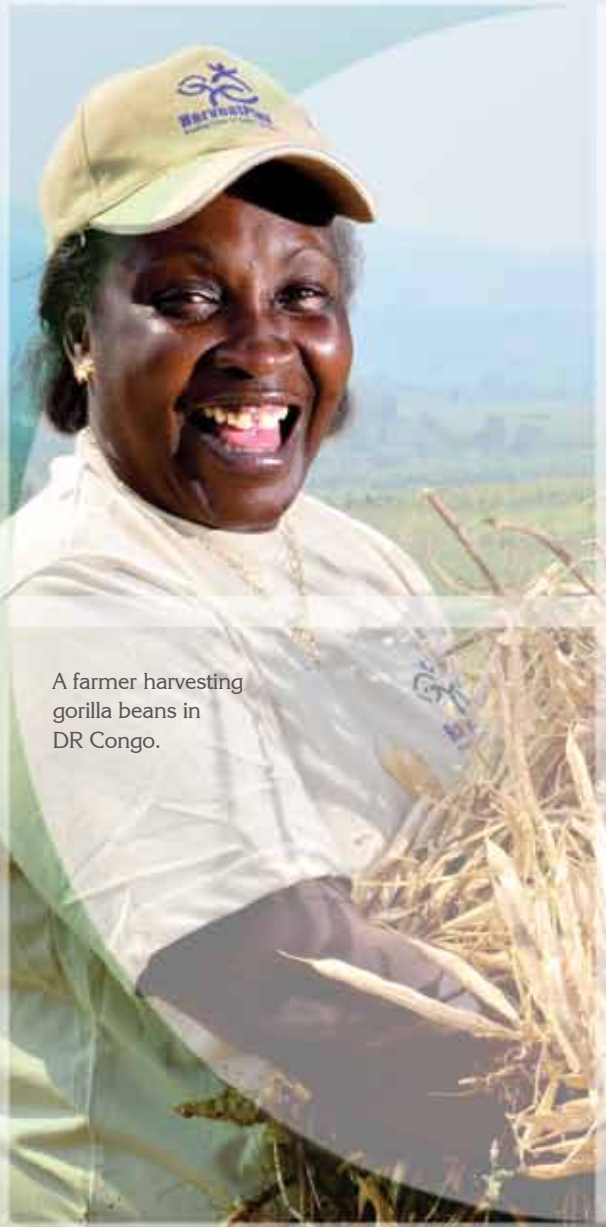
Turning away from the bean threshing and winnowing, Lubobo points to the hills. “Over there, where you can see the tall, thick trees,” he says, “that’s Kahuzi-Biega National Park, where the gorillas are. Sometimes they come down from the forest to eat the beans in farmers’ fields.” It’s another reason the name gorilla beans stuck.

As good as meat

At a food market in Bukavu, it’s obvious why beans are so important in local diets. A good cut of beef sells for around US$4 per kilogram or more. In contrast, beans can cost as little as $0.60–$0.80 per kilo. When you combine their protein content with higher levels of iron, zinc, and other essential nutrients, it’s easy to see why many people regard gorilla beans as being as good as meat.

Bean production offers several advantages over other crops as well as livestock keeping, which are more labor intensive and subject to many diseases, Lubobo explains. Also, while animals are regularly stolen, people don’t steal beans from the field. To obtain enough for a decent meal they’d have to uproot them, thresh them, bag them, and carry them away discreetly. Only gorillas, it seems, can get away with stealing beans from the field.

Winnowing seeds of biofortified beans.



A farmer harvesting gorilla beans in DR Congo.

Lubobo also believes that, in general, nutritionally improved food crops are better than relying on handouts of vitamin and micronutrient tablets from relief agencies. He explains that distributing these supplements is expensive and easier said than done in places like DR Congo, where rural infrastructure is poor and the countryside often lawless.

"With gorilla beans, we only have to supply the farmers with high-quality seed once, and they can grow their own nutritious food for 3 or 4 years before they need to buy more seed. That's why we see this program as helping DR Congo move from reliance on food aid to sustainable development."

Farmer buy-in

Just breeding and releasing nutritionally improved beans isn't enough to get buy-in from farmers. At the Kabushwa nutrition center in Katana village, around 100 mothers and toddlers have gathered for a meeting under a tin-roofed bivouac. Using a megaphone, HarvestPlus representatives explain the benefits of growing the new varieties, serving up plates of steaming gorilla beans, plantain, and potato for all in attendance.

In the local market, a short ride from the nutrition center, previous awareness-raising work has clearly had an impact. Within minutes of being opened, 400-kilogram sacks of gorilla beans sell out within minutes. For smallholders with too little money to buy the seed directly at markets like that at Katana, HarvestPlus provides a kilo of seed in exchange for a "payback" of 1.5 kilos at harvest.

Around 75,000 households in South and North Kivu are growing the new gorilla beans, the majority in the south. In North Kivu the work is more complicated due to the volatile security situation.

"It's a great shame," Lubobo says, "because some parts of North Kivu have up to four distinct bean-growing seasons, compared to two in much of South Kivu."

He keeps in regular contact with partners there, however, making cash transfers via his mobile phone to keep the trials running. Despite the challenges, HarvestPlus aims to introduce the gorilla beans into DR Congo's Eastern Province, expanding its ever-growing network of local partners, trial sites, and interested farmers.

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Fast-tracking nutrition in cassava

Newly bred cassava that offers quadrupled vitamin A content could provide a lifesaving solution to millions in Africa suffering from micronutrient malnutrition. Globally, an estimated 250 million children are vitamin A deficient, according to the World Health Organization. Up to 500,000 will go blind every year, and half of them will die within 12 months of losing their sight.

This has led CIAT to fast-track improvement in the nutritional value of cassava, Africa's second most important staple crop. The results indicate a fourfold boost in beta-carotene – the orange pigment used by the body to make vitamin A – from 5 micrograms in the first experimental materials to about 20 in the most recent ones.

The research contributes to HarvestPlus, which forms part of the CGIAR Research Program on Agriculture for Nutrition and Health. Its results are all the more remarkable for having been achieved in record time. Usually, the process needed to demonstrate genetic gain takes about 8 years. To meet the ambitious 10-year goal set by HarvestPlus, they devised a "rapid-cycling" breeding method to achieve the impossible.

"It was magical," said CIAT cassava breeder Hernán Ceballos. "None of us expected that it would be possible to achieve such a large increase so quickly."

Stretching the boundaries of science

Unlike other genetic traits of cassava, beta-carotene is "trustworthy." That is, you can demonstrate increased or decreased levels in a short time, without carrying out multi-location trials and multiple root tests to verify results. This is typical of what scientists call "high-heritability" genetic traits. An example in humans is eye color – a "reliable" result can be determined relatively soon after birth.

"Root yield is a more elusive, low-heritability trait, because it's very site specific," explained Ceballos. "A genotype can give certain results in one location but completely different ones 10 kilometers away. To improve yield, you need to test at multiple locations in a process that can take about 8 years."

Because beta-carotene is a high-heritability trait, scientists were able to test only one plant per cassava variety and then cross the selected plants with others showing high beta-carotene content. This rapid-cycling process reduced the cassava breeding time from 8 to 3 years.

Unraveling the mystery

The results, published in the journal *Crop Science*, have implications beyond boosting beta-carotene content in cassava. By unraveling some of the mystery surrounding the genetic makeup of the crop, scientists now know that rapid breeding for other high-heritability traits is possible.

But a number of hurdles still need to be overcome in fully applying this research. "The work on beta-carotene is tremendous, but it's not a silver bullet," Ceballos admitted.

There remains the hard work of getting improved materials into the field and ensuring that they are acceptable to farmers. This baton has been picked up by another CGIAR center, the International Institute of Tropical Agriculture (IITA), together with national research organizations, particularly in Nigeria and Democratic Republic of the Congo, where varieties high in beta-carotene have already been released. In Nigeria, HarvestPlus partners distributed stem cuttings of these varieties to more than 100,000 rural households in 2013.

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System Foundations

"Grassroots action" to curb climate change

Paola Pardo, a former research assistant with CIAT's Tropical Forages Program, who is now completing her Master's degree.

New scientific evidence demonstrates that a potent chemical mechanism operating in the roots of a tropical grass used for animal feed has enormous potential to reduce greenhouse gas emissions from crop and livestock systems.

Referred to as "biological nitrification inhibition" or BNI, the mechanism markedly reduces the conversion of nitrogen applied to soil as fertilizer into nitrous oxide, according to papers prepared by CIAT scientists and partners for the 22nd International Grasslands Congress held in Sydney, Australia. Nitrous oxide is the most powerful and aggressive greenhouse gas, with a global warming potential 300 times that of carbon dioxide.

"Nitrous oxide makes up about 38% of all greenhouse gas emissions in agriculture, which accounts for almost a third of total emissions worldwide," said Michael Peters, who leads CIAT's research on tropical forages. "BNI offers what could be agriculture's best bet for helping keep global climate change within manageable limits."

Proof of concept

Scientists at CIAT and the Japan International Research Center for Agricultural Sciences (JIRCAS) have researched BNI collaboratively for the last 15 years. Today, this work forms part of CIAT's new LivestockPlus initiative, which contributes importantly to the CGIAR Research Program on Livestock and Fish and that on Climate Change, Agriculture and Food Security (CCAFS).

"This approach offers tremendous possibilities to reduce nitrous oxide emissions and the leaching of polluting nitrates into water supplies, while also raising crop yields through more efficient use of nitrogen fertilizer," said G.V. Subbarao, a senior scientist at JIRCAS.

As a result of recent advances, which have consolidated the proof of concept for BNI, scientists now have the means to exploit this phenomenon on a large scale. For example, CIAT researchers have found ways to increase BNI through plant breeding in different species of *Brachiaria* grasses. The new techniques include methods for rapidly quantifying BNI in *Brachiaria* together with molecular markers, which reduce the time needed for field testing.

Center scientists have also gathered evidence that a maize crop grown after *Brachiaria humidicola* pastures gave good yields with only half the amount of nitrogen fertilizer normally

used, because more nitrogen was retained in the soil, thus reducing nitrous oxide emissions and nitrate leaching.

In addition, scientists have developed hybrids of *B. humidicola* and delivered these, with support from the German government, to farmers in Colombia and Nicaragua for productivity and quality testing. Based on evaluation of the new hybrids and with the aid of simulation models, researchers are studying where else the hybrids can be introduced.

Triple-win technology

"Livestock production provides livelihoods for a billion people, but it also contributes about half of agriculture's greenhouse gas emissions," Peters explained. "BNI is a rare triple-win technology that's good for rural livelihoods as well as the global environment and climate. It defies the widespread notion that livestock are necessarily in the minus column of any food security and environmental calculation."

"Today's crop and livestock systems are very leaky," said Subbarao. "About 70% of the 150 million tons of nitrogen fertilizer applied globally is lost through nitrate leaching and nitrous oxide emissions. The lost fertilizer has an annual estimated value of US$90 billion."

"BNI has huge possibilities for reducing nitrogen leakage," said CIAT plant nutritionist Idupulapati Rao. "Grassland pastures are the single biggest use of agricultural land – covering 3.2 billion hectares out of a global total of 4.9 billion. In Brazil alone, 11 million hectares of grassland have been converted to maize and soybean production. Instead of more monocropping, farmers in the tropics can integrate *Brachiaria* grasses into mixed crop–livestock systems to make them more sustainable."

Back to Africa

Originally from sub-Saharan Africa, *Brachiaria* grasses found their way to South America centuries ago – possibly as bedding on slave ships. Improved varieties of the grass are widely grown on pasturelands in Brazil, Colombia, and other countries, and they have recently been taken back to Africa to help ease severe shortages of livestock feed.

In a major breakthrough, JIRCAS scientists discovered several years ago the chemical substance responsible for BNI and developed a reliable method for detecting the nitrification inhibitor coming from plant roots. Scientists at CIAT then validated the BNI concept in the field, demonstrating that *Brachiaria* grass suppresses nitrification and nitrous oxide emissions, compared with soybean, which lacks this ability.

"Our work on BNI started with a field observation made by one of our scientists in the 1980s – back then it was nothing more than a dream," said Peters. "But now it's a dream with a lot of scientific proof behind it."

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Preserving Kenya's lifeblood

CIAT and The Nature Conservancy (TNC) are collaborating in an innovative effort to make farming more eco-efficient, while preserving essential ecosystem services. In Kenya, they expect to launch Africa's first water fund in 2014, centered on the Tana River – Kenya's lifeblood.

Flowing from the peaks of the Aberdare Mountains, the river stretches 1,000 kilometers, providing the primary source of water for people, crops, livestock, and much of Kenya's wildlife. Its upper reaches, occupied predominantly by rural communities, supply drinking water to four million people in Nairobi and generate 60% of the country's electricity.

North of Nairobi among the lush, lime-green, tea-carpeted hills of the Upper Tana region, more than one million smallholder farmers rely on the land for food and income. The land is fertile, supporting the production of coffee, maize, avocado, and vegetables between pockets of tea. But intensive agriculture comes at a high cost.

Nearly half of the farmland lies on steep slopes, which make its cultivation labor intensive and also highly susceptible to erosion. As heavy rain washes over the land and down the hills, it carries with it crops and fertile topsoil, causing landslides and turning the Tana River brown with silt.

Water woes

The effect on smallholder farmers can be devastating. John Njerona has a 2-hectare plot near Gatanga, which sustains 15 members of his family. Five years ago, a landslide washed away one-third of his crops and left a scar one-half hectare wide across his land, which grows wider each year.

Since then, Njerona has struggled to grow enough food to feed the family and pay school fees. His efforts to rehabilitate the land by planting trees on the exposed soil were thwarted by unpredictable rains, which washed the saplings away before they could take hold. He fears that, without training and support to introduce improved land management practices, he will lose more land.

This farmer's woes are part of a much wider predicament. Sedimentation runoff from farmland, quarries, and unpaved roads poses a serious threat to water supplies and quality downstream. The silt-laden water washes from upstream rural communities, reducing drinking water quality for downstream farming communities and urban dwellers, impacting electricity generation, and clogging water treatment equipment.

Nairobi Water Company reports that water treatment costs increase by more than one-third during the wet season. Without action, water quantities and quality will continue to worsen, raising the price of water and electricity.

Africa's first water fund

The Nature Conservancy (TNC) is leading efforts to bring water users and land managers together to find shared solutions to the Tana River challenges. In June 2013, CIAT joined the partnership to provide the research and monitoring needed for TNC and its partners to launch Africa's first water fund in 2014.

Water funds are financial tools that gather investment from water users and direct it towards conservation of land upstream to protect water supplies. First developed by TNC in Latin America, water funds have proven successful at attracting voluntary contributions from large downstream water users, such as water utilities and hydroelectric companies, to help land users manage their land more sustainably – for example, by adopting farming practices that reduce soil erosion.

In Kenya, a water fund could serve as the catalyst for preserving the Tana River and the livelihoods it sustains.

Without proof, no investment

Working through the CGIAR Research Program on Water, Land and Ecosystems, CIAT plays a dual role in the partnership: first, conducting research that helps target interventions to the most vulnerable areas, thus ensuring greater impact and a better return on water fund investments, and, second, assisting partners with assessment of the impact of interventions on water quality, land health, and livelihoods.

Center research includes using satellite imagery to monitor changes in land use and cover, monitoring water quality, hydrological modeling, and scenario assessment to predict the impact of land use practices on sediment levels.

Soil scientist Fred Kizito is leading CIAT's research: "The challenge is to reduce sedimentation and erosion in rural upstream areas to provide enough good quality water for Nairobi – and to prove that on-farm interventions work. Without proof, there is no incentive for investment."

CIAT's research will support the efforts of local partners, like the Sustainable Agriculture Community Development Programmes (SACDEP), who work with farmers to introduce sustainable land management practices. As part of a pilot study aimed at proving the water fund can have an effect downstream, they are currently working with 600 farmers, including John Njerona, in the Upper Tana region.

The water fund has given hope to him and many other farmers in the region. With training from SACDEP, he is planting Napier grass strips, building terraces, and planting trees and bamboo to protect his land from further destruction. With the water fund in place, he hopes to reclaim the land he lost to landslides.

If the Tana River Water Fund proves successful, it could pave the way for similar investment initiatives across Africa and have a major impact on livelihoods and ecosystems.

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Kenyan farmer John Njerona.

Rethinking yield gaps in Africa

A Rwandan farmer weeds her bean crop.

Since the 1960s, scientists, governments, and development experts in Africa have struggled to close the gap between average yields and those possible with improved technology – but without a great deal of success. The reason for limited progress, CIAT scientists believe, is that much research has failed to take into account the complexity of Africa's farming systems and the constraints that farmers face. Recent advances in soil research have shed much light on these constraints, opening up new possibilities to narrow yield gaps and achieve sustainable intensification of agriculture.

Working with diverse partners, CIAT researchers have carried out agronomic trials in many African countries, which reveal the huge spatial variation of soil fertility across the continent – from area to area and even from field to field. This is why blanket recommendations – for the application of mineral fertilizer, for example – have proved ineffective and even risky for farmers. The research has also shown that, apart from nitrogen, phosphate, and potassium limitations, yields are constrained by many other soil factors, such as the micronutrient deficiencies detected in 15% of the study areas.

But advanced tools for mapping soils and diagnosing specific constraints have made it easier to tackle these problems. Based on new thinking, CIAT scientists are making fundamental changes in research aimed at narrowing yield gaps.

Measuring the gaps

Past studies have generally measured yield gaps by means of trials conducted on experiment stations, which compare local practices with those recommended by researchers, producing biophysical explanations for the gaps and identifying technical options for narrowing them. But this approach doesn't give a complete picture of the constraints farmers face or reveal the underlying causes of yield gaps.

Through on-farm research trials conducted in Tanzania and Malawi, CIAT researchers are learning more about farmers' management strategies and major constraints, while measuring yields in farmers' fields. This not only reveals the productivity levels that can be achieved on farm but also helps explain why some farmers achieve higher yields than others. For both countries, preliminary results reveal significant gaps between the lowest and highest maize yields among farmers in the same area.

So, if high yields are achievable on farm, why are so many farmers failing to reach the productivity levels of their neighbors? To answer this question, researchers are using high-yielding plots and their characteristics as benchmarks for identifying the biophysical and farm management constraints to crop productivity. But science needs to delve deeper.

Beyond agronomy

CIAT's research reaches beyond environmental and agronomic factors to consider socio-economic constraints and whole system productivity. In addition to understanding how farmers manage their fields, this research

considers what shapes their on-farm decisions and examines farms in their wider social and environmental context.

This work is giving rise to a new approach that involves bio-socio-economic mapping of yield gaps, which enables researchers to quantify the real potential for increasing yields. By investigating gaps and their causes from a new angle, CIAT is building a better understanding of why they persist and developing tailor-made interventions that help farmers achieve their full crop yield potential.

"We need to rethink how gaps are defined and measured, and get a lot more specific about the socio-economic obstacles and incentives that farmers face," said Katherine Snyder, a CIAT social scientist.

CIAT's soil research is supported by various donors, including the US government through the Africa RISING Program and the Bill & Melinda Gates Foundation, and contributes to the CGIAR Research Programs on Water, Land and Ecosystems and Dryland Systems.

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Common ground on soil fertility in Africa


nature

Farmers dig into soil quality

Analytical technique promises to match fertilizers to soil in bid to boost yields in Africa.

Quirin Schiermeier

Efforts to bring chemical fertilizers to sub-Saharan Africa are often met with concerns over harmful environmental and economic side effects. The products improve soil quality — useful in Africa, where soils often lack crucial nutrients — and help to increase yields. But fertilizers are costly for subsistence farmers and can leach into water supplies, leading to health problems. Soil scientists have long wanted to assist poor farmers with their selection and use of fertilizers so that they can better match them with soil types and use less of them.

The goal says Rolf Sommer, an agricultural scientist at the International Center for Tropical Agriculture (CIAT) in Nairobi, is to provide smallholders with easy-to-understand information that will help them to decide what works best, economically and ecologically.

Related stories

- African agriculture: Dirt poor
- Climate-smart agriculture

New thinking about yield gaps could result in better interventions for reaching the controversial goal of increasing smallholder farmers' use of mineral fertilizer in sub-Saharan Africa. While many believe this is necessary for the continent to become food secure, others argue against it, insisting that farmers are better off turning to environmentally friendly organic fertilizer.

This issue hit the headlines as soil scientists from around the world gathered for Global Soil Week in Berlin during October 2013, where CIAT co-hosted a discussion on sustainable nutrient management in Africa. The event brought to the table advocates from both sides of the argument, including World Wildlife Fund Germany, representatives from the fertilizer industry, the president of the Tanzania Organic Agriculture Movement, and supporters of the Abuja Declaration, which sets targets for mineral fertilizer use.

Ultimately, the dispute proved to be a false dichotomy. While contentious issues initially rose to the surface, all participants agreed that Africa should aim for balanced integrated soil fertility management.

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Clamp-down on cassava pests and diseases in Asia

CIAT scientists have ramped up efforts to clamp down on emerging pests and diseases, which pose a significant threat to cassava-based farming systems in Southeast Asia.

The spread of new cassava pests and diseases is fueled by unchecked movement of cassava planting stakes between countries. In the absence of effective controls, the pests and diseases are coming dangerously close to engulfing cassava harvests, biting into smallholder incomes from this increasingly important crop.

"It's difficult to gauge the exact impact of these novel pests and diseases, but they cause considerable yield reductions and have spread rapidly throughout Southeast Asia," said Kris Wyckhuys, a CIAT entomologist.

In a series of workshops organized by CIAT and its partners in Colombia and Vietnam, participants have received hands-on training in the detection, analysis, and prevention of cassava witches'-broom disease and cassava mealybug (*Phenacoccus manihoti*), known locally as the pink mealybug.

Trinh Xuan Hoat, deputy director of Vietnam's Plant Protection Research Institute, said training courses are critical to equip the regional research community with new knowledge about the threats to cassava and about pest and disease management techniques. "We consider cassava pests and diseases to be a new and severe problem for the whole region. Broad thinking is needed, and cross-border research cooperation is crucial to address these emerging threats."

Prevention is better than cure

Taking the view that prevention is better than cure, the workshops focused on strengthening regional capacity to identify and prevent threats from spreading. This capacity will be further rolled out – particularly among farmers – in 2014.

The workshops, supported by the International Fund for Agricultural Development (IFAD) and the Colombian Presidential Agency of International Cooperation (APC), gathered international speakers and top experts from Finland, Colombia, Indonesia, and USA. Researchers attended from Vietnam, China, Myanmar, Laos, Cambodia, the Philippines, and Thailand to learn about management and prevention tactics.

Nguyen Anh Vu, from Vietnam's Agricultural Genetics Institute, attended training on management of cassava witches'-broom disease at CIAT headquarters in Colombia. "The last 2 weeks were a great experience for me," he said. "I have learned a lot from Colombian scientists as well as researchers from other cassava-growing countries in Asia. We aim to make cassava witches'-broom a thing of the past."

Paving the way to better management

The clamp-down event in Vietnam was the first to focus on the mealybug threat in the region – and what to do next. Aunu Rauf, professor of agricultural entomology at Bogor Agricultural University in Indonesia, spoke during the 3-day workshop about the current mealybug threat in Indonesia.

"Accurate species identification and in-depth knowledge of the pest's biology and ecology are key ingredients to an effective control program for the region," he said. "We hope to have planted the seed for long-term control, not only for cassava mealybug, but for many other invasive pests in the region."

In the meantime, regional researchers have emerged from training workshops equipped with diagnostic methods to detect and monitor cassava threats. Khanxay Somchanda, an entomologist from Lao PDR's Plant Protection Center under the Ministry of Agriculture and Fisheries, said: "This workshop has provided information essential to many of the region's plant health officers and quarantine entomologists."

Typical symptoms of cassava witches'-broom disease.

Throughout 2014, information about the pink mealybug and other cassava threats will be extended to farmers in Laos, Myanmar, China, Vietnam, Cambodia, Thailand, and Indonesia, in an effort to curb encroaching cassava pests and diseases in the region.

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Participants in a workshop on cassava witches'-broom disease, held at CIAT headquarters.

Cassava impacts: Plenty at stake

There's plenty at stake in CIAT's collaborative effort to protect Asia's cassava crops from emerging diseases and insect pests, according to a 2013 study carried out by the Standing Panel on Impact Assessment of CGIAR's Independent Science and Partnership Council. The study documented significant impact from a single improved cassava variety (Kasetsart 50 or KU 50), which Center scientists developed in partnership with Thailand's Department of Agriculture and Kasetsart University.

KU 50 is currently grown on well over 1 million hectares in Thailand and Vietnam (where it is referred to as KM 94), mostly by smallholders in marginal uplands, and it has also been adopted in Cambodia and Indonesia. KU 50 and other high-yielding cassava varieties have effectively removed the obstacle of a narrow genetic base in Asia's production of the crop.

As a result, the study found, a steady decline in cassava yields has been reversed since the mid-1990s. In Thailand, yield growth has been the principal driver of production increases, with little area expansion. Vietnam's cassava area, in contrast, has doubled since the mid-1990s, but production has quadrupled, owing to yield gains.

The study calculates conservatively that the aggregate economic benefits accruing from the adoption of KU 50 in Thailand exceed US$44 million each year, while the annual figure for Vietnam is $53 million, not counting the substantial benefits also captured by cassava processors. Since the benefits largely reflect gains that producers have received by adopting KU 50, the study authors suggest that the improved variety "has had a substantial impact on poverty alleviation" in both countries.

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Inside Latin America's Eco-Efficiency Workshop

In Peru, ecosystem health has its rewards

A creative new effort to reduce wealth inequality in Peru centers on sharing the benefits of ecosystem services provided by the country's Andean river basins. To this end, the Ministry of Environment is developing a new scheme that will provide poor communities with rewards for helping secure water supplies over the long term.

In December 2013, the Peruvian Congress voted in favor of a new law on ecosystem services, intended to foster benefit-sharing mechanisms. A vote to ratify the law will take place during 2014.

The Cañete River Basin is highly representative of all the 53 basins along the Peruvian coast," said Marcela Quintero, who leads CIAT research on ecosystem services. "So, if the new scheme works, it can be applied in any of those watersheds to promote more equitable distribution of the benefits from water resources across the country."

A vertical water world

Peru's Environment Ministry chose the Cañete River Basin as its official pilot site, because the basin is widely recognized as being important for regulating the flow of water to multiple downstream sectors and for conserving biological diversity. Located in central Peru, the basin stretches across 6,000 square kilometers. Water users include rural households and the mining industry in the basin's upper reaches; shrimp farmers and hydropower companies in the middle part; and farmers, industries, and an urban population in the lower area.

Annual precipitation upstream can be as high as 1,000 millimeters, while the downstream landscape is far more arid. The upper region thus provides most of the water used downstream, and the water supply for consumers in the central and lower basin depends entirely on the willingness and ability of rural communities upstream to conserve the ecosystems in which they live and work. Over the past 40 years, however, climate change, pollution, and soil erosion (caused by extensive livestock grazing in the upper part of the basin) have seriously jeopardized the future availability and quality of water supplies.

"We and our research partners in Peru found that water users downstream recognize the benefits

they receive from the ecosystem upstream and are willing to reward communities there for maintaining ecosystem health," said Quintero.

Change by design

In response, the Peruvian Ministry of Environment has introduced a rewards-for-ecosystem services scheme, designed with support through CIAT from the CGIAR Challenge Program on Water and Food, which is now part of the new CGIAR Research Program on Water, Land and Ecosystems. The scheme will allow communities downstream to continue benefitting from water-related ecosystem services, while ensuring that some of the benefits – in the form of economic rewards – are transferred back to the people who conserve the ecosystem upstream.

Under the scheme, water users in the lower basin can make voluntary contributions to a Trust Fund created by the International Fund for Agricultural Development (IFAD) in 2013. Communities in the upper watershed can apply to the fund for support of projects aimed at restoring degraded lands and creating businesses based on farm products. Transferring resources from relatively wealthy communities downstream to poorer communities upstream will not only spur ecosystem conservation but also help achieve socio-economic equity and reduce water-related conflicts.

CIAT has been invited to take part in discussions of the new ecosystem services law, which has been drafted in such a way that it can be easily understood by all stakeholders. Center researchers have also contributed by formulating lessons learned from the Cañete Basin scheme and other, similar experiences. Once ratified by Congress, the law is expected to create a much more favorable environment for establishing benefit-sharing mechanisms in Peru.

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A farmer in the lower region of Peru's Cañete River Basin.

A wider window for collaboration in Peru

The signing of an agreement in March 2014 that unites CIAT with Peru's Ministry of Environment will extend the reach of our collaborative efforts, begun in 2010, to create novel schemes for rewarding improved management of water supplies.

"This agreement represents a new opportunity for CIAT to contribute to sustainable development in Latin America – a region where better natural resource management is decisive for the future of Peru and other countries," said Elcio Guimarães, the Center's regional director for Latin America and the Caribbean. In the signing ceremony, he accompanied Ruperto Taboada Delgado, the Ministry's secretary general, representing Gabriel Quijandría Acosta, Peru's vice minister for strategic development of natural resources.

Within this framework, CIAT also committed itself to a 3-year initiative, aimed at building capacity in the Ministry to employ Terra-i, a system that permits near real-time monitoring of vegetation cover and has proved highly effective for bringing deforestation hotspots into sharp focus. It works by using the satellite images of Latin America taken every 16 days, overlaying them onto Google Maps, and analyzing changes in vegetation cover.

"Together with CIAT, we're evaluating the potential of Terra-i to support our work on land-use planning," said Fernando Neyra of the Ministry's Directorate for Land-Use Planning.

With about a thousand registered users, Terra-i is gaining wide recognition. It received the 2013 GeoSUR Award during the Sixth Meeting of the Geospatial Network of Latin America and the Caribbean (GeoSUR). The versatile tool was developed by CIAT, The Nature Conservancy (TNC), King's College London, and the University of Applied Sciences and Arts Western Switzerland. Highlights of its application in 2013 include analysis of an alarming increase in deforestation resulting from expanded mining in the Peruvian Amazon.

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Deforestation near the city of Pucallpa in the Peruvian Amazon.

Changing the backstory of smallholder coffee production

Discriminating coffee enthusiasts expect a lot from their espressos, cappuccinos, and lattes. These consumers want a "mind-blowing" coffee, which not only has an extraordinary taste but also comes with an upbeat backstory about its origins. Collaborative CIAT research in Guatemala, Mexico, and Nicaragua has helped reveal what the backstory of smallholder coffee production really is, how it has changed for the better in recent years, and why.

The approximately 25 million rural people in the tropics who depend on coffee production face many hardships. And these are made much worse by volatile prices for coffee and other crops that rural families grow.

Consumers have become increasingly aware of these difficulties, thanks in large part to the fair trade-certified coffee model. Created in the late 1980s, it offers growers an above-market "fair-trade" price on the condition that they meet specific production and environmental standards. Certification of fair-trade coffee provides consumers – who pay a premium price for this product – with some assurance that it's grown in conditions favoring social justice and environmental sustainability.

Hard evidence

While still accounting for only a small proportion of total coffee sales, the market for fair-trade coffee has expanded significantly in recent years and has evidently benefitted many smallholder producers. To further ensure that coffee's backstory is getting better, Keurig Green Mountain, Inc. (formerly Green Mountain Coffee Roasters) – the world's biggest buyer of fair trade-certified coffee – invests millions of dollars in projects intended to improve the conditions in which smallholders work and live.

With the aim of grounding these investments in hard evidence, Keurig Green Mountain has entered into a partnership with CIAT, which revolves around scientific studies on the livelihoods of smallholder coffee-producing families. The most recent of these studies, called "Thin Months Revisited," was carried out collaboratively with the Agroecology and Rural Livelihoods Group at the University of Vermont, USA, in 2013. "Thin months," or *meses flacos* in Spanish, refers to a seasonal hunger period, when food and cash from previous harvests run short.

The Matamoros family, who grow coffee and other crops in the community of Las Escaleras, Matagalpa Department, Nicaragua.

"We began to recognize seasonal hunger as a major threat to our agricultural supply chain when CIAT conducted a baseline study for us 6 years ago in Guatemala, Mexico, and Nicaragua," explained Colleen Popkin, manager of the company's coffee supply chain outreach. "It found that two-thirds of the growers surveyed reported facing extreme food scarcity during 3 months or more every year. These results had a sobering effect on our leadership and on many others in the fair-trade coffee movement."

In response, Keurig Green Mountain began to focus its outreach on bolstering food security, often with projects designed to diversify household livelihoods. Judging from the results of Thin Months Revisited – which involved interviews with 100 families, many of whom took part in the earlier study – these efforts are paying off.

In the words of the study report, new research offers "irrefutable evidence that the situation has improved for most families" over the last 6 years – particularly with respect to food security. Across study locations, the average number of thin months has declined from 3.81 in 2007 to 2.83 today.

Diversification for a better future

The study doesn't claim that Keurig Green Mountain-funded projects alone accounted for this significant shortening of the hunger period. But it does show that, in Mexico's Chiapas State as well as Nicaragua, farmers taking part in these projects saw "marked improvements in livelihood diversification." In fact, some farmers have begun using income from their coffee harvests to expand into other enterprises (like fruits, vegetables, cocoa, livestock, and honey) and vice versa.

"Diversification lowers the pressure on coffee through a system that is in harmony with the environment and offers alternative sources of income," said Santiago Dolmus, a member of the technical assistance team with Cecocafen, an organization that supports coffee-grower associations in northern Nicaragua.

Why is a company in the coffee business helping coffee farmers with other crops? The answer is that Keurig Green Mountain views the coffee value chain through the lens of sustainable rural livelihoods. "Diversifying into other crops," said Popkin, "helps smooth out household income across the year and makes families more resilient to a volatile coffee market. A more resilient farmer will continue producing coffee and supply us with the quality and quantity we need to grow our business."

Diversification should also help growers weather another, longer term threat to their way of life and the coffee business. According to a CIAT study carried out several years ago, gradually rising temperatures will make coffee production far less viable in areas of Mesoamerica where it thrives today, requiring that farmers both modify their coffee management and explore other options.

"The news isn't all bad, though," said CIAT scientist Peter Läderach. "Climate change will create both losers and winners. And the winners will be those who learn to adapt through diversification and other strategies."

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El Plan, the 2.6-hectare coffee farm of the Matamoros family in Nicaragua.

Climate-smart solutions – Made in Colombia

One of the world's most ambitious national efforts to confront climate change in agriculture got underway last year in Colombia and already shows promise as a successful model for other countries. Launched under a scientific partnership that unites CIAT with the Ministry of Agriculture and Rural Development (MADR), the initiative also brings together farmer associations, universities, nongovernment organizations, and research institutes.

"This project has put Colombia at the cutting edge of global efforts to adapt agriculture in the face of climate change," said Andy Jarvis, director of CIAT's Decision and Policy Analysis (DAPA) Research Area and leader for climate change adaptation with the CGIAR Research Program on Climate Change, Agriculture and Food Security (CCAFS). "This work is already proving to be a successful case, which can be replicated in any other country of Latin America."

Climate change is expected to have significant impacts on Colombia's agriculture, which employs 21% of the nation's workforce and accounts for more than a tenth of its gross domestic product. In a major effort to curb these impacts, the project is pursuing four lines of action: (1) climate forecasting and modeling, (2) improved technologies for adaptation of high-priority crops, (3) site-specific agriculture, and (4) environmentally sustainable production systems.

Better decisions for better production

The cornerstone for any effort to develop effective adaptive measures is an effective system for making periodic climate forecasts. To this end, CIAT and MADR are drawing on successful experience in Senegal to develop a tool for predicting short-term climate variation and its effects on particular crops, aimed at supporting the decisions and recommendations of farmers associations. At the same time, the project is simulating longer term, fine-scale projections of climate change impacts on different crops and regions to provide scientists and government decision-makers with a firm basis for adaptation planning.

"We hope this pilot project in Colombia will repeat Senegal's success in motivating farmers to incorporate climate information into their decisions, so they can not only protect but increase their production," said Patricia Guzmán, assistant technical manager for Colombia's National Rice Growers Association (Fedearroz).

New crop varieties that are disease resistant and tolerant to drought and high temperatures are critical for bolstering the current and future food

A visit to rice variety trials in Colombia's Córdoba Department.

security of Colombian families in the face of climate change. To identify the best options available, the CIAT–MADR project is conducting large-scale experiments to test improved germplasm under diverse conditions. On this basis, researchers have identified resilient varieties of beans, cassava, maize, and rice that are well adapted to the various parts of Colombia that are most vulnerable to climate change impacts.

In a further effort to make crop production more climate smart, the project is implementing an approach referred to as "site-specific agriculture." The idea is to better target improved technologies, based on the analysis of climate information for different regions. For this purpose, the project is creating an information platform, designed to help achieve more efficient use of resources and narrow yield gaps. The platform will also be used to identify areas of Colombia where there is high potential for replacing livestock pastures with fruit production, in accordance with national policies aimed at mitigating greenhouse gas emissions.

Eco-efficiency is climate smart

Climate-smart agriculture requires smart, or eco-efficient, use of resources. In search of better options for enhancing water use and carbon sequestration, the project is analyzing the water and carbon footprints of maize, oil palm, potato, and rice production under different crop management practices across the country. The results of this work, while informing environmental planning at the national level, are also influencing farmers' attitudes and practices.

"Before, we used so much irrigation water that sometimes by 3 p.m. there was no more water left in the reservoir. The new system is very good, because it measures how much water we're using and helps us conserve," said Colombian farmer Lisimberg Nieva.

In support of its ambitious research-for-development objectives, the CIAT–MADR project is implementing a knowledge management strategy, which engages diverse audiences and encompasses innovative approaches to data management, documentation, communications, capacity strengthening, and monitoring and evaluation.

Facts on the Colombian model for confronting climate change

9 national partners
52 municipalities with field work underway
800 experimental plots at multiple locations
200 farms with ongoing participatory research
40 planning and training events held so far
97 researchers involved

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CIAT research associate Miguel Romero takes measurements of water use in a maize crop in Colombia's Valle del Cauca Department.

A soil information power tool

CIAT and a large group of partner organizations have completed the first phase in developing a state-of-the-art resource called the Latin American Soil Information System (or SISLAC, its acronym in Spanish). Getting this resource into the hands of key decision makers is critical for national and regional efforts to grapple with the complex challenges of climate change, land degradation, rural poverty, and food insecurity. The system is particularly important for identifying where soils are degraded, determining the potential to restore them, and identifying the causes of crop yield gaps.

The vast amounts of soil information available have until now been relegated to scattered reports and databases that are not widely accessible. Some regional sources of soil information exist, but they provide the data at a relatively low resolution, which often doesn't meet users' requirements.

To overcome these limitations, CIAT joined a regional initiative promoted and partially financed by the Food and Agriculture Organization of the United Nations (FAO) through the Global Soil Partnership (GSP). The initiative gave particular attention to strengthening national capacity in digital soil mapping and reinforcing national leadership in regional networks.

The initiative's first phase was implemented and co-financed under a strategic alliance uniting CIAT and the Brazilian Agricultural Research Corporation (Embrapa) with partner organizations in 19 countries (Argentina, Bolivia, Brazil, Chile, Colombia, Costa Rica, Cuba, Dominican Republic, Ecuador, El Salvador, Guatemala, Honduras, Mexico, Nicaragua, Panama, Paraguay, Peru, Uruguay, and Venezuela). This first phase, led by CIAT, strengthened the database management capacity of dozens of experts in soils and geographical information.

Their joint efforts centered on three main tasks: (1) recovering, harmonizing, and storing the information available (referred to as "soil legacy data," which includes soil profiles and maps); (2) developing a digital regional map of soil classes, based on national maps adapted to the classification system of the World Soil Reference Base; and (3) developing a beta version of the SISLAC online tool (www.sislac.org). A second phase, led by Embrapa, focused on developing capacity to generate digital maps of soil properties.

"The key to success was the commitment and active participation of our partners, who brought a lot of expert knowledge to an important shared task," said CIAT soil scientist Aracely Castro. "We see this as a long-term initiative, resulting in a versatile and robust system that responds to users' demand for diverse information of very high quality."

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Soil mapping goes underground in Colombia

A few decades ago, "nobody talked about Colombia's Eastern Plains," said Juan Lucas Restrepo, director of the Colombian Corporation of Agricultural Research (Corpoica), in a recent media opinion piece. "But since then, a lot has happened."

Corpoica, CIAT, and others have developed improved production technologies suited to the region, while the private sector has put new knowledge to work, planting thousands of hectares of maize, soybean, rice, oil palm, rubber, and improved pastures. As a result, the vision of this unique ecosystem as a sustainably managed "promised land" is no longer sheer fantasy.

In addition to the species already mentioned, there are real prospects for establishing forest plantations and promoting widespread adoption of agrosilvopastoral systems (combining crops, pastures, and trees) amidst large expanses of cotton, sugarcane, and other crops.

But not all of the region's potential for sustainable development lies above ground. 2013 marked the 20th anniversary of a landmark CIAT study in *Nature* magazine, which offered intriguing evidence that improved forage grasses in the Eastern Plains can capture large amounts of carbon deep in the soil.

Several years ago, CIAT and Corpoica renewed the exploration of this potential under a strategic alliance that also includes Colombia's Ministry of Agriculture and Rural Development. Researchers confirmed that adequately managed improved pastures have high potential to sequester carbon, in comparison with degraded pastures, annual crops, and native savanna. They also investigated the trade-offs involved in realizing this potential and created a preliminary map of the region's carbon reserves.

In 2013, the two organizations undertook the laborious task of validating this map through extensive soil sampling – 3,816 samples, to be precise, representing an area of nearly 1 million hectares. Then, researchers created a digital soil map, using new tools and methods, and validated the opportunity costs for different land uses.

The resulting tools and information provide a solid foundation for determining the viability of different options to reduce greenhouse gas emissions while enhancing agricultural productivity under various combinations of soil and land use.

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Soil sample collection at La Libertad experimentation station in Colombia's Meta Department.

Colombian partnership platforms

Established in 2011 with strong support from local government in the country's southwest, the Biopacific Park is a collaborative platform, whose aim is to promote agricultural development in this region and beyond.

In 2013, the Park entered into a new arrangement with Colombia's Administrative Department of Science, Technology, and Innovation (Colciencias) and the Korea International Cooperation Agency (KOICA) to devise a comprehensive plan for capacity development in support of science and technology parks in Colombia.

Under this agreement, the Korean government will provide US$2.5 million over 3 years to accelerate the development of three such parks: Guatiguará Park in Santander Department; National University of Colombia Park in the nation's capital, Bogotá; and Biopacific Park in Valle del Cauca. KOICA's support for the Biopacific Park will center on designing its overall development plan, strengthening its service portfolio, and developing value-adding options for agro-industrial products.

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Another key mechanism by which CIAT promotes research partnerships for agricultural development in Colombia and elsewhere is the Agronatura Science Park, which brings together 10 national and international organizations around a common collaborative platform to address shared research challenges.

Agronatura Science Park

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Research Publications

Articles and other information resources are among the primary means by which CIAT shares the results of collaborative research. Following is a selection from the total of 246 items published by Center scientists with partners in 2013; more than half of the total appeared in international refereed journals and books.

The articles listed here represent the full breadth of Center research; most are already being cited in the literature, reflecting the relevance and high quality of our science.

Outstanding research publication award

In 2012, the recipient of this CIAT internal award was the journal article listed below, which explains how molecular and phenomic analysis can aid the identification of genes for valuable traits in rice, such as disease resistance.

Lorieux M; Blein M; Lozano J; Bouniol M; Droc G; Diévart A; Périn C; Mieulet D; Lanau N; Bès M; Rouvière C; Gay C; Piffanelli P; Larmande P; Michel C; Barnola I; Biderre-Petit C; Sallaud C; Pérez P; Bourgis F; Ghesquière A; Gantet P; Tohme J; Morel JB; Guiderdoni E. 2012. In-depth molecular and phenotypic characterization in a rice insertion line library facilitates gene identification through reverse and forward genetics approaches. Plant Biotechnology Journal 10(5):555–568. http://dx.doi.org/10.1111/J.1467-7652.2012.00689.x

Complete lists of scientific publications in 2013 and previous years as well as other information resources are available at:
http://ciatlibrary.blogspot.com/p/ciat-publications-2013.html

Agrobiodiversity Research Area

Assefa T; Beebe S; Rao IM; Cuasquer JB; Duque MC; Rivera M; Battisti A; Lucchin M. 2013. Pod harvest index as a selection criterion to improve drought resistance in white pea bean. Field Crops Research 148:24–33. http://dx.doi.org/10.1016/j.fcr.2013.04.008

Beebe SE; Rao IM; Blair MW; Acosta-Gallegos JA. 2013. Phenotyping common beans for adaptation to drought. Frontiers in physiology 4(35):1–20. http://dx.doi.org/10.3389/fphys.2013.00035

Blair MW; Díaz LM; Acosta-Gallegos JA. 2013. Race structure in the Mexican collection of common bean landraces. Crop Science 53(4):1517–1528. http://dx.doi.org/10.2135/cropsci2012.07.0442

Ceballos H; Morante N; Sánchez T; Ortiz D; Aragón I; Chávez AL; Pizarro M; Calle F; Dufour DL. 2013. Rapid cycling recurrent selection for increased carotenoids content in cassava roots. Crop Science 53(6):2342–2351. http://dx.doi.org/10.2135/cropsci2013.02.0123

Cortés AJ; Monserrate FA; Ramírez-Villegas J; Madriñán S; Blair MW. 2013. Drought tolerance in wild plant populations: The case of common beans (*Phaseolus vulgaris* L.). PLoS ONE 8 (5):e62898. http://dx.doi.org/10.1371/journal.pone.0062898

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De Souza J; Fuentes S; Savenkov EI; Cuéllar W; Kreuze JF. 2013. The complete nucleotide sequence of sweet potato C6 virus: A carlavirus lacking a cysteine-rich protein. Archives of Virology 158(6):1393–1396. http://dx.doi.org/10.1007/s00705-013-1614-x

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Kordas K; Fonseca-Centeno ZY; Pachón H; Jiménez-Soto AZ. 2013. Being overweight or obese is associated with lower prevalence of anemia among Colombian women of reproductive age. The Journal of Nutrition 143(2):175–181. http://dx.doi.org/10.3945/jn.112.167767

Kreuze J; Koening R; De Souza J; Vetten HJ; Muller G; Flores B; Ziebell H; Cuéllar W. 2013. The complete genome sequences of a Peruvian and a Colombian isolate of Andean potato latent virus and partial sequences of further isolates suggest the existence of two distinct potato-infecting tymovirus species. Virus Research 173(2):431–435. http://dx.doi.org/10.1016/j.virusres.2013.01.014

Mosquera-Espinosa AT; Bayman P; Prado GA; Gómez-Carabalí A; Otero JT. 2013. The double life of *Ceratobasidium*: Orchid mycorrhizal fungi and their potential for biocontrol of *Rhizoctonia* solani sheath blight of rice. Mycologia 105(1):141–150. http://dx.doi.org/10.3852/12-079

Okogbenin E; Setter TL; Ferguson M; Mutegi R; Ceballos H; Olasanmi B; Fregene M. 2013. Phenotypic approaches to drought in cassava: Review. Frontiers in Physiology 4(93):1–15. http://dx.doi.org/10.3389/fphys.2013.00093

Pais TM; Foulquié-Moreno MR; Hubmann G; Duitama J; Swinnen S; Goovaerts A; Yang Y; Dumortier F; Thevelein JM. 2013. Comparative polygenic analysis of maximal ethanol accumulation capacity and tolerance to high ethanol levels of cell proliferation in yeast. PLoS Genetics 9(6):e1003548. http://dx.doi.org/10.1371/journal.pgen.1003548

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Soils Research Area

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Decision and Policy Analysis Research Area

Bose P. 2013. Individual tenure rights, citizenship, and conflicts: Outcomes from tribal India's forest governance. Forest Policy and Economics 33:71–79. http://dx.doi.org/10.1016/j.forpol.2012.09.016

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CIAT's Corporate Services and Finances

CIAT's financial position continues to be strong, with net assets of US$20 million (excluding capital invested in fixed assets), an amount that represents 105 days of operating reserves.

The Center's Corporate Services area underwent a review of its current performance and preparedness to meet the future demands expected to result from changes in the way CGIAR research is carried out. Comparing CIAT with similar organizations, two international experts noted significant improvements since the previous review, conducted in 2007, and called for a more flexible system with increased delegation of authority.

Corporate Services highlights

The Center met increased reporting requirements in a timely manner for 12 CGIAR research programs and nearly 200 bilateral projects.

After contracting a total of 130 new staff members – twice the number hired in 2012 – CIAT now has just over 900 employees with over 40 nationalities. The Center has implemented a "one-staff" policy with a new job classification system. Compensation and benefits were analyzed in major markets where the Center operates, and adjustments are being made, as needed.

The consolidation of Africa's corporate services into the Regional Office in Nairobi, Kenya, was successfully completed. The same approach will be implemented in Hanoi, Vietnam, for Asia.

CIAT prepared to undertake a significant infrastructure initiative at headquarters, with the aim of replacing our aging irrigation system with a modern and eco-efficient, automatic water-distribution network.

As a participant in the CGIAR Consortium's One Corporate System inter-center initiative, the Center began implementing the replacement of its Oracle ERP platform with Agresso. While the One Corporate System (OCS) approach has proved daunting, it promises to provide significant benefits for the nine participating centers and CGIAR Consortium Office.

CIAT determined that in 2012 its global carbon footprint amounted to 5,200 metric tons, consisting of 8,400 tons of carbon output minus 3,200 tons avoided through mitigation activities at Center research stations. Air travel contributes 46% of CIAT's carbon output, about the same proportion reported by other international organizations. The Center will implement further mitigation activities, including the purchase of carbon bonds, with the aim of making CIAT carbon neutral within 3 years.

In response to increased demand, the Center expanded its video conferencing and internet capacity at headquarters as well as the regional and subregional offices. The trend towards more mobile computing requirements continues to place high demands for IT services and support.

Financial results for 2013

CIAT's revenues increased by 5% to US$114.3 million, while research execution reached $102 million, representing a 9% increase over 2012. Self-generated income from other revenues and gains (such as investments, fees, sale of assets, and farm operations) accounted for most of the $2.5 million surplus. Disbursement of window 1 and 2 funds[2] from the CGIAR Fund and Consortium, while starting late, was completed by year's end, with minor exceptions.

Partners in the CGIAR Research Program on Climate Change, Agriculture and Food Security (CCAFS), including CIAT, executed 94% of the CCAFS funds disbursed from windows 1 and 2. The program's total execution, including window 3 and bilateral funds, amounted to $51.5 million. As lead center for CCAFS, CIAT disbursed

[2] Donor contributions through window 1 of the CGIAR Fund provide overall support and are allocated to CGIAR research programs according to the finance plan proposed by the Consortium and approved by the Fund, while contributions going to window 2 are allocated by donors to specific CGIAR research programs. Funds for bilateral projects are channeled through window 3 or disbursed directly to centers.

window 1 and 2 funds within a few days after they were received from the CGIAR Fund to those partners that had submitted timely financial reports.

CIAT managed the volatility of the Colombian peso by protecting the budget exchange rate with forward hedges. Investments complied at all times with the investment policy approved by the Center's Board of Trustees.

CIAT is starting to implement International Financial Reporting Standards (IFRS) in 2014 and expects to achieve IFRS compliance by the end of 2015.

Statement of Financial Position
As of December 31, 2013 and 2012
(expressed in thousands of U.S. dollars)

	2013	2012
Current assets	59,002	58,589
Non-current assets	26,178	27,691
Total assets	**85,180**	**86,280**
Current liabilities	53,959	58,277
Non-current liabilities	3,580	2,644
Total liabilities	**57,539**	**60,921**
Undesignated net assets	17,123	13,962
Designated net assets	10,518	11,232
Unrealized gain - Hedging operations	0	165
Total net assets	**27,641**	**25,359**
Total liabilities and net assets	**85,180**	**86,280**

Financial outlook for 2014

The Consortium Financing Plan for 2014 and 2015 has helped reduce uncertainty surrounding the allocation of window 1 and 2 funds to CGIAR research programs. The programs, in turn, have made early commitments to partners. The forecast for CIAT's bilateral-project income in 2014 was increased from $5.5 million in new projects to $8.5 million, reflecting greater investment in fundraising activities. Uncertainty continues regarding donor decisions to shift funds between CGIAR Fund windows 1, 2, and 3 and bilateral projects developed directly with centers.

2014 is an election year in Colombia, and this implies some uncertainty about contract renewals. CIAT operates a large initiative with Colombia's Ministry of Agriculture and Rural Development and also has a major joint initiative with the Colombian Corporation of Agricultural Research (Corpoica), so the Center can expect significant budget uncertainty during the second half of 2014. A similar situation is expected in relation to renewed funding for the Pan-Africa Bean Research Alliance (PABRA).

CIAT will initiate planning for a new state-of-the-art genebank, aimed at expanding the Center's capacity to store seed, share genetic information, provide training, and raise public awareness. Fundraising for the new building will involve a significant effort by the Center's management and Board of Trustees.

The 2014 budget approved by CIAT's Board includes revenues of $114.4 million. Approved research expenses include a 16% increase over 2013 in research support and administration, resulting in a break-even budget. This includes steps taken to increase CIAT staff compensation, compared to the median for CGIAR as a whole. In the absence of an operating surplus and with continued increases in the daily burn rate, reserves are expected to decline by an amount corresponding to 10–15 days of operations.

Contact:
Albin Hubscher (a.hubscher@cgiar.org), Deputy Director General, Corporate Services

Statement of Activity
As of December 31, 2013 and 2012
(expressed in thousands of U.S. dollars)

	2013	2012
Windows 1 & 2	68,939	63,487
Window 3	6,106	890
Bilateral	37,513	40,080
Total grant revenue	**112,558**	**104,457**
Other revenue and gains	1,730	4,269
Total revenue and gains	**114,288**	**108,726**
Research expenses	102,390	93,980
General and administration expenses	7,838	7,542
Other expenses and losses	1,613	1,804
Total operating expenses	**111,841**	**103,326**
Surplus (deficit) for the year	**2,447**	**5,400**

Expenses by Function
As of December 31, 2013 and 2012
(expressed in thousands of U.S. dollars)

	2013	2012
Personnel	31,883	29,161
CGIAR collaboration	39,136	35,618
Other collaboration	13,978	16,354
Supplies and services	17,114	15,681
Travel	6,254	4,603
Depreciation	3,476	1,909
Total operating expenses	**111,841**	**103,326**

Donor support

CIAT conducts high-quality research for development impact with support from the multi-donor CGIAR Fund and with grants from the many other organizations listed below. We are grateful to all who have invested generously in our collaborative work, which enables millions to escape from hunger and poverty through improved technologies and policies.

CGIAR Fund

Bill & Melinda Gates Foundation, USA

Canadian Department of Foreign Affairs, Trade and Development (DFATD)

German Agency for International Cooperation (GIZ) GmbH, Federal Ministry for Economic Cooperation and Development (BMZ)

International Fund for Agricultural Development (IFAD)

Ministry of Agriculture and Rural Development (MADR), Colombia

Swedish International Development Cooperation Agency (SIDA)

Swiss Agency for Development and Cooperation (SDC)

The World Bank

United States Agency for International Development (USAID)

Administrative Department of Science, Technology and Innovation (Colciencias), Colombia
Alliance for a Green Revolution in Africa (AGRA), Kenya
Biotechnology and Biological Sciences Research Council (BBSRC), UK
Common Fund for Commodities (CFC), The Netherlands
Directorate-General for Development Cooperation (DGD), Belgium
European Commission (EC)
Food and Agriculture Organization of the United Nations (FAO)
Ford Foundation, USA
Forum for Agricultural Research in Africa (FARA), Ghana
Global Crop Diversity Trust, Germany
Howard G. Buffett Foundation, USA
Inter-American Development Bank (IDB)
Natural Environment Research Council (NERC), UK
The Nippon Foundation, Japan
United States Department of Agriculture (USDA)

Australian Agency for International Development (AusAID)
Australian Centre for International Agricultural Research (ACIAR)
Austrian Development Agency (ADA)
Climate and Development Knowledge Network (CDKN), UK
Colombian Association of Horticultural and Fruit Crop Growers (ASOHOFRUCOL)
Environment Canada
Government of Mexico
Japan International Research Center for Agricultural Sciences (JIRCAS)
Keurig Green Mountain, Inc.
Ministry of Agriculture, Forestry and Fisheries (MAFF), Japan
National Science Foundation, USA
Netherlands Development Organisation (SNV)
OPEC (Organization of the Petroleum Exporting Companies) Fund for International Development (OFID), Austria
Regional Fund for Agricultural Technology (FONTAGRO)
Seed and Plant Improvement Institute (SPII), Islamic Republic of Iran
The McKnight Foundation, USA
United Nations Environment Programme (UNEP)

Agricultural Research for Development (CIRAD), France
CARE International in Nicaragua
Catholic Relief Services (CRS), USA
Colombian National Planning Department (DNP), with funds from the Inter-American Development Bank (IDB)
Colombian Presidential Agency of International Cooperation (APC)
Department for International Development (DFID), UK
Donald Danforth Plant Science Center, USA
Solidaridad, The Netherlands
UNEP (United Nations Environment Programme) World Conservation Monitoring Centre (UNEP-WCMC)

Autonomous Regional Corporation (CAR) of Cundinamarca, Colombia
Brazilian Agricultural Research Corporation (EMBRAPA)
Chinese Academy of Agricultural Sciences (CAAS)
ensome, Nicaragua
French National Institute for Agricultural Research (INRA)
Fund for Environmental Action and Childhood (FPAA)
Fund for Financing the Agricultural Sector (FINAGRO), Colombia
Government of Peru
Government of Thailand
National Coffee Research Center (CENICAFÉ), Colombia
National Institute of Forestry, Agriculture and Livestock Research (INIFAP), Mexico
National University of Engineering, Nicaragua
Northern Rangelands Trust (NRT)
Norwegian Agency for Development Cooperation (NORAD)
Pangea Foundation, Colombia
People's Republic of China
The Nature Conservancy (TNC), USA
Tropical Agricultural Research and Higher Education Center (CATIE)
Unit for Rural Land Use Planning (UPRA), Colombia
University of Florida, USA
University of the Valley of Guatemala

Private sector partners

Dynamic partnerships that unite key actors in the public and private sectors are critical for conducting high-quality research and translating its results into development impact. CIAT is proud of the important contributions that its private sector partners are making to both these goals.

Colombia's National Petroleum Company (Ecopetrol)
Colombian Agricultural Company (COACOL)
Dow AgriSciences, USA
Ingredion Incorporated
Papalotla Group, Mexico
Pioneer Hi-Bred International, Inc., USA
RiceTec, Inc., USA
Syngenta S.A., Colombia

CIAT Today

The International Center for Tropical Agriculture (CIAT), working in collaboration with hundreds of partners across the developing world, develops technologies, methods, and knowledge that better enable farmers, mainly smallholders, to enhance eco-efficiency in agriculture. This means we help make production more competitive and profitable as well as sustainable and resilient through economically and ecologically sound use of natural resources and purchased inputs.

Since no single organization can address the whole of tropical agriculture, CIAT complements the efforts of others by focusing strategically on selected crops and research areas. Our scientists work globally to develop more resilient and productive varieties of two key staples, cassava and common bean, together with tropical forages for livestock. In Latin America and the Caribbean, we also improve rice production. Representing diverse food groups and a key portion of the world's agricultural biodiversity, the crops CIAT improves are vital for global food and nutrition security.

Mission

To reduce hunger and poverty, and improve human nutrition in the tropics through research aimed at increasing the eco-efficiency of agriculture.

In our research on agrobiodiversity, we rely on advanced biotechnology to accelerate crop improvement. Progress in this work also depends on unique collections of genetic resources – 65,000 crop samples in all – which we hold in trust for humanity.

CIAT works in two other key areas – soils and decision and policy analysis – which cut across all tropical crops and production environments. Our soil scientists use the latest tools and knowledge to improve soil health, restore degraded land, and make agriculture climate smart. Through our work on decision and policy analysis, we harness the power of information to influence decisions about climate change, ecosystem services, and linking farmers to markets.

CIAT scientists work in Latin America and the Caribbean (LAC) as well as sub-Saharan Africa and Asia. In LAC, we focus on several distinct environments, including Colombia's Orinoquia Region, Central America, the Amazon, and selected areas of Brazil. Our research for Africa, focusing primarily on common bean, soils, and tropical forages, supports major initiatives aimed at bolstering food and nutrition security, restoring degraded landscapes, and fostering sustainable, climate-smart agriculture. In Asia, we concentrate on cassava and tropical forages in smallholder rainfed systems of the Greater Mekong Region, while also helping curb land degradation, create beneficial market links for farmers, and cope with climate change impacts.

CGIAR global research

CIAT is a member of the CGIAR Consortium and Lead Center of the CGIAR Research Program on Climate Change, Agriculture and Food Security (CCAFS). The Center contributes importantly to other CGIAR Research Programs as well (see page 53).

CGIAR is a global partnership that unites organizations engaged in research for a food secure future. CGIAR research is dedicated to reducing rural poverty, increasing food security, improving human health and nutrition, and ensuring more sustainable management of natural resources. It is carried out by the 15 centers who are members of the CGIAR Consortium in close collaboration with hundreds of partner organizations, including national and regional research institutes, civil society organizations, academia, and the private sector.

CIAT and the CGIAR research programs

The CGIAR research programs address major issues in agricultural development around the world by aligning the work of the 15 international research centers of the CGIAR Consortium and their partners in coherent and efficient multidisciplinary efforts. CIAT contributes to 12 of these programs and is lead center for the program on Climate Change, Agriculture and Food Security (CCAFS).

Contributions that count

A large part of CIAT's work contributes strategically to CGIAR's global research agenda, as documented in many of the achievement stories presented in this annual report. In 2013, two CGIAR research programs reported breakthroughs in CIAT science among the two main highlights of their work for the year.

One of these involved research that provided "proof of concept" for the use of certain *Brachiaria* forage grasses to reduce emissions of nitrous oxide (a potent greenhouse gas), while permitting more efficient use of nitrogen applied to maize after grass pasture (see page 26). This breakthrough was widely publicized in the international news media, including an article in *Nature* magazine.

CGIAR Research Program	Led by	CGIAR Fund donors
Agriculture for Nutrition and Health	International Food Policy Research Institute (IFPRI)	Australia, Canada, IDRC, Ireland, Netherlands, Russia, Sweden, and USA
Climate Change, Agriculture and Food Security	CIAT	Australia, Denmark, Ireland, Netherlands, Portugal, Russia, Switzerland, and UK
Dryland Systems	International Center for Agricultural Research in the Dry Areas (ICARDA)	Australia, Belgium, India, Netherlands, Russia, Sweden, and Switzerland
Forests, Trees and Agroforestry	Center for International Forestry Research (CIFOR)	Australia, Belgium, Finland, Netherlands, and Sweden
Grain Legumes	International Crops Research Institute for the Semi-Arid Tropics (ICRISAT)	Australia, India, Mexico, and USA
Humidtropics	International Institute of Tropical Agriculture (IITA)	Australia, Belgium, Sweden, and Switzerland
Livestock and Fish	International Livestock Research Institute (ILRI)	Australia, Finland, India, Netherlands, Sweden, and USA
Managing and Sustaining Crop Collections	Global Crop Diversity Trust	Japan and Switzerland
Policies, Institutions and Markets	International Food Policy Research Institute (IFPRI)	Australia, Denmark, Netherlands, Russia, Sweden, Switzerland, and USA
Rice (known as the Global Rice Science Partnership or GRiSP)	International Rice Research Institute (IRRI)	Australia, China, Japan, Switzerland, UK, and USA
Roots, Tubers and Bananas	International Potato Center (CIP)	Australia, Belgium, IDRC, Netherlands, Sweden, Switzerland, and USA
Water, Land and Ecosystems	International Water Management Institute (IWMI)	Australia, Gates Foundation, Netherlands, Sweden, and Switzerland

Organigram

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Andrés Palau Central Services	**Michael Peters** Tropical Forages				
Gloria Rengifo Finance	**Edgar Torres** Rice				

CIAT's principles and values

Shared organizational ethic. We respect each other, our partners, and the people who benefit from our work. We act with honesty, integrity, transparency, and environmental responsibility in all of our joint endeavors.

Learning through partnerships. We work efficiently and pragmatically together and with partners. Considering our diversity to be a key asset, we adapt readily to change and strive to improve our performance through continuous learning.

Innovation for impact. We develop innovative solutions to important challenges in tropical agriculture, resulting in major benefits for the people who support, participate in, and profit from our work.

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Juan Lucas Restrepo
Executive Director, Colombian Corporation of Agricultural Research (Corpoica), Colombia.

[3] Official Board member since 1 January 2014.

Staff

CIAT has a total of 913 staff, including 528 professionals, of whom 325 are scientists; 740 are based in Colombia or elsewhere in Latin America and the Caribbean (LAC), while 147 are in sub-Saharan Africa, 25 in Asia, and 1 in Europe. In the list that follows, staff members are based at headquarters in Cali, Colombia, unless otherwise indicated.

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David de Abreu, Knowledge and Data Sharing Coordinator
Osana Bonilla-Findji, Science Officer

* Left CIAT during the period covered by this report.

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