INTERNATIONAL CENTER FOR TROPICAL AGRICULTURE

CIAT 50
1967–2017

Forever Pioneers

CIAT: 50 years contributing to a sustainable food future
...and counting

CGIAR

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The International Center for Tropical Agriculture (CIAT) – a CGIAR Research Center – develops technologies, innovative methods, and new knowledge that better enable farmers, especially smallholders, to make agriculture eco-efficient – that is, competitive and profitable as well as sustainable and resilient. Eco-efficient agriculture reduces hunger and poverty, improves human nutrition, and offers solutions to environmental degradation and climate change in the tropics. Headquartered near Cali, Colombia, CIAT conducts research for development in tropical regions of Latin America, Africa, and Asia.

CIAT is proud to celebrate *50 years* **of agricultural research and development impact**

In 1967, the majority of poor and hungry people in the tropics were smallholder farmers. Increasing the productivity of their crops was, therefore, the critical entry point for CIAT's research. Since that time, we have been concerned with nearly every aspect of tropical agriculture: 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. Today, we also look forward at emerging challenges, with a renewed commitment to feed the planet and offer a better deal for both farmers and consumers.
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CGIAR is a global research partnership for a food-secure future. CGIAR science is dedicated to reducing poverty, enhancing food and nutrition security, and improving natural resources and ecosystem services. Its research is carried out by 15 CGIAR Centers in close collaboration with hundreds of partners, including national and regional research institutes, civil society organizations, academia, development organizations, and the private sector.
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ISBN: 978-958-694-173-0
E-ISBN: 978-958-694-174-7

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CIAT: 50 years contributing to a sustainable food future ...and counting

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CIAT 1967-2017

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CIAT Publication No. 444
Print run: 200
October 2017

Lynam J; Byerlee D. 2017. Forever pioneers – CIAT: 50 years contributing to a sustainable food future… and counting. CIAT Publication No. 444. International Center for Tropical Agriculture (CIAT), Cali, Colombia. 140 p. Available at: http://hdl.handle.net/10568/89043

ISBN: 978-958-694-173-0
E-ISBN: 978-958-694-174-7

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Derek Byerlee, a citizen of Australia, has held senior positions at Michigan State University, USA, the International Maize and Wheat Improvement Center (CIMMYT) in Mexico and South Asia, and in the World Bank, where he was the lead author of the World Development Report 2008: Agriculture for Development*. He also writes extensively on agricultural history.*

Photos: CIAT Flickr www.flickr.com/photos/ciat/

Acknowledgments

The writing of any recent history depends on the input of a broad range of participants in that history in terms of their insights, their particular vantage points, and their contributions to that history. This is no less the case for this history of CIAT, and the two lead authors would like to acknowledge the critical inputs provided by a host of present and former CIAT personnel who generously gave their time to ensuring that the information provided here is as factually correct as possible.

The idea of writing a history of CIAT, where no comprehensive history had yet been written, was conceived by the present Director General, Ruben Echeverría. Besides being the originator of the idea, he read and commented on every draft, wrote particular pieces, and saw the work through to completion. He also assembled a support team to help the two authors. We would particularly like to acknowledge Megan Zandstra, who chased down innumerable documents, put together an expanding file of key reference documents, and basically provided us with a road map through 50 years of institutional history. Many key documents could not be found and have been essentially lost, as the period covered that transition from a dependence on paper copies to digital files, where in both cases the need for a robust archiving system was not a key priority. That problem will not limit the next version of the history in the centenary anniversary. The authors would like to acknowledge as well the key support of Ricardo Labarta and Robert Andrade in documenting the impact of CIAT's work over the half-century.

We would also like to thank Carolina Rayo Herrera, who works in the Director General's office, and who tracked down the current contacts for alumni spanning the last 50 years, which often required significant detective work. She then organized interviews either in person or via Skype or telephone with most of them. These interviews and comments on the drafts were critical to ensuring that this history is a credible, if not selective, representation of the last 50 years. The authors would like to thank the following people for their input: Cecilia Acosta, Jacqui Ashby, Dindo Campilan, James Cock, Fernando Correa, Daniel Debouck, Mabrouk El Sharkaway, Myles Fisher, Elcio Guimarães, Guy Henry, Clair Hershey, Andy Jarvis, Peter Jennings, Peter Jones, Douglas Laing, Carlos Lascano, Brigitte Maass, César Martínez, John Miles, Douglas Pachico, Michael Peters, Per Pinstrup-Andersen, Rafael Posada, Maya Rajasekharan, Pedro Sánchez, Luis Sanint, Rainer Schultze-Kraft, Grant Scobie, Carlos Sere, Jim Spain, Joe Tohme, Alberto Valdés, and Bob Zeigler. Thanks also to Cacilda Borges do Valle and Flavio Breseghello from EMBRAPA, who provided valuable reviews. Joyce Moock and Gary Toenniessen, formerly of the Rockefeller Foundation, provided useful comments on the first section. Finally, Janice Goldblum, from the US National Academy of Sciences, gave valuable support in locating documents and correspondence related to the early discussions on a tropical agricultural research center in Latin America, which subsequently resulted in CIAT.

This is only a small sample of the scientists and personnel who have been part of CIAT's history over the past 50 years. It is not possible to contact or acknowledge all who have contributed to the collective enterprise that is an international agricultural research center.

Preface

The original four international agricultural research centers (IARCs) were established with a prospective but unspecified expiry date, as the intent was that they would work themselves out of a job through capacitation of national programs. As is true of most CGIAR Centers, that has not been the case, but CIAT has evolved beyond its original aim to working on an increasing number of global challenges that lie beyond the scope of individual national programs and where articulation from local, farm-level problems and contexts to regional and global challenges is required. CIAT, and many of the other CGIAR Centers, has undergone a continuing process of institutional change and innovation to adapt to changing global challenges.

As CIAT celebrates its 50th anniversary, we need to record and assess that institutional change process by writing a history of the Center. The International Rice Research Institute (IRRI) and International Maize and Wheat Improvement Center (CIMMYT) have quite detailed histories already. The closest to a history of CIAT were the papers presented at the 30th anniversary celebration, which focused on the early development of the Center.[1] The 50th anniversary offers an opportunity to fill this void, and this volume is offered as an initial framing of the history of the institution, in the hope that it may spur further analysis and writing on this complex organization.

We can start by analyzing what goes into a history of an institution, particularly a research institution. It starts with the ideas and the context that went into the initial design of the organization and then, as in evolutionary biology, how the organization adapted, changed, and evolved in relation to what is often a dynamic external environment. Because CIAT is an IARC producing both new science and development impacts, there is an inherent complexity in the role of its key personnel, the design of the research programs, and how it sets its goals, especially as these were established in relation to potential development impact. This history attempts to combine all these elements, but must be selective. To a large extent, the overarching structure of the history provides the basis for that selectivity.

The structure of this history is relatively simple but at the same time it tries to capture some of the complexity of an IARC. The first section charts the development and evolution of the Center and focuses on how it responded to a changing external context. A significant part of this context is the changes and various reform processes within CGIAR. This relationship is complex. CIAT, as well as the other IARCs, is an autonomous international organization existing as a legal entity with its own governance. CIAT is also a member of CGIAR, where that membership status involves meeting certain conditions, which have evolved over time (and some would argue have become much more stringent). At the same time, the agricultural development context within which CIAT operates and in which it defines its mission has also changed radically over the last 50 years and varies significantly by region. Similarly, global development agendas have also evolved, which define the funding environment in which the Center must operate. Matching global agendas to evolving regional agricultural economies and needs is the context in which the Center both mobilizes resources and achieves impact.

1 CIAT. 1998. 30 Anniversary of the Foundation of CIAT, 1967–1997. CIAT Publication No. 308. CIAT, Cali, Colombia. 101 p.

How CIAT as an institution has responded to these changes in external context is the focus of the first section. This starts with an in-depth analysis of the origins of CIAT. This part of CIAT's history has not previously been written; more space is given to this than to other sections, providing somewhat of an imbalance but which the authors feel is justified. The design of CIAT (and the International Institute of Tropical Agriculture-IITA) was a radical departure from the design of both IRRI and CIMMYT, with a shift from commodity centers to eco-regional centers and a focus by CIAT on the development of the agricultural frontier in Latin America. In many ways, the design of CIAT was a product of its time, and this is covered in some depth. The rest of this section is organized around three stages, in the evolution of the Center. CIAT's Management And Board of Trustees have over its history reinterpreted the overall mission of the Center, which in turn has resulted in significant programmatic changes. The history explores the drivers and implications of this redefinition of mission and strategy. It also explores several creative tensions in the organization of the program structure, the three most salient being smallholder intensification vs. expansion of the agricultural frontier, commodity research vs. natural resource management (NRM) research, and eco-regional vs. global program development.

The second section is a survey of the individual research programs, i.e. the component parts of a research center. These have not remained constant over time, and there was some difficulty in defining research programs to assess over CIAT's history. Some had expanded or contracted over time. Some were a clustering of research themes that evolved into a programmatic strategy. At one point in CIAT's history, where there were both financial constraints and a shift to project funding, program structures were dissolved in favor of project clusters. In many ways the program structure of CIAT has been much more fluid and flexible than in most other IARCs. Nevertheless, coherence across program structures has been maintained over CIAT's history. Research programs are also utilized in this history to chart CIAT's impact on development goals and to identify innovative lines of research.

The final section was written in consultation with the current Director General of CIAT, Ruben Echeverría, and builds on these historical foundations to project the future development of the Center. Given the evolving changes in the global development agenda and the current program structure, the principal lines of institutional and programmatic evolution are outlined.

The process in writing this history went through three steps. An outline of the history of CIAT was developed and circulated among current, principal CIAT staff for comment. Two principal authors drafted individual sections, and potential interviewees for each of the sections were identified. The drafts of the individual sections (based on archives including CGIAR reports) were assembled into a first draft of the manuscript. Sections or the whole first draft report were sent to selected former and current staff for review and further input. In many cases, this also involved interviews either over the phone or in person. The interviews are documented and are available as an additional resource. The history (compiled based on feedback from former employees on the first draft) now follows in the next three sections.

Contents

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From past to present:
Major themes in the evolution of CIAT

In the 1950s, Latin America had a population growth at around 2.9% a year, higher than in any other region of the world, and stagnant food production.

The birth of CIAT

A focus on Latin American agriculture in the 1960s

The nexus of population, food, and land

The post-WWII period saw an upsurge in interest in the challenge of global food security. Indeed, the first UN conference on world food issues convened by US President Franklin Roosevelt during the war in 1943 in Hot Springs, Virginia called for an end to hunger. A major follow-up focused on the war-ravaged countries of Europe and Asia, and the founding of FAO. However, by the 1960s, there was a veritable chorus clamoring for more attention to be paid to world hunger, echoed in the FAO Freedom from Hunger Campaign (1961), the Rockefeller Foundation Conquest of Hunger program (1963) and the US Government's War on Hunger (1966).

There were several drivers of the burgeoning interest in food security. One was the rapid growth of world population that surged from over 20 million annually in the decades of the 1940s and 1950s, to 50 million in the 1960s and was projected to increase by around 80 million per year in the 1970s and 1980s. At the same time, cereal production per capita had declined in the developing world compared to the pre-war period.

Latin America was no exception and indeed population growth at around 2.9% in the 1950s was higher than in any other region of the world. With stagnant food production, per capita grain production had fallen from 254 kg in the pre-war period to 213 kg in 1957–59.[2] Tropical Latin America was also a growing importer of food in the 1950s

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2 Brown LR. 1963. Man, land and food: Looking ahead at world food needs (No. 143860). Foreign Agricultural Economic Report No. 11. Regional Analytics Division, Economic Research Service, United States Department of Agriculture (USDA), Washington, DC, USA.

and if Brazil is excluded, the deficit doubled over the 1960s. Many countries in tropical Latin America had population growth above 3% and at least eight tropical countries including Colombia, Peru and much of Central America had per capita calorie supplies of about 2,000 or less, similar to that in India and a level considered by FAO to be well below adequate energy levels.[3]

In the 1960s, there was also a major shift in thinking about world hunger from a single-minded focus on calories to protein as an equally if not more important nutritional problem. The evidence for the protein deficit was provided by published findings on the severity of protein deficiency for the Caribbean and Northeast Brazil in the 1950s and in Guatemala in 1961.[4] The UN had established a Protein Advisory Group in 1955 and FAO highlighted the problem in 1964 with their influential publication, *Protein at the Heart of the World Food Problem*, followed by a UN report in 1968, *International Action to Avert the Impending Protein Crisis*. The focus on protein gave impetus to investing in legumes and livestock in the 1960s, although by the mid-1970s, the 'protein problem' was being played down.[5]

These trends in Latin America were similar to trends in Asia at the time but with one big difference. Latin America was regarded as a region with vast tracts of underutilized land in the lowland tropics with sparse population. An estimated 40% of the area of Latin America or 850 million ha experienced good rainfall for agriculture but only 5% of this was cultivated despite estimates that about 340 million ha was cultivable.[6,7] All of the reports on Latin American agriculture at the time emphasized the potential of increasing agriculture production by bringing this land into production to not only feed Latin America but also to help feed the world. This was especially so for the estimated 250 million ha of savannas, such as the sparsely populated Brazilian Cerrados that made up about 30% of the land with adequate rainfall. As a well-known ecologist, Joseph Tosi, at the Inter-American Institute for Cooperation on Agriculture (IICA) expressed it in 1964:

> *There are fundamental and well-known reasons for proposing that high-productivity land-use systems* can *be developed for the humid tropical regions and for urging that this task be considered a high-priority item in economic development research and planning*.[8]

Not surprisingly, Latin America was commonly described as a 'sleeping giant" in reference to its favorable land base in relation to the size of its population.[9]

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3 FAO. 1965. The State of Food and Agriculture 1965. Review of the Second Post War Decade. Rome, Italy.

4 Semba RD. 2016. The rise and fall of protein malnutrition in global health. Annals of Nutrition and Metabolism, 69(2):79–88.

5 McLaren DS. 1974. The great protein fiasco. The Lancet 304(7872):93–96.

6 Turk L; Crowder LV. (eds.). 1967. Rural development in tropical Latin America. New York State College of Agriculture. Ithaca, New York. 446 p.

7 Hardin LS. 1984. CIAT as originally conceived and CIAT today: mandate, objectives and achievements. In: CIAT, Proceedings of the 10th Anniversary. Cali, Colombia.

8 Tosi JA; Voertman RF. 1975. Making the best use of the tropics. Unasylva. Vol. 27, No. 110. p 2.

9 Turk and Crowder. 1967. op. cit.

Cold War politics and foreign aid

Partly, out of humanitarian concerns in the new 'development era' and partly to combat communist influence in the emerging Cold War era, US President Truman launched his Point 4 program of foreign assistance in 1949. In Latin America, agriculture was a priority given that most insurgencies were rural, but much of the aid was focused on technical assistance to extend available (but often inappropriate) technologies.

Shortly after taking office in 1961, US President John F. Kennedy stepped up assistance to Latin America through a new Alliance for Progress. The growing ties between Cuba and the then Soviet Union quickly gave new urgency to this program. In 1961, a team led by Frank Press, a member of the president's science advisory council prepared a list of priority investments for USAID in Latin American science and technology, but there was little immediate follow up.[10] After 1962 facing Congressional criticism on insufficient attention to agriculture, the agricultural agenda became central to the Alliance for Progress.[11] Nonetheless, little of this was available for research. IDB projects in 1967 largely focused on credit and none addressed research[12] and the only USAID projects focusing on agricultural research up to 1970 were in Brazil and Peru.[13] Nonetheless, there was growing faith in science, and the US, with its huge human resource and infrastructural base in the agricultural sciences increasingly saw its comparative advantage in facilitating the transfer of scientific knowledge and building scientific institutions in the region.

Latin America on the move

Within Latin America, there was growing political interest in developing the lowland tropics. With over half the population still living in rural areas, rapid population growth and declining farm size in the highlands where most of the people lived were stimulating migration to the lowlands. The state facilitated and encouraged this migration through a swathe of colonization programs throughout the region.[14] Even without these programs, the location of strategic infrastructure such as the new Brazilian capital, Brasilia (completed in 1961 linked to the south via a highway across the Cerrados) was steadily drawing migrants into the lowlands.

The paucity of scientific knowledge to develop the lowland tropics and the weaknesses of local scientific capacity were well recognized. However, there were also examples of success. By the late 1940s, Brazil had become the first country outside of the USA to develop and widely adopt hybrid

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10 Press F. 1961. Proposed initial program for support of science and technology in Latin America. US Agency for International Development, Washington, DC, USA.

11 LASB (Latin American Science Board). 1965. Proposal for the creation of a Tropical Research Foundation. Report to AID. National Academy of Science. __Humphrey HH. 1963. A report on the Alliance for Progress to the Committee on Appropriations and the Committee on Foreign Relations. US Senate. Washington, DC, USA.

12 IDB (Inter-American Development Bank). 1967. Agricultural Development in Latin America: The Next Decade. Washington, DC, USA.

13 Alex G. 1996. USAID and Agricultural Research: Review of USAID support for agricultural research. USAID and World Bank. Washington, DC, USA.

14 Nelson M. 1973. The development of tropical lands: Policy issues in Latin America. Published for Resources for the Future. Baltimore: Johns Hopkins University Press.

maize and the first for the subtropical regions.[15] Also by 1958, Brazilian soil scientists L.M.M. Freitas and W.L. Lott, and CIAT's future Deputy Director General, Colin McClung, had carried out pioneering research that showed the potential of vast areas of acid soils of the Cerrados for crop agriculture.[16] As expressed by Latin America's most influential economist, Raúl Prébisch at CIAT's initiation of its new campus in 1973, the need of the moment was to break the "intellectual dependency" of the region. Accordingly, by the early 1960s, the National Agricultural Research Institutes, commonly known as INIAs, were being established across the region, although at the time in most countries there was an overall lack of trained agricultural scientists.

Despite the talk in the North of the tropical lands of Latin America becoming a solution to the world food problem, countries of the region looked inwards to develop their economies through import substitution supported by high trade protection – the prevailing economic doctrine espoused by Prébisch and others.[17] Outside of Argentina, Latin America in 1960 was an importer of cereals (including Brazil) and livestock products (except Brazil) so the priority was to achieve food self-sufficiency. Later studies would find that the import-substituting polices advocated by Prébisch implied a very significant implicit tax on the agricultural sector – so stagnation of investment, innovation and output in Latin American agriculture was a direct consequence. Small farmers produced most of the food, especially the cereals, root crops, and food legumes, while large farmers grew tropical commodities such as bananas, coffee, and sugar, and were involved in extensive livestock production.

The highly unequal distribution of landholdings in Latin America, the world's highest, gave rise to a debate (that continues until today) about the role of small farmers in not only providing their own subsistence but also in provisioning the burgeoning cities. A related and highly charged political challenge was needed for land reform to level the playing field for small farm-led development.[18] Although many of the colonization programs of the 1950s and 1960s espoused the development of the lowland tropics through family farms, the paucity of infrastructure and the political economy of support services such as credit and extension services frequently favored large commercial interests. These debates would shape the context for the choice of commodities and research approaches in CIAT when it was created in 1967.

A CIAT predecessor: The Colombian Agricultural Program, 1950–1967

One lineage of the ancestry of CIAT can be traced through the Rockefeller Foundation (RF) activities in supporting the agricultural sciences in Latin America. One of the earliest and best-known programs began in Mexico in 1943 under the leadership of J. George Harrar who would become the Foundation's

15 Byerlee D. 2016. The birth of CIMMYT: Pioneering the idea and ideals of international agricultural research. CIMMYT, El Batán, Mexico.

16 Freitas LMM; McClung AC; Lott WL. 1960. Field studies on fertility problems of two Brazilian Campos Cerrados, 1958–1959. IRI Research Bulletin No. 21, IBEC, NY, USA. Note that McClung and two later generation Brazilians would belatedly win the World Food Prize in 2006.

17 Prébisch R. 1962. The economic development of Latin America and its principal problems. Economic Bulletin for Latin America.

18 De Janvry A. 1981. The agrarian question and reformism in Latin America. Johns Hopkins University Press, Baltimore, MA, USA.

president during the 1960s, to support research, training, and institution building. This program would eventually grow into the International Maize and Wheat Improvement Center (CIMMYT) which was first established in 1963, by merging the Mexican program and 12 other Rockefeller and Ford Foundation-supported maize and wheat programs around the world.[19]

The Mexican program became the model for a number of subsequent RF programs in Latin America, beginning with the Colombia program in 1950, and programs in Chile from 1955 and Ecuador in the 1960s. The Colombian agricultural program (CAP), that would provide the genesis of CIAT, started with maize and wheat by transferring two RF staff members from Mexico. Lewis (Jocko) M. Roberts, a maize breeder in the Mexican program, was made the program director. Roberts was succeeded in 1959 by Ulysses J (Jerry) Grant, who had been a maize breeder in the Colombian program from 1951 to 1957 and in the RF Indian Program, from 1957 to 1959. Both Roberts and Grant would play leading roles in the founding of CIAT.

The CAP grew to become the largest RF agricultural program outside of Mexico, larger even than the RF India program. At its peak in the early 1960s, it had some 19 RF staff and over 130 Colombian staff that worked in a broad ranging research program of 7 crops, 4 livestock species, and pastures, supported by a number of disciplinary programs across different ecologies in the country.[20] A substantial part of the program was focused on the lowland humid tropics at four experimental stations and four substations located in those ecologies.[21]

There has been little evaluation of the impacts of the CAP. Undoubtedly, its major achievement was the training of a large number of Colombian scientists at the postgraduate level, as well as an active program of in-service training. By 1966, some 80 scientists had been sent for graduate degrees in the US and over 200 had received in-service training.[22] The increasing number of trained staff and the physical infrastructure built under the RF program was the nucleus for the establishment of the Colombian Agricultural Institute (ICA) (the forerunner of today's Colombian Corporation for Agricultural Research-CORPOICA) in 1963.

The CAP also carried out pioneering work on collection of germplasm, especially in maize and beans that contributed to the core of today's germplasm banks in those species within CGIAR. However, the productivity impact of CAP was patchy.[23] The research on wheat closely linked to the Mexican program was undoubtedly a success but Colombia had limited wheat areas. In the lowland tropics, the main successes were the wide adoption of hybrid maize and improved soybean varieties in the Cauca Valley and other favored areas with medium and large commercial farmers. However, nationwide, improved hybrids covered only about

19 See Byerlee. 2016. op. cit., for full details of the creation of CIMMYT. CIMMYT did not become an autonomous legal entity until 1966 and that is usually given as the date for the founding of CIMMYT.

20 Rockefeller Foundation. 1963. Program in the agricultural sciences: Annual report 1962–63. Office of Publications, NY, USA.

21 Ibid.

22 Stakman EC; Bradfield R; Mangelsdorf PC. 1967. Campaigns against hunger: Berknap Press of Harvard University Press, Cambridge, MA, USA.

23 Ardila J; Hertford R; Rocha A; Trujillo C. 1975. Returns to agricultural research in Colombia. In: Pinstrup-Andersen P; Byrnes FC. Methods for allocating resources in applied agricultural research in Latin America: CIAT/ADC workshop, 26–29 November 1974, Cali, Colombia.

10% of the total area of maize, the most important food crop, and the RF admitted that impacts on small farmers was limited.[24] The Rice Program initiated in 1958 claimed early successes in finding resistance to hoja blanca virus.

From bilateral to international centers, 1960–66

The RF had been moving from bilateral programs to regional and international programs from 1950. The Mexican and Colombian programs were closely linked through international exchanges of germplasm and research results, and both became hubs for training of scientists from elsewhere in Latin America. As early as 1951, Harrar was calling for "international integrated programs of agricultural sciences with free exchange of material, information and personnel…toward the goals of greater food production and subsequent social benefits."[25]

A critical first step in realizing this vision was the creation of the Central American maize improvement program, a forerunner to today's Central American Cooperative Program for Crop and Animal Improvements (PCCMCA), established in 1954, initially covering five countries. The program included a regional coordinator, regional trials, networking through annual workshops, and a training and nucleus-breeding program at a tropical research station in Veracruz State, Mexico. This concept was expanded in 1961 to the Inter-American Corn Improvement Program, aimed at linking maize programs throughout the Americas, including in

The RF-Mexican wheat program spurred the Green Revolution that earned Norman Borlaug the Nobel Peace Prize in 1970 and put the emerging international research system at the top of the development agenda.
Photo: Germplasm bank/CIMMYT

24 Rockefeller Foundation. 1963. op. cit. Annual reports give adoption figures for the Cauca Valley of over 85% for hybrid maize in 1962/63.

25 Harrar JG. 1963. Strategy for the conquest of hunger. Rockefeller Foundation, NY, USA.

the USA, around a hub at Chapingo in Mexico. One component of this was an Andean regional maize program that was based out of CAP. PCCMCA added a network on beans in 1965 under the coordination of the Inter-American Institute for Cooperation on Agriculture (IICA).

The RF-Mexican wheat program based at the Northwestern Agricultural Research Center (CIANO) in northwest Mexico, under the leadership of Norman Borlaug, became the first truly international research program. By the late 1950s, it was already an integrated program across much of Latin America with international trials and training and with strong links to US and Canadian programs. In 1961, through a strategic partnership with FAO, it became the International Wheat Improvement program that covered major spring wheat producers across the world through a large hub-breeding program in Mexico, a global in-service training program, and international nurseries and networking. This program was soon to spur the Green Revolution that earned Borlaug the Nobel Peace Prize in 1970 and put the emerging international research system at the top of the development agenda.

A further major institutional innovation was the establishment of the International Rice Research Institute (IRRI) in the Philippines in 1960, which become operational in 1962, funded jointly by the RF and the Ford Foundation (FF). Harrar and Warren Weaver, Director of Natural Sciences, RF first articulated this concept in 1954 after an extensive visit to Asia. However, it was not until 1958 that concrete steps were made to put the idea into practice. IRRI was created to serve the rice producing countries of Asia. The institute incorporated much of the software of international research of the wheat and maize programs in Mexico but went further in forming an independent organization with international status under Philippine law, constructing a state-of-the art research station and recruiting staff internationally, under the governance of an international Board of Trustees. The IRRI governance model and its infrastructure would become a model for the establishment of CIAT.[26]

From commodity centers to eco-regional centers, 1963–66

A significant development was a speech on 22 October 1963, by President J.F. Kennedy on the occasion of the centennial celebration of the National Academy of Sciences in Washington DC. In that speech, Kennedy stated:

> *"I look forward eventually to the establishment of a series of international agricultural research institutes on a regional basis throughout the developing world. I can imagine nothing more unwise than to hoard our knowledge and not disseminate it and develop the means of disseminating it throughout the globe."*[27]

All evidence shows that George Harrar wrote that paragraph – an extraordinary accomplishment in a relatively short speech (see Annex 1). Harrar

26 CIMMYT, which started with no legal status or campus of its own in 1963, followed the IRRI model when it was constituted as an autonomous organization under Mexican law in 1966, bringing together the international wheat improvement program and a loose federation of Rockefeller Foundation (RF)-supported maize programs, including the RF program in Colombia. Only then did it begin the process of identifying suitable land and constructing a new headquarters (Byerlee, 2016, op. cit.).

27 Kennedy JF. 1963. Address at the Anniversary Convocation of the National Academy of Sciences. 22 October 1963. Online by Peters G; Woolley JT. The American Presidency Project. www.presidency.ucsb.edu/ws/?pid=9488

had been deeply involved with NAS programs as discussed below and was by now President of the RF. By 1964, the RF, now under Harrar's leadership, was articulating this same vision of regional research centers "strategically located to deal in depth with a particular crop or set of problems".[28] This vision was further refined in 1965 in terms of setting ecological and regional boundaries for program development of the centers[29] and in 1966, defining what we now know as international public goods by "complementing national programs with more fundamental research of international importance".[30]

The next two centers created in 1967 with almost identical names were the International Institute of Tropical Agriculture (IITA) based in Ibadan, Nigeria, and the International Center for Tropical Agriculture (CIAT) headquartered in Cali, Colombia.[31] However, they departed from the CIMMYT and IRRI models as they were designed not around one or two commodities but around an important ecological zone, the humid tropics, within their respective continental regions, sub-Saharan Africa and Latin America.

Why and how did this this shift from commodities to ecological zones come about as a way of organizing research? The first step appears to have been taken by the US National Academy of Sciences in 1959 when a large number of countries in Africa were on the brink of independence. With funding from the International Cooperation Administration (a predecessor to USAID), a NAS report was prepared by a team of scientists with experience in Africa through desk reviews and workshops. Harrar was the Executive Director of this study and the agricultural team included Richard Bradfield of Cornell University who had been involved in establishing and advising the Mexican program and in designing IRRI's program. The NAS report recommended a highly ambitious program of support to at least three countries modeled along the lines of the RF country programs with attention to regional spillovers and training, and continent-wide programs such as soil mapping and control of tsetse fly in livestock. The large budget estimate of US$150 million (US$1.25 billion in today's terms) probably prevented this program from being implemented.

In 1963, Harrar and Bradfield, along with Forest (Frosty) Hill, who was vice-president of the Ford Foundation, visited Nigeria to explore the setting up of an international center for tropical agriculture to serve Africa, to complement the two emerging centers, IRRI in Asia and CIMMYT, based in Latin America. The RF had recently established a small program at the University of Ibadan as part of its university development program and the FF was supporting research in northern Nigeria. By 1965, the two foundation Boards had approved the idea of an institute for tropical agriculture focused on Africa, and the RF had charged Will M. Myers, a forage geneticist from the University of Minnesota who had spent a year in the RF program in India, as

28 Rockefeller Foundation. 1964. Annual Report. NY, USA.

29 Rockefeller Foundation. 1965. Program in the agricultural sciences: Annual Report 1964–65. Office of Publications, NY, USA.

30 Rockefeller Foundation. 1967. Annual Report 1966. NY, USA.

31 The Rockefeller Foundation funded another program for the arid lands ecological region at the University of California, Riverside, in 1964.

interim director to design the program.[32] In 1966, Myers clearly defined the program in terms of what we would call today, sustainable natural resources management.

> *The research of the Institute is to focus primarily on problems of improving food crop production in the humid tropics and on the soil and crop management requirements for developing a stable, permanent agriculture in which food crops occupy a central position.*[33]

IITA was created by decree of the Government of Nigeria in July 1967 but due to the civil war, the research program was not initiated until 1970.

CIAT conceived as a regional international center

Like IITA, CIAT had its origins in a National Academy of Sciences study. The Frank Press report on science and technology in Latin Americas in 1961 had recommended strengthening regional research and education. One recommendation that was undoubtedly prepared by Will M. Myers – the only agricultural science member of the team and a forage specialist – was to develop a regional program for tropical forages and pastures. There was little follow-up until USAID requested and funded a NAS study on agricultural research for the tropics in Latin America. The study was initiated in October 1964 by a NAS Latin American Science Board that had been established in 1963 under the chairmanship of the same Will Myers who went on to found IITA. The Board also included Kenneth Turk, an animal scientist from Cornell University (more below), John Niederhauser of the RF Mexican program, and William Paddock, author of the recently published *Hungry Nations*, as the Executive Secretary.[34] The task force consisted of 17 members of mostly mid-level scientists and with no official leader. The team did include David Timothy, who had served as a maize geneticist with the RF CAP from 1956 to 1963.

Unlike the Africa task force four years previously, the Latin American task force undertook extensive visits to eight countries in Latin America that included consultations with local scientists and policy makers. Like the Africa task force, it recommended an ambitious research agenda. The most important of these was to establish a Tropical Research Foundation (TRF) to build research facilities in three ecological zones, the humid tropics (Belem, Brazil), dry tropics (Salvador, Brazil), and temperate highlands (Cuzco, Peru), supported by a central facility for laboratory research, seed collection and administration in Puerto Rico. The name, Tropical Research Foundation, and its structure was adapted from a pre-WWII Tropical Plant Research Foundation also linked to the NAS (Box 1).

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32 He was assisted by John McKelvey of the Rockefeller Foundation, who had worked on the NAS Africa study.

33 Myers WH. 1967. Tentative scope of the scientific program. Quoted in: IITA (International Institute of Tropical Agriculture). 1992. Sustainable food production in sub-Saharan Africa: IITA's contributions. IITA. Ibadan, Nigeria.

34 Paddocks' fame today is for his 1967 doomsday book with his brother Paul, *Famine 75!: America's Decision—Who Will Survive?* This was the first of several books on the uncertain future of world food supply including Paul Ehrlich's 1968 book, *The Population Bomb*, and Meadow's 1972 book, *The Limits to Growth*.

BOX 1

Even earlier CIAT ancestors?

The idea of a center for research on tropical agriculture for Latin America dates back to 1924 when the Tropical Plant Research Foundation (TPRF) was established under the auspices of the National Academy of Science, with William A. Orton, a plant pathologist from USDA, as scientific director, and as president of the Board.[35] The TPRF with its own Board composed of five US technical experts and four business leaders, aimed to "promote research for the advancement of knowledge of the plants and crops of the tropics; to conduct investigations in plant pathology, entomology, plant breeding, botany and forestry, horticulture, and agronomy, and to publish the results thereof; and to establish and maintain such temporary or permanent stations and laboratories as may be necessary for the accomplishment of these objects."[36]. Initially, the TPRF focused on research on sugar diseases with financing from the Cuban Sugar Club, a private association of sugar companies, but over time it carried out studies on other topics in tropical Latin America, especially on soils and forests. When Orton died in 1930 and funding dried up in the economic depression, the TPRF became defunct. An unsuccessful effort was made within NAS to revive it in 1937 by transforming it into a Pan-American Institute for Tropical Agriculture for research and education in Latin America. The association with NAS and the similarity of the name and structure to the Tropical Research Foundation proposed by the 1965 Task Force of the Latin American Science Board is surely not a coincidence.

A similar institute was proposed by a pioneering leader of agricultural science in Puerto Rico, Carlos E. Chardón, Commissioner of Agriculture in Puerto Rico, 1924–30. Chardón espoused "pan-Americanism" with a vision of linking US scientists to Latin America via the Tropical Research Institute he had founded in Puerto Rico.[37] Chardón regularly undertook consultancies with other countries in Latin America and developed a proposal with the TPRF for a ten-year program to build the Colombian Ministry of Agriculture and experiment stations. In the first Inter-American Conference on Agriculture, Forestry, and Animal Industry, Washington, 8–20 September 1930, Washington, Chardón called for an agricultural tropical research station under the umbrella of the then Pan-American Union to be financed by fees levied on countries according to their population to undertake research on crops and problems of common interest, especially coffee but also food crops.[38] The proposal was endorsed by a resolution of the conference but was not implemented in the hard economic times of the depression. However, an important legacy of Chardón is that in 1929 he had been contracted by the Government of Colombia to establish the experimental station at Palmira that is today part of CORPOICA and adjacent to CIAT.

35 The Orton Memorial Library at IICA is named in his honor.

36 National Research Council. 1924. Tropical Plant Research Foundation: Its organization, objects and personnel. Washington, DC, USA.

37 McCook S. 1996. The agricultural awakening of Latin America: Science, development and nature, 1900–30. [PhD thesis]. Princeton University.

38 Chardón CE. 1930. A Pan-American Union Agricultural Tropical Research Station, Documentary Material on the Inter-American Conference on Agriculture, Forestry and Animal Husbandry, Washington, DC, Government Printing Office, Washington, DC, USA.

Each regional center within the TRF, which would initially be supported by the US Government, would have about 20 scientists and would have an explicit objective of fostering training and spillovers across political boundaries with the zone. The TRF included some of the elements of the existing international center, IRRI, but was narrowly conceived in terms of the Boards (US and host country only) and staffing and funding (US recruited).

The NAS report was submitted in March 1965 and was followed up in two ways. First, USAID, through the Alliance for Progress voiced strong reservations about the proposal and the NAS convened a panel to review the report. This panel was chaired by Harrar of the RF, and a high level team of six members – one Nobel Prize winner (George Beadle), one future Nobel Prize winner (T.W. Schultz), and three university presidents, all with strong links to the RF and Frosty Hill of the FF (Annex 1). The revised report delivered in December 1965 criticized the original task force report as being too US-centric, lacking partnership with Latin American institutions, and giving insufficient attention to institution building. The report recommended the establishment of a single international tropical research institute for Latin America with international governance and staffing similar to IRRI. RF, FF and USAID would support it (Annex 1).

The second follow-up was an international conference on the "Potentials of the Hot Humid Tropics in Latin American Rural Development" convened at Cornell University from 29 November to 3 December 1965 as part of its Latin American Year that was supported by the Rockefeller and Ford Foundations, USAID and the Carnegie Corporation. This conference brought together about 70 scientists from both the USA and Latin America with many of the presentations made by leading Latin American scientists. Cornell professors, Kenneth Turk, a member of the NAS Latin American Board, and Loy Crowder, a forage agronomist, who had recently transferred from CAP organized it. A total of seven scientists associated with the NAS task force attended, as well as key foundation personnel, notably Roberts of the RF, and Lowell Hardin, an agricultural economist with the FF who had played a key role in establishing CIMMYT. Another notable attendee and the keynote speaker was Armando Samper, a Colombian graduate in agricultural economics from Cornell, and at the time, Director General of IICA.[39]

The conference covered a wide range of topics from the crop sciences, animal science, nutrition, natural resources, the social sciences, and institutional development. Almost all speakers emphasized the vast underutilized and sparsely populated land area in the lowland tropics and the great potential of this land to support food production in the region and supply the world. Another recurring theme was the need to invest in science to realize this potential, both the natural sciences and the social sciences. T.W. (Ted) Schultz, professor of economics at the University of Chicago, in particular chastised the short-term focus of much US support to the region and emphasized the need to invest for the long term in institutional capacity. In his words "we always end up long on projects and short on viable organizations of research."[40]

39 A number of CIAT founders and early directors had a Cornell pedigree – Lowell Hardin, PhD Cornell in 1943, Armando Samper BS in 1943, Jerry Grant PhD in 1952, Eduardo Álvarez Luna in 1964, and Colin McClung in 1950.

40 Schultz TW. 1965. Transforming traditional agriculture. Yale University Press, New Haven, CT, USA.

Latin America had vast underutilized land area in the lowland tropics with great potential to support food production in the region and supply the world.

Roberts, no doubt echoing the Harrar panel report on the Tropical Research Foundation, went further in stating the case for investment in international research: "the time is right for scientists to come together in an international effort to solve problems that do not recognize national boundaries."

The conference organizers recognized that science must be deeply rooted in ecology and develop practices and systems suited to the tropics through an integrated multidisciplinary approach.[41] We can reasonably assume that over beer and coffee, the idea of a center for tropical agriculture in Latin America was further advanced based on the Harrar panel report and that a Colombia location for the new center was discussed, given the presence of Roberts and Crowder who had worked in CAP, and Samper. In many ways Colombia was a logical choice. Colombia was the poorest of the medium and large countries in Latin America; per capita calorie food supply was just 2,080 per day, and it had large areas of lowland humid tropics. It also had 15 years of RF investments in agricultural research and a core set of scientists and programs that could give the new center a running start. Finally, there was strong political support from the Government of Colombia, especially after Samper left IICA to become Minister of Agriculture in August 1966.

Roberts and Harrar visited Colombia in early 1966 and very likely the potential to locate the center in Colombia was discussed during this visit and the Government of Colombia expressed its interest in hosting the center.[42] Shortly after, at a high-level meeting of the RF, FF, and USAID in Washington, Harrar proposed Colombia as the site for the center (Annex 1).

This led to an extended visit by Roberts and Hardin in the second half of 1966 to develop a detailed proposal on the new center. The RF justified the center in terms of the potential of the "large and unexploited lowland tropics" of Latin America in increasing food production.[43] It was also made clear that this would be a different type of center based on multi-commodity systems and would be the first center that would include livestock.[44] Even so, the design of CIAT was a hybrid of CIMMYT experience in merging existing RF programs and staff and IRRI's 'greenfield approach' of building a completely new facility.

The choice of food and forage legumes and beef and dairy as the top priorities reflected the great amount of attention on the 'protein deficit' in the mid-1960s. Maize and rice were the dominant cereals in tropical Latin America but CIAT would address these through small satellite programs to the major programs in CIMMYT and IRRI. The commodity programs would be supported by a series of disciplinary programs such as soils, plant protection, animal health, animal nutrition, and agricultural economics.

All of these programs built on the long-standing RF CAP programs that were still quite large and active despite the fact that the national research institute became operational in 1963. Initially a staff of 23 senior scientists was proposed with up to 10 of

41 Turk and Crowder. 1967. op. cit.

42 Roberts L; Harrar G. 1966. Trip report. In: Rockefeller Foundation archives.

43 Rockefeller Foundation. 1969. President's Five-Program Review and 1968 Annual Report. NY, USA.

44 Hardin. 1984. op. cit.

these being potentially filled by transfers from CAP. The major exception was agricultural economics, which did not exist in CAP. Even so, and despite a great deal of discussion within the foundation about the role of institutional and policy issues such as land tenure[45] and price instability in Colombian agriculture, policy research was not included.[46]

In common with the other international centers, a major objective was to strengthen national systems and extend the Center's results through training, regional networking, and collaboration. At this stage, CIAT was envisaged almost entirely as a Latin American center serving three ecological zones, the favorable zones of the Andean region between 500–1000 m altitude, unfavorable zones of the "hot humid jungles" and areas of still unknown potential of the acid soil savannahs of the Cerrado of Brazil and the Plains of Colombia and Venezuela.[47]

Roberts and Hardin also recommended that the new Center be located near Palmira. The estimated cost of the Center was US$4–5 million for capital costs and US$3.2 million for annual operations once fully established (about US$30–37 million and US$24 in today's dollars). Roberts and Hardin cautioned that their respective foundations were investing for the long term and that patience would be needed to see impacts. In so doing they were heading off unrealistic expectations created by the spectacular early successes of CIMMYT and IRRI – 1966 was the year when the adoption of semi-dwarf varieties of the Green Revolution took off in Asia. Roberts was also probably mindful of the modest impacts on productivity in Colombia after more than 15 years' investment by the RF.

Based on the Roberts–Hardin proposals, both the Foundations and the Government of Colombia moved quickly to create CIAT. By 12 May 1967, an agreement had been reached with the Government of Colombia on the charter and statutes of CIAT. The preamble to that agreement reads:

> *The warm, tropical lowlands of Latin America, Africa and Asia offer the greatest potential of adding new lands to production. Much of the knowledge, however, which might permit rational utilization of the lowland tropics for food production remains to be developed. These tropical regions, except for export crop technology developed by colonial powers, have been largely bypassed by modern agricultural science. Consequently, an obvious and urgent need arises for strengthening those research and training programs existing in these areas to promote timely and efficient production of food of both plant and animal origin.*[48]

45 The Roberts–Hardin design study in fact specifically said that the Center would not be involved in land tenure issues although it was a major policy issue on the continent.

46 See for example, Rockefeller Foundation. 1966. Report and summary of the Agricultural Sciences Field Director's Meeting. 25–28 July 1966. http://bit.ly/2jL7ji4

47 Roberts LM; Hardin LS. 1966. A proposal for creating an international institute for agricultural research and training to serve the lowland tropics of the Americas. Rockefeller Foundation and Ford Foundation. http://hdl.handle.net/10568/72329. p 30.

48 CIAT. 1970. Legal documents. p 29. Available at: http://bit.ly/2z0RqH5

The Act of Foundation and Statutes of CIAT were officially registered on 17 October 1967 and approved by the Government of Colombia on 4 December of the same year.

The first five years of CIAT: Building the commodity programs

Designing CIAT

During the first part of 1968, Jerry Grant, and Colombian colleagues, especially Samper (until he stepped down as Minister of Agriculture) and Jorge Ortiz Méndez, Director General of the Colombian Agricultural Institute (ICA), worked quickly to build CIAT's program and infrastructure. The Government of Colombia made a major contribution to the founding of CIAT when it acquired 520 ha of irrigated land in the fertile Valle de Cauca in February 1968. This land has been leased to CIAT at a symbolic price for nearly 5 decades for agricultural research activities. Plans were immediately initiated to develop it as an experimental station and to design the headquarters.

From the governance side, a Board of Trustees was appointed and met on 28–30 June 1968. The first chair was Enrique Blair Fabris, Minister of Agriculture for Colombia, but he soon stepped down and was replaced by Francisco (Chicho) de Sola, a private businessman and Harvard graduate from El Salvador who was the founding president of INCAE, the Central American Institute of Business Management. De Sola led the Board for the critical first five years of CIAT's establishment. Other Board members were drawn from countries of the region, including four from Colombia and the president of the Inter-American Development Bank (IDB). Authors of the 1966 CIAT proposal, Roberts and Hardin represented the two of the initial donors, the RF and the FF, respectively.[49] The Kellogg Foundation was the third donor from 1969 and was also represented on the Board. Grant, who was already acting as an interim director, was appointed the first Director General in the inaugural Board meeting.

Grant, based in a temporary headquarters in Bogotá, had started working on a detailed implementation plan for CIAT that was finished by May 1968. This plan was based on reports of four review teams – pastures, plant proteins (legumes), plant starches (cassava), and animal sciences. The organizers of the Cornell conference, Turk and Crowder (also previously CAP) played leading roles in the areas of livestock and pasture, respectively. All 10 review team members were from the US, except one in animal physiology who was from Australia.

The plan document does not specify CIAT's mandate but it lists six broad objectives:[50]

1. To stimulate and facilitate the economic development of nations
2. To increase food production potentials by developing economically feasible solutions to the problems of crop and animal production and distribution
3. To facilitate rapid spread and use of improved materials and practices by developing and

49 CIAT. 1970. Annual Report 1969. Proposed Program, Staff and Budget 1968. Cali, Colombia.

50 However, the Rockefeller Foundation stated that the mandate of CIAT was to develop "agricultural systems of the tropics of the Americas with emphasis not only on crops but also on the animal species that could convert vast quantities of unused grasses and legumes to meat and dairy products." In: Rockefeller Foundation. 1969. op. cit. p 12.

employing selected social strategies and techniques

4. To contribute to the health and physical well-being of the people – rural and urban.
5. To increase the numbers of professionals and sub-professionals trained in agricultural research, production systems and effective extension
6. To develop and strengthen national institutions, public and private, concerned with the agricultural and economic development, research, education and extension.

Neither the plan nor the statutes of CIAT restricted activities to Latin America although the actual plan was very specific to the region.

The plan contemplated a staff of 32 senior staff and 60 junior staff by 1971 with an annual operating budget of US$2.72 million (about US$20 million today). The RF, FF, and Kellogg Foundation provided initial funding, with the RF picking up a large share of the capital costs. The original commitment by USAID to help fund the center did not happen until 1970.

The plan followed the Roberts–Hardin proposal in most respects but added tropical root crops and swine. The addition of root crops followed an influential paper published in 1967 that highlighted the high yield potential of root crops in the tropics relative to cereals.[51]

It is concluded that root crops should play an important role in increasing food production [in the tropics] as they have a far higher production of edible calories per day, and that these crops should therefore receive much more attention in breeding and selection.[52]

The fact that Latin America was the center of origin for cassava was also probably a factor in CIAT prioritizing cassava research that could not only serve the region but provide diverse germplasm for the planned Cassava Program at IITA. The addition of swine, which had been part of CAP, may have related to the focus of that program on using tropical roots for feed. A review paper was apparently also commissioned on the potential to include horticulture in CIAT but this was not implemented.

The initial list of commodities was broad with three tropical legumes and three root crops as in the Roberts–Hardin report. Crop and livestock improvement was to be supported by disciplinary divisions with strong emphasis on plant protection, soils, and agricultural economics. This arrangement was 'transitory' as CIAT moved to multidisciplinary teams.

The 1968 plan also recognized the original broad agroecologies in the tropics – coastal plains, savannahs, and "tropical jungle". However, and in line with the way research was organized at the time, the plan proceeded from commodities that would then be fitted as appropriate into these ecological zones. An alternative of starting with the ecologies and selecting the best commodities for these ecologies does not seem to have been considered. A vaguely defined production systems program was included under crops but not elaborated. The fit

51 James Cock, pers. comm.

52 de Vries CA; Ferwerda JD; Flach M. 1967. Choice of food crops in relation to actual and potential production in the tropics. Netherlands Journal of Agricultural Science 15:241-248. p 241.

between commodities and ecological zones would be an ongoing tension in CIAT for decades.

Building CIAT

By 1969, CIAT was up and running with an ambitious mission "to accelerate agricultural and economic development and to increase agricultural productivity in order to improve the diets and welfare of the people of the world".[53] By year end, it had hired 21 staff (with five of these as carry-overs from CAP and two RF staff recruited from IRRI), including the agricultural engineer, Lloyd Johnson, who had managed the construction of the IRRI station and would now do the same for CIAT.[54]

The original program structure designed in 1968 (Figure 1) was carried forward for the next 5 years. However, the plan to have small, complementary programs in rice, maize, and swine was dropped and all commodities were given equal standing in the organogram. Cassava soon emerged as the focus of the tropical roots unit and became a multidisciplinary program in 1972 while food legumes continued to experiment with beans, cowpeas, and soybeans until it settled on a multidisciplinary program in beans in 1972. Soils research was strongest in the beef program but CIAT in its early years did not fully develop the strong focus on soils that had been anticipated.[55]

The names of all commodity units were changed in 1970 by adding "production systems" to represent their systems orientation.[56] The beef cattle unit was evaluated as having an especially effective systems approach to exploring livestock, pasture, crop and soil interactions in its family ranch prototype in the Colombian Eastern Plains.[57] However, systems thinking was a moving target as the commodity production systems were complemented by another unit, variously named in the first 5 years as: agronomy systems, agricultural systems, agricultural production systems, and finally, small farm systems in 1973. The Center was clearly searching for a more comprehensive approach to inserting its commodity technologies into systems to enhance productivity over the long term. It was also gravitating toward a focus on small farmers that were regarded as having more complex systems due to acute resource constraints, local institutional realities, risk aversion, and food security. The Small Farm Systems Program formalized its approach in 1974 into a systematic process from analysis (or diagnosis), simulation of alternatives to validation at sites on the Colombia coast and in the Guatemalan lowlands.[58]

CIAT recognized that with such a broad mandate, it would need to prioritize carefully among commodities. The *1969 Annual Report* laid out seven criteria for doing so in what would become

53 CIAT. 1970. Annual Report 1969. Proposed Program, Staff and Budget 1968. Cali, Colombia.

54 The CAP staff were: Jerry Grant (Director), Jerome Maner (Animal Science), James M. Spain (Soil Science), and Dale Harpstead (maize breeder). Peter Jennings, rice breeder, had worked in CAP and then IRRI before joining CIAT. Lloyd Johnson and Frank Byrnes (Head, Training and Communications) also moved from IRRI. Colin McClung, RF staff and former CAP, would join in 1971 from IRRI as Deputy Director.

55 TAC (CGIAR Technical Advisory Committee) Secretariat. 1977. Report of the TAC Quinquennial Review Mission to the International Center for Tropical Agriculture (CIAT). TAC Secretariat. Rome, Italy.

56 Food Legumes was considered an exploratory thrust in the 1970 Annual Report.

57 Dillon JD; Plucknett DL; Vallaeys G. 1978. Farming systems research at the International Agricultural Research Centers. TAC, CGIAR, Rome, Italy.

58 Franklin D; Scobie G. 1974. The Small Farm Systems Program: A program document. CIAT. Cali, Colombia.

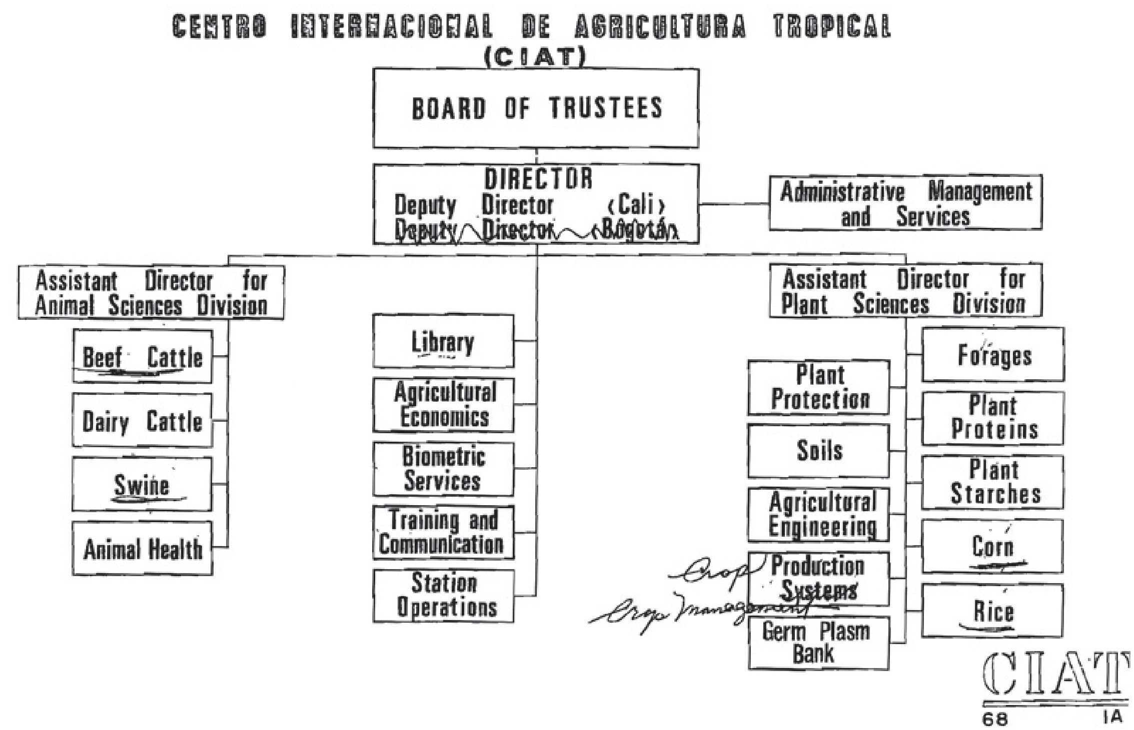

Figure 1 Original organigram of CIAT, 1968.

Note: This is the only surviving copy of the original organogram. The notes on this figure indicate much uncertainty. Forages is separate from beef cattle, and agricultural economics is seen as service function separate to the other disciplines.

Source: CIAT. 1970. op. cit.

the forerunner of many priority-setting exercises in CGIAR: (i) area and number of people served; (ii) present level of development of production systems; (iii) nutritional importance, particularly with respect to protein; (iv) significance for economic growth of country or area; (v) income redistribution effects; (vi) expected time of program impact; and (vii) activities of national agencies and other international or regional Centers.[59] CIAT followed this with a workshop on research resource allocation in applied research in 1974.[60] It also pioneered analysis of specific crop research priorities through field level surveys of crop yield losses and animal disease losses.[61] These contributions reflected the exceptionally strong team of economists hired by CIAT in its early years – Per Pinstrup-Andersen, later DG of the International Food Policy Research Institute (IFPRI) and World Food prizewinner in 2001, Grant Scobie, later DG of CIAT, and Alberto Valdés, later a Senior Adviser in the World Bank.

Perhaps as important as the research, CIAT immediately launched a large and comprehensive training program that attracted 56 professionals from the region in its first full year of operation (1969), about half of whom were undertaking postgraduate studies. By 1974, the number of trainees annually had grown to a truly impressive 162. The training program was complemented by strong information services, including the library and several regional and international conferences. Many of these activities were supported through the Kellogg Foundation, which not only built the training and conference facilities but also provided significant operational budget.

A landmark achievement during this period was the completion and the inauguration of its new headquarters near Palmira, the current site of CIAT, on 13 October 1973. The Center chose to celebrate the occasion through a high-level symposium on the "Potential of the Lowland Tropics", including addresses by: Lewis Roberts, Armando Samper (recently elected chair of the Board of Trustees), Galo Plaza (former president of Ecuador and president of the Organization of American States), and Raúl Prébisch (Latin America's best-known economist). Notably, this symposium reiterated the big picture vision for CIAT in the Latin American tropics to address the "vast regions of tropical lowlands with great potential for agriculture" with little attention to the six commodities that were by now the bread and butter of CIAT's research.

Outreach programs

CIAT research was closely focused on Colombia during the early years. Networking and training activities were strongest in the Andean region through its regional maize and bean networks. However, after reaching its initial staffing complement and moving to its new headquarters, CIAT began active discussions on engagement with the region. Stakeholder consultations were held with donors and regional organizations, and a major cassava conference in 1972 set research priorities for the crop and a similar conference in 1973 for

59 Pinstrup-Andersen P. 1974. Toward a workable management tool for resource allocation in applied agricultural research in developing countries. Paper presented at the Ford Foundation Meeting for Program Advisors in Agriculture, Ibadan, Nigeria.

60 Pinstrup-Andersen P; Byrnes FC. 1975. Methods for allocating resources in applied agricultural research in Latin America: CIAT/ADC Workshop, 26–29 November 1974, Cali, Colombia.

61 Ruiz de Londoño N; Pinstrup-Andersen P; Sanders JH; Infante MA. 1978. Factores que limitan la productividad de fríjol en Colombia. CIAT, Cali, Colombia.

beans led to the formation of the Latin American Bean Program, organized into three ecological regions similar to the original zoning of tropical Latin America.[62] A major conference on beef cattle in 1974 helped elevate the role of animal nutrition in the program.[63] CIAT also organized its first outreach office in Guatemala in 1973 in collaboration with the national research institute, with special funding from the RF.

More fundamental research was pursued through partnerships with advanced research organizations. The largest of these was a collaborative project with Texas A&M on hemoparasites in cattle, but CIAT also started to receive visiting scholars from the UK and the Netherlands. In 1973, CIAT received its first research fellows from West Africa and Asia and by 1974, CIAT was recognizing the relevance of its work for those regions.

CGIAR and TAC

A major milestone in the external environment was the creation of CGIAR in 1971. This had two immediate implications for CIAT. First, the funding was now channeled via CGIAR. By 1970, the USAID that had committed to fund CIAT at the beginning finally joined as a donor; by 1974, CIAT received funding from nine donors including the World Bank that chaired CGIAR.

Second, TAC was very active in the early years in setting the overall direction for the CGIAR System. Food legumes were on almost every meeting agenda, given the ongoing priority to increasing protein in human nutrition. During this period, CIAT and IITA had active legume programs and the International Crops Research Institute for the Semi-Arid Tropics (ICRISAT) was founded in 1972, also with a focus on legumes. There was considerable discussion of creating a new Center for legumes, a strategy favored by TAC member and a father of the Green Revolution, M.V. Swaminathan, from India. Others, including Lewis Roberts, a consultant to TAC, favored distributing the legume programs across the centers. By 1973, beans had clearly been allocated to CIAT and cowpeas to IITA. Soybeans was left for further study with the University of Illinois making a strong pitch for CGIAR to fund its international soybean network. In the end, CIAT discontinued its small effort in soybean, and IITA became the major center for soybean. IICA, under which Armando Samper had strongly supported the creation of CIAT, also made a pitch for funding its bean network in Central America and beef research, in direct competition with CIAT. In the end, TAC declined the support and IICA joined as a partner in the new Latin American bean improvement program.

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62 TAC (CGIAR Technical Advisory Committee) Secretariat. 1973. Proposal for the establishment of a cooperative program for field bean research in Latin America and the Caribbean zone. TAC Secretariat, Rome, Italy.

63 CIAT. 1975. Proceedings of the Seminar on Potential to Increase Beef Production in Tropical America. Cali, Colombia. 18–21 February 1974.

In search of the Green Revolution in upland crops (1973–1990)

A multi-commodity international crop research center

The formation of CGIAR in 1972 led to the creation of four more Centers by 1975 with the continuing objective of ensuring global food security.[64] The first CGIAR System Review in 1976 framed its assessment in terms of the food production needs of developing countries. Expansion in the CGIAR System, therefore, focused on food commodities and regions of actual or potential food deficit. The emerging priority was in generating a Green Revolution in rain-fed, upland areas, especially where crops other than rice and wheat were grown. At issue was how best to organize international research around this agenda, and the System Review focused on three principal dimensions: the balance between commodity and systems research; inter-Center program linkages; and the balance of research with national programs. For the first dimension, the Review noted that, "interdisciplinary commodity research, including off-campus cooperative research with national programs is the dominant activity at the (four) developed centers."[65]

In addition to the growing investment in CGIAR, there was large donor investment in developing national agricultural research capacity, especially in sub-Saharan Africa. This in turn created large demands on Center training programs. As the 1976 System Review noted, "The research program of a center or related activity should achieve a functional balance between the major

64 The four new centers were CIP, ICRISAT, ILCA, and ILRAD.

65 CGIAR (Consultative Group on International Agricultural Research). 1977. Report of the Review Committee. CGIAR Secretariat. Washington, DC, USA. p 76.

program thrusts. For most centers, these include commodity research, often framed within a systems approach, cooperation with national programs, other off-campus activities involving interactions with advanced research institutions, training, and conferences."[66] The review was concerned that restricted funding was distorting program balance toward cooperative activities and suggested that, "It is not difficult to state an appropriate principle for Centers. The central thrust of each Center should be to engage in research and technology development and to cooperate with national research and production programs to the extent necessary to further the Center's own research activities."[67] This concept of program balance was at the heart of the next phase of CIAT program development.

A characteristic of CIAT's development over the last 50 years is that the Director General has always played a leading role in setting the strategic direction of the Center, although this had to be aligned with both the fiscal and scientific environment of the time. Sometimes it would be evolutionary and sometimes quite radical programmatic change. As John Nickel who was appointed DG in 1974 pointed out, "A research director must be more than a manager and a leader; he must be a strategist." [68] He was a RF staff member, first serving as part of the RF's Universities in Development program as the first Dean of Agriculture in the University of East Africa in Uganda and then with the creation of IITA, transferred to become Deputy DG for Research. Nickel would serve for 15 years at CIAT (just short of the combined tenure of the next three DGs) and came from IITA with a clear vision of the changes he would introduce, i.e. organizing CIAT around the concept of interdisciplinary crop research programs. Nickel consolidated the research programs begun under Grant by integrating the disciplinary units within four commodity programs: cassava, beans, rice, and tropical pastures, – in effect creating four mini CIATs.

Three factors can be posited as the rationale for narrowing the scope of CIAT's research program: the success of the Green Revolution research model; the critical mass needed in a research program; and an organizational structure required to develop truly interdisciplinary research teams. The Green Revolution research model consisted of the centrality of the crop improvement enterprise, supported by a large pool of genetic resources and an international varietal testing system. How to effectively do this for rain-fed crops was to become a central challenge for research organizations for the next couple of decades. There was a difference in approach in how production systems research – central to achieving the yield gains from breeding – would be integrated with the breeding, i.e., whether to have separate systems and breeding programs or a single integrated program. For CIAT this also depended on having sufficient critical mass in each of the commodity programs, which forced a reduction and focusing of the research programs. Finally, Nickel's experience in both university and IITA contexts suggested inadequacies in "matrix"

66 Ibid. p v.

67 Ibid. p 80.

68 Nickel JL. 1989. Research management for development: An open letter to a new agricultural research director. IICA, San José, Costa Rica. p 99.

approaches to organizing research.[69] CIAT, in many ways was unique among the IARCs in developing and adapting the model of the interdisciplinary crop research program within a multi-commodity Center.

Interdisciplinary crop research programs

Nickel's first term saw a significant restructuring of CIAT. This included a major reduction in the number of research programs, the assignment of all research scientists to one of the four commodity research programs and the incorporation of integration of training and outreach programs into each of the commodity programs. Unlike at IITA, maize research was devolved to CIMMYT and CIMMYT maize scientists working on the Andean Zone were based at CIAT (Box 2). There would be very little research interaction with the maize program, where a particularly promising area was joint breeding for maize and climbing bean intercropping systems in the Andes and Central America. Although the *1976 Quinquennial Review* had noted that CIAT "had become unique among International Centers in having research programs on both crops and livestock." (p 4), the Swine Program was phased out during the 1975 to 1979 period and the Beef Program, which included a significant veterinary research component, was restructured to focus on tropical pastures – cattle nutrition and grazing system management would remain part of the Pasture Program (see Box 3). Whereas the Quinquennial Review had recommended that research on the tropical forest margins should not proceed until progress had been made on the savannas, the Pastures program under its new director Pedro Sánchez (who had just written the primary text on tropical soils) expanded its scope to include pasture rehabilitation in formerly cleared humid forest areas. Similarly, the Rice Program expanded its scope in 1976 from a focus on irrigated areas to include upland areas.

69 John Nickel wrote an early paper on research management that was over time developed into a book. It is useful to quote from that paper on how the university and IITA experience shaped his thinking: "Merely placing a breeder, a pathologist and an economist together in the same team does not automatically ensure interdisciplinarity. Without some 'organization coercion', the individual scientists may continue to think and work within their own disciplines and remain multidisciplinary. In my opinion, in many agricultural research institutions such organizational coercion can best be accomplished by eliminating the matrix and organizing the research scientists into interdisciplinary programs along commodity lines. I have managed all three types: i.e., a coordination matrix in a university context; a leadership matrix, with the "woof and warp" cross-hatching of disciplinary departments and commodity-oriented programs; and, more recently, an interdisciplinary organization in which all scientists are assigned to one commodity program or another... The simplicity of the chain of command and the loyalty and motivation that come from building an effective team effort around a single commodity or set of related commodities give this type of organization great advantage when it can be achieved." Nickel JL. 1983. Agricultural research management. Paper for Workshop on Agricultural Policy and Management in the Caribbean. Port of Spain, Trinidad.

BOX 2

Maize versus rice in CIAT

The original design for CIAT included maize and rice but only as small units that would link to the respective global programs already established at CIMMYT and IRRI. In both cases, RF scientists had worked on these crops in Colombia and were logically mapped to CIAT (Peter Jennings who had initiated IRRI's rice breeding then headed CIAT's Rice Program). However, in the early years, the trajectories of these units diverged sharply. Rice evolved into one of the four commodity programs and went on to become one of the most important programs in CIAT (see p. 72). By contrast, the status of maize in CIAT remained ambivalent in the early years and was finally transferred to CIMMYT as the lead Center with a base in CIAT, in 1975. The RF maize breeder, Dale Harpstead, had been based in Colombia and after the establishment of CIAT his program, including the Andean Regional program and considerable research on quality protein maize, was extensively reported in the CIAT Annual Reports. Harpstead was listed in the CIMMYT staff list but not in the CIAT staff list.

The transfer of maize to CIMMYT reflected a number of factors. Unlike IRRI, CIMMYT was based in the same continent, and germplasm from Mexico and Central America was useful in much of the Andean zone as well. In addition, CIMMYT had a mandate to work on highland maize that was not in the CIAT mandate. Finally, there were differences early on in philosophy between CIAT and CIMMYT. CIAT was already targeting low-input, small-scale farmers while CIMMYT at that time focused on high-input farming and did not support practices such as intercropping that were common in the region and had implications for crop research priorities. The CIMMYT/CIAT program that eventually emerged enjoyed considerable success especially when it turned to the challenge of maize varieties and hybrids for the acid soil savannas.

CIAT developed and adapted the model of the interdisciplinary crop research program within a multi-commodity Center.

The crop research programs developed strategies for their commodity with clearly defined objectives. They integrated economists and farming systems research into the program. The head of the research program was known as the Program Leader and was selected for their leadership skills. There was no joint research developed between the programs, because each focused on very different agro-ecologies and because these were managed as independent programs.[70] Interdisciplinarity was developed within each of the programs, so that each discipline understood what the other brought to achieving the program objectives and these skills were valued within the program. This produced very tightly integrated teams, which in turn developed something of a constructively critical internal competition between the four CIAT programs. At this point, given that CIAT primarily depended on unrestricted funding, this was not competition for funds but rather for advances in both the science and the impact. A comparative framework developed which allowed the programs to understand differences in research orientation and to take on board those innovations that seemed useful for other programs.

This basic structure did not change for the 15 years of Nickel's tenure. In its 1985 *CGIAR Priorities and Strategies*, TAC reaffirmed the approach: "In looking at the challenges that will confront international agricultural research in the future, TAC has concluded that the multidisciplinary commodity approach should continue to be the central research thrust within the CG System and, indeed, should be strengthened further."[71]

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70 The one exception was the development of acid-tolerant rice varieties as a crop for pasture establishment in the savannas.

71 TAC (CGIAR Technical Advisory Committee). 1986. TAC review of CGIAR priorities and future strategies, TAC, Rome, Italy. p 62.

BOX 3

The Swine Program

During its first decade, CIAT had two livestock programs, Beef and Swine. The Swine Program was small with two international staff. Although pork accounted for less than 20% of meat consumption in the region, the program was justified by its perceived importance to small farmers in the lowland tropics, both for subsistence and for cash income. The program, originally known as the Swine Production Systems program, focused on swine nutrition using locally available feed materials to substitute for imported cereals. These included various by-products such as molasses, rice polishings and banana waste; but above all the program emphasized the use of cassava as way of stimulating demand for another of CIAT's commodities. The research examined the minimum cost rations in terms of both energy and protein. For protein, the program explored the use of emerging commercial varieties of quality protein maize from the CIAT/CIMMYT Maize program carrying the *Opaque 2* gene discovered in the 1960s. Later, in collaboration with the University of Guelph, it explored microbial protein based on cassava fermentation.

After an external review in 1974 by one of its main donors, IDRC, the program included a strong focus on training swine research and extension specialists and providing technical assistance to swine research and development programs in the Andean countries and Costa Rica. The training course reached 88 professionals from 1969 to 1978, including two each from Nigeria and Thailand, both major cassava-producing countries. The course was very practical with over half of the time spent working in medium to large swine operations in the Cauca Valley. On returning to their countries, these trainees formed the nucleus of the outreach program within the region that sought to upgrade herd quality through in-country breeding and nutrition improvement. In 1979, the program also undertook a number of farm surveys to characterize the swine sector and identify its major constraints.

Although the Swine program was endorsed by the 1977 EPMR, its strategic value was increasingly questioned within CIAT. Accordingly, the Swine team prepared a review and plan of action in 1978 that emphasized scaling up its existing research, training and regional cooperation activities. It also recommended a doubling of its size and budget within three years to implement the plan. Prophetically, they ended by noting that, "The Swine Commodity Team would like to emphasize that the status quo is an untenable position". Soon after the CIAT Board decided to depart from the status quo and terminated the program.

The rapid developments in biotechnology, beginning with tissue culture techniques in the late 1970s, forced a departure from the interdisciplinary crop research programs, as the Biotechnology Research Unit (BRU) was created in 1985 as a linkage point to the rapid progress being made in the field. CIAT would have a long history of creating and disbanding different types of research units through succeeding periods, but the BRU and the Agroecological Studies Unit (AESU) would remain the two constants from the early days. The BRU would support and augment the breeding programs in the four commodities and the AESU would help to ensure better targeting and prioritizing of the germplasm collection, breeding for heterogeneous upland areas, and varietal testing.

CIAT and small farmers

In Latin America, the highly skewed distribution of land and the concentration of small farmers on more marginal land had spillover into the political arena of agrarian reform. A 1961 law in Colombia had established the Colombian Institute of Agrarian Reform (INCORA) in the Ministry of Agriculture and Rural Development. One of the core characteristics of the international centers were that they were apolitical and the Roberts-Hardin proposal had reaffirmed this by stressing that CIAT would not be involved in the land reform question. Rather CIAT would give particular consideration to improving productivity of small farmers. These considerations gave impetus, together with support from the Ford Foundation, to the creation of the Small Farm Systems program in 1973, as an evolution of the Agricultural Production Systems program, which was designed to foster more systems research but was not particularly oriented towards small farmers.

The initial assessment of the Green Revolution quickly focused on second generation problems and a principal issue was addressing equitable access to new technology, with implications for the nutritional benefits from new technology. The issue was particularly problematic in Latin America given the skewed land distribution. The first impact study of CIAT-produced technology was done by Grant Scobie (who had moved from the Small Farm Systems Program after its closure to the Rice Program) and Rafael Posada in 1976, who studied the impact of improved rice technology in Latin America, with a particular focus on Colombia. Their findings noted that, "the group most negatively affected was the small (i.e., low income) upland producers. For these producers, the annual average income foregone through lower rice prices (and no compensating technological change) represented a high proportion of their assumed 1970 income."[72] Upland production was constrained by poor soils and irregular rainfall, and the potential for productivity increase was limited. Rather the impact came in the irrigated and rainfed areas which were dominated by medium and large scale farmers.

The intent of the Small Farm Systems program was to "integrate the efforts of the commodity production systems programs in the context of the whole farm unit."[73] This would be done through interdisciplinary teams within the program. The Small Farm Systems program aimed to introduce a higher order integrative function

72 Scobie G; Posada R. 1977. The impact of high-yielding rice varieties in Latin America: With special emphasis on Colombia – A preliminary report. CIAT, Rice Program, Cali, Colombia. 218 p.

73 Franklin D; Scobie G. 1974. The Small Farm Systems Program: A program document. CIAT, Cali, Colombia. p 10.

into a programmatic design based on independent commodity research programs. This problem was intermixed with two other basic questions. The first was the technology design question – particularly whether agricultural technology could be specifically designed for small farmers. This in turn was linked to the second question, i.e., the role of economists (and social scientists) in international agricultural research Centers and whether this role included *ex ante* appraisal of technology in the technology design process. The debate within the Center over these questions was reflected in a paper and response at an International Conference on Economic Analysis in the Design of New Technology for Small Farmers held at CIAT in 1975. The paper by James Cock (the leader of the Cassava Program) entitled *Biologists and Economists in Bongoland* generated this question from Reed Hertford – who would become chair of the CIAT Board of Trustees – "Why is it that the role of economics in the international Centers in Latin America has not yet been clearly defined? Why are economists still searching for their place?"[74] Was there a disciplinary, economics research agenda that extended beyond just the design and evaluation of new crop technologies? A separate economics program, or even the Small Farm Systems Program (where social scientists predominated), ran counter to Nickel's vision of interdisciplinary crop research programs. The Small Farm Systems Program was the first program that was closed in 1975. The three original economists were incorporated into the commodity programs, who for various reasons left CIAT in the mid-1970s. The next generation of economists would continue to evolve their disciplinary role in multidisciplinary crop research programs.[75,76]

There were two further dimensions to the equity debate in CIAT. Both cassava and beans were essentially small farmer crops and unless there were incentives for large farmers to take up the technology, the benefits of new technology would go essentially to small farmers.[77] In many ways, the principal impact on small farmers in the Bean Program were achieved in Africa and for cassava, in Asia. The second dimension was CIAT's philosophy of producing low-input technology. The initial argument for this was more efficient use of the limited inputs available to small farmers, particularly for beans and cassava. The approach, however, was also found to

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74 Cock J. 1979. Biologists and economists in Bongoland, with comment by Reed Hertford. In: Valdes A; Scobie G; Dillon JL. (eds.). Economics and the design of small-farmer technology. Iowa State University Press, Ames, IA. p 76.

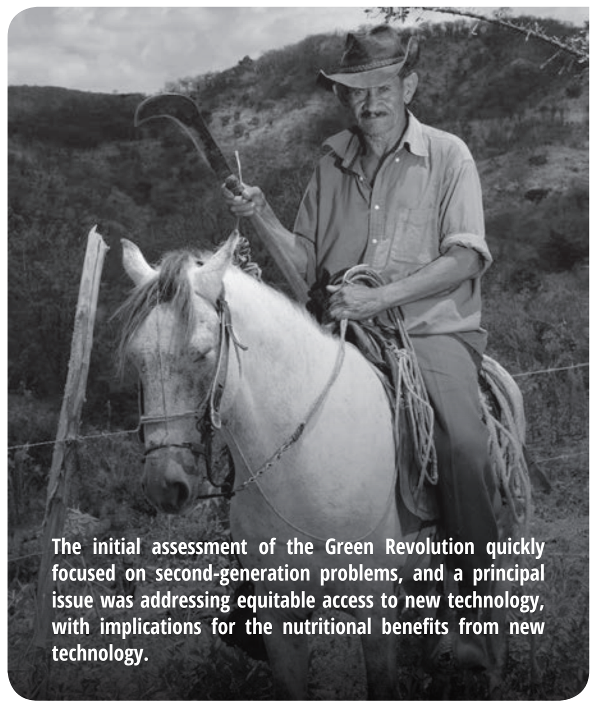
75 For a more detailed review of the factors that went into the closing of the Small Farm Systems Program, see: Holland D; Ashby J; Mejia M. 2002. Growing social research in CIAT, 1968–2002. Paper presented at the Social Research in the CGIAR Conference "Looking to the Future, Learning from the Past", 11–14 September 2002, CIAT, Cali, Colombia.

76 The 1978 *Stripe Review of Farming Systems Research* had these observations on the Small Farm Systems Program: "The Small Farm Systems Program was discontinued in 1975. In the Review Team's judgment, this became inevitable (with hindsight) because of the combined effect of the following factors: it was too ambitious in scope; it overemphasized both formal systems methodology and computer modeling; and its focus was more that of a rural development program than of farming systems. In such terms, the Review Team sees CIAT's decision as correct. Moreover, CIAT's geographical area is so diverse in ecological, institutional, economic, and social conditions as to make any widely relevant in-depth study of whole farm systems on small farms impossible within the scope of reasonable budget limitations. For a center such as CIAT, the comparative advantage obviously lies with a commodity approach aimed at the production of components to be integrated into whole-farm systems via local institutions. This gives the advantages of a multidisciplinary approach within the frame of a focus that is both relevant and achievable. Moreover, it places the concern for small farmer impact within the commodity teams." (Annex 2, p 4).

77 There was a question in cassava, however, of the effect of opening industrial markets, such as ethanol in Brazil, and the response of large-scale producers.

be economically viable for larger farmers in frontier areas, with limited transport infrastructure and high cost of inputs. This conceptual framework would later be turned on its head in the Brazilian Cerrado, where the technology for acid, infertile soils relied on the high use of inputs, particularly lime and fertilizer, and this was supported by both credit subsidies and road infrastructural investment. The approach to low-input technology depended primarily on germplasm adapted to principal edaphic and biotic constraints. Legumes in the system and associated nitrogen fixation were also promoted, particularly the combination of adapted grasses and legumes in improved pastures. Finally, "an important component of a low-input research strategy is on-farm testing" that would lay the base for CIAT's leadership in participatory on-farm research.[78]

As CIAT focused on the organization of its research programs, farming systems research was at its formative stages in CGIAR, in many respects building on experience in Latin America. Plan Puebla initiated in 1967 in Mexico was perhaps the originator of on-farm research for small farmers, followed by the IDRC-supported Cáqueza project in Colombia started in 1970, and the USAID supported farming systems work at CATIE, which began at about the same time.[79] Farming systems research was incorporated into the Bean and Cassava Programs and was built on the recognition of agronomy and social science as important components of commodity research teams. The Pasture Program focused on developing diagnostic baselines by which to monitor progress in the complex cattle ranching systems. For cassava, this work evolved into an integration with postharvest processing and market development that were viewed as essential for achieving impact.



The initial assessment of the Green Revolution quickly focused on second-generation problems, and a principal issue was addressing equitable access to new technology, with implications for the nutritional benefits from new technology.

Pursuing global mandates

The 1980s were a period of strong shifts in global agendas. The Independent Commission on International Development Issues – the Brandt Commission – in 1980 focused on the divide between the North and South and brought poverty

78 Nickel JL. 1987. Low-input, environmentally sensitive technologies for agriculture. Grant F. Walton International Lecture presented at Rutgers, The State University of New Jersey. 16 October 1984. CIAT, Cali, Colombia. p 16.

79 See: Escobar G. 2000. My initiation into FSR in Latin America. In: Collinson M. (ed.). A history of farming systems research. CABI Publishing Wallingford, UK.

more clearly onto the global agenda. In 1983–1985 there was a major famine in Ethiopia, which put the world's focus on sub-Saharan Africa, as reflected in the first CGIAR John Crawford Memorial lecture in 1985 by Robert McNamara, which focused on the continent.[80] The situation in Africa raised the issue of sustainable management of the natural resource base. These emerging issues were reflected in a change in the CGIAR's new goal statement: "Through international agricultural research and related activities to contribute to increasing sustainable food production in developing countries in such a way that the nutritional level and general economic well-being of low-income people are improved."[81] This represented a major expansion in the objectives by which international agricultural research would be assessed. CIAT was already responding to these emerging agendas. The 1981 Strategic Plan stated: "CIAT has identified limited resource producers and consumers, that is, the rural and urban poor, as the principal beneficiaries of its work. This decision clearly associates human welfare objectives with production goals and influences the design of technology." Moreover, sustainable production goals were compatible with the low-input research orientation.

The 1980s marked the programmatic expansion into other regions, particularly sub-Saharan Africa and Southeast Asia. CIAT started the process of developing a bean research network in East and Southern Africa in 1983. The focus was small-scale, semi-subsistence farmers and the research encountered a similar context to Latin America, namely a remarkable heterogeneity in grain size and color preferences and in the distribution of principal pest and disease constraints. The breeding work initially focused on varietal assessment in the region and bulk breeding at CIAT and this rapidly evolved to doing most of the breeding in the African region, although backed up by pre-breeding for particular constraints at headquarters. The expansion into Southeast Asia was more focused and built on the national program capacity in Thailand that had previously been developed through the Cassava Program's training program. A regional liaison cassava scientist was based in Los Baños in 1977 before an office was established in 1983 in Thailand. The germplasm flow and breeding activities would set the stage for the first yield take off in cassava in Thailand that spilled over to other countries in the region.

By the time of the EPMR in 1990, TAC was beginning to question the longer range viability of the 4-in-1 commodity research program model, particularly in relation to the expanding set of CGIAR objectives, as expressed in this comment: "TAC would welcome more information from CIAT as to the justification for the retention of its ongoing programs, and the exclusion of possible new initiatives."[82] A change in Director General would in fact move CIAT into developing some very different initiatives in the next phase of its development.

80 McNamara R. 1985. The challenges for sub-Saharan Africa. Sir John Crawford Memorial Lecture. Washington, DC, USA.

81 TAC (CGIAR Technical Advisory Committee). 1986. op. cit. p xvi.

82 TAC (CGIAR Technical Advisory Committee). 1990. Report of the Fiftieth Meeting of the Technical Advisory Committee. TAC Secretariat, Rome, Italy. p 11.

Adapting to the sustainability agenda and organizational flux

The years from 1991 to 2008 was a period of quite radical organizational and programmatic change at CIAT. As the 5th EPMR in 2000 noted, "CIAT has undergone more changes over the years than perhaps any other CGIAR Center."[83] There was significant program restructuring throughout the period, in part due to increasing dependence on restricted funding. Programmatically, however, the continuing challenge (as noted in the three EPMRs during the period) was "to integrate natural resource management research with CIAT mandated commodities in regional programs." This has been a challenge for the larger CGIAR as a whole, but CIAT is in many ways a microcosm of the difficulties inherent in integrating commodity and NRM research.

The phase change from a four-in-one commodity Center back to an eco-regional Center with integrated commodity and NRM programs began in 1990 with the selection of Gustavo Nores as the Director General and the production of a new strategic plan in 1991. Nores joined CIAT in 1976 as the economist in the Beef program and would rise through the ranks to become Deputy Director General and then Director General. This strategic plan was a direct response to the emergence of sustainability on the global agenda, coming out of the Bruntland report in 1987, and coincided with the UN Earth Summit in Rio in 1992. The response at the level of CGIAR was to expand the number of Centers, adding what have been characterized as the NRM Centers. The expansion increased the number of strategic objectives of CGIAR, adding sustainable management of the natural resource base to food security and an increasing emphasis on poverty

83 TAC (CGIAR Technical Advisory Committee). 2001. Report of the Fifth External Programme and Management Review of the Centro Internacional de Agricultura Tropical (CIAT). TAC Secretariat, Rome, Italy.

alleviation. The shift from a primary emphasis on commodities significantly complicated for TAC the task of budgeting and priority setting. This problem was refined into what was termed the eco-regional approach. In particular, "TAC saw the integration of continued research on genetic improvement with increased research on the conservation and management of natural resources as one of the organizational challenges facing international agricultural research in the future."[84] In many respects, that challenge remains to today, as it does for CIAT.

The strategic shift during a period of uncertain and declining core funding would have repercussions on CIAT research programs and management for the next decade and a half, especially reflected in a continuing series of changes in the organizational and program structure. The genesis of this organizational instability was reflected in the production of two strategic plans in the span of just two years. Nickel at the end of 15 years as Director General decided to produce a strategic plan to close out his tenure. In that plan, there was a section on sustainability with the leading question of "what role is appropriate for an IARC to have when dealing with the related issues of sustainability and environment?" The answer was to focus on sustainable production systems through adapted, low-input technologies developed within the four commodity programs. However, it was suggested that "serious consideration should be given to developing a research program dedicated to one or more major ecosystems". This possibility became the central organizing framework for the strategy that was written a year and a half later under the direction of Nores.

The 1991 strategic plan returned to many of the design elements in the original proposal of Roberts and Hardin. In particular, "CIAT is fully prepared to assume the role of an eco-regional research center," where the focus would be on target agroecologies in Latin America that "are linked by an underlying theme central to tropical American agriculture: the problems and opportunities of frontier development."[85] The plan was in many ways a model of an eco-regional approach, anticipating many future developments across CGIAR. It integrated the three principal dimensions that continue to drive the organization of international agricultural research: region, agroecology, and production system, particularly combining "commodity and resource management into an integrated systems approach." The plan proposed the creation of three agroecology-based programs: forest margins, savannas, and hillsides – supported by a cross-cutting program on land use, which built on the database development and spatial analysis done in the Agroecological Studies Unit (AESU) created in 1982. The aim was to integrate the commodity research into the target agroecologies by working at and integrating different scales of analysis – and by building on what was learned in the Small Farm Systems Program. This is captured in the following:

> *We are aware of the pitfalls of a systems orientation per se that could easily result in endless systems analyses and location-specific research activities. Thus, we will seek to identify practical and relevant entry points into agricultural production systems. Work*

84 TAC (Technical Advisory Committee) Secretariat. 1987. CGIAR Priorities and Future Strategies. TAC Secretariat, Rome, Italy.

85 CIAT. 1991. CIAT in the 1990s and beyond: A strategic plan, 2 parts. Cali, Colombia. Part 1. p 23.

on these entry points will be undertaken with a c1ear perspective concerning the physical, biological, socioeconomic, policy and land use dimensions that may impinge on technology options. That is, throughout the process, a macro agro-ecosystems perspective will be combined with a micro-production systems perspective.[86]

The idea of entry points was emphasized in the 2000 EPMR as particularly innovative in CIAT's systems approach.[87]

Major organizational change is challenging at the best of times but this took place in a declining funding context – the CGIAR expansion to include the NRM Centers, at the same time as a decline in overall donor support to agriculture. There was also a notable shift to project-based funding and concurrently a shift in that funding to sub-Saharan Africa. Moreover, the interdisciplinary commodity research programs were well-balanced teams that had been working together for over a decade. As foreseen in the strategy, changing a well-established research culture organized around commodities would be difficult to manage: "CIAT has a track record in solving problems along a commodity research approach. This approach, however, does not provide a strong framework on which to base a systems-oriented research paradigm, geared toward resource management research in important agroecological settings."[88]

The integration of commodity and NRM research would continue to be a central challenge in the organization of CIAT's research programs throughout the 1991–2008 period and one that was difficult to achieve with the increasing dependence on short-term, project-based funding, on the one hand, and the critical differences in how commodity and NRM research is organized, on the other (see Box 4). As the EPMR in 2000 noted: "This is a complex problem as it involves cooperation among staff with radically different scientific orientations. However, the Panel believes that, with its dedication to the cause and lengthy experience in addressing the issue, CIAT has a unique comparative advantage to generate novel means of bridging the gap."[89]

86 Ibid. p 16.

87 TAC of the CGIAR. 2001. op. cit.

88 CIAT. 1991. op. cit. p 15.

89 TAC of the CGIAR. 2001. op cit. p 97.

For eco-regional Centers such as CIAT, there are core issues of how best to organize commodity and NRM research, how to balance the two, and how best to effectively integrate the two to achieve the expected synergies in terms of impact, what has now been termed 'sustainable intensification.'

BOX 4

The challenge of integrating NRM and commodity research

The CGIAR's response to the sustainability agenda was to expand beyond the focus on commodity research to natural resource management (NRM) research, which entailed the expansion of the CGIAR System to include the "NRM" Centers. There has over time developed a marked separation in research culture between these two areas although with persistent calls for more effective integration (see for example ISPC, 2012[90]). For eco-regional Centers such as CIAT there are core issues of how best to organize commodity and NRM research, how to balance the two, and how best to effectively integrate the two to achieve the expected synergies in terms of impact, what has now been termed sustainable intensification.

Commodity research at CIAT started with a focus on production systems, in essence integrating commodity and NRM research at a plot level with some extension into farming systems where the commodity dominated in the system. Virtually 20 years of commodity-based research consolidated a research base on the four crops within the Center. The restructuring in the early 1990s focused the research on pre-breeding including the new science of molecular biology and moving away from cropping systems. The resulting Agrobiodiversity Program has functioned as a core program up to today with little change in organization. Moreover, the regions maintained a commodity focus, which has only just changed recently. This focus was strengthened by the expansion in work on value chains, where commodities are the organization framework. Moreover, this included a major element of developing seed systems as the means of distributing the improved varieties. The impact of CIAT programs has essentially been achieved through adoption of improved varieties, with beans in Africa, cassava in Southeast Asia, and forages and rice in Latin America. Cropping system research involving soils and agronomy continued in the regions, and interdisciplinary research was done within research networks.

NRM has had a very different history at CIAT. It was started much later, was never fully funded, and went through continual phases of organizational restructuring. NRM research is organized around the production of knowledge, which is then applied in particular contexts through tools, methodologies, and participatory research. Organizing the knowledge production is either done through agroecologies – the first organizational NRM framework – or themes, particularly soil and water research. The application of new management practices was done in reference sites in particular agroecologies, which were intended to be long term enough to generate consistent longitudinal data that could then be compared across sites to produce international public goods (IPGs). CIAT's early work on forages in the savannas was a hybrid of commodity and NRM research within a systems framework but restructuring led to a focus

90 CGIAR ISPC (Independent Science and Partnership Council). 2012. A stripe review of natural resources management research in the CGIAR. Independent Science and Partnership Council Secretariat, Rome, Italy.

on components, such as *Brachiaria* breeding, within a commodity frame and management of acid soils within an NRM framework. Implementation was organized around participatory research on forage introduction in the Asian regional program. Although systems research has been a hallmark of CIAT's history, continual programmatic restructuring in the period 1995–2009 has limited the ability of CIAT to establish sustained systems research programs with the potential of producing impacts in the NRM area.

As with CGIAR, CIAT today has a programmatic structure that separates agro-biodiversity/commodity research from NRM research in the Soils and DAPA programs. This tracks the current structure of the CGIAR research programs where NRM themes such as forests and trees and fish are "commodified" within agri-food system programs and water/land use is organized as a cross-cutting program. Nevertheless, global agendas such as mitigation of climate change, sustainable intensification, land degradation, and working within planetary boundaries, all require a more effective integration of commodity and NRM research.

In many ways, the cultural conflict created by downsizing the established commodity programs while not being able (because of funding constraints) to fully staff the NRM programs put huge pressure on management. The divide became so wide that the Director General at the time felt that he had lost the authority to manage the situation and Nores stepped down in 1994. The former CIAT economist, Grant Scobie, was appointed Director General in 1995 but due to family reasons only served one term. However, the 1990s continued to be a period of very sharp drops in unrestricted funding and slow growth in project funding (Figure 2). Scobie maintained the 1991 strategic plan but went through a number of programmatic restructurings to accommodate the budget situation.

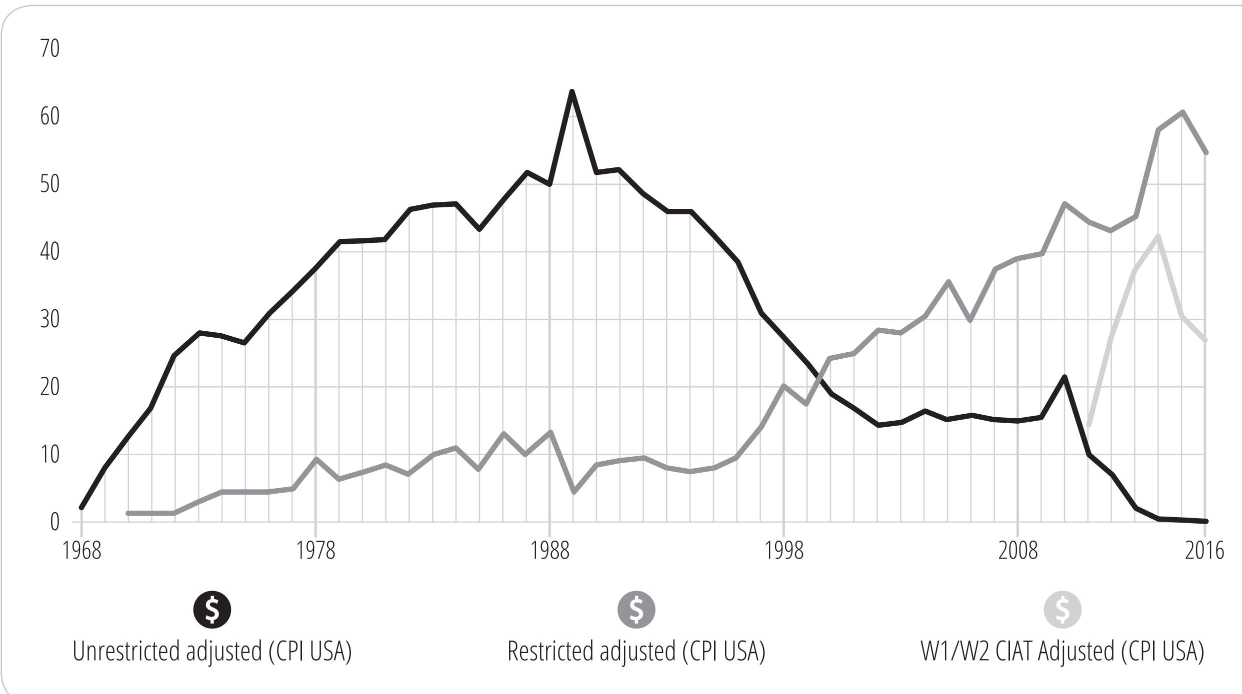


Figure 2 CIAT adjusted income 1968–2016 (million constant 2016 US$).

During this period of declining budgets, the host country, Colombia, became one of the major partners to CIAT. The Agreement for Technical and Scientific Cooperation was signed in 1993 with the Ministry of Agriculture and Rural Development (MADR) and would run through three 5-year phases. As the 2008 EPMR stated, "During the 12 years of this agreement through 2005, Colombia was one of the leading investors in CIAT and one of the leading investors in CGIAR among tropical countries, with an investment averaging around US$2 million annually."[91] The agreement was organized around joint work programs between CIAT and Colombian institutions on the Eastern Plains, including research on principal commodities such as improved pastures, soils, and land use, and including a new program area in tropical fruits. A review of the results of this joint program from 1994–2001 argued that for every

91 CGIAR Science Council. 2008. Report of the 6th External Program and Management Review of the Centro Internacional de Agricultura Tropical (CIAT). Science Council Secretariat. Rome, Italy. p 66.

US$1 million invested, the return in the Eastern Plains was US$74 million.[92] A further assessment found that in the 1994–2003 period, a total of 1,618 Colombian researchers and technicians had been trained at CIAT under the agreement.[93]

The central strategy during the 1990s was a systems approach, which included system characterization, farmer participatory research, and integration of commodity and NRM research in targeted reference sites. The spatial characterization work was central to the development of the 1991 strategy and continued through the decade in differently named units. CIAT was a leader in the development of farmer participatory research, first in support of the commodity programs in the 1980s, and then as a central element of the emerging NRM research agenda. The integration of commodity and NRM research was to take place in reference sites within the respective agroecologies. On-farm trials integrating these components were supported by long-term systems trials on research stations of collaborating NARI's. This long-term approach, however, was constrained by the declining budget and short-term project funding both in terms of adequately staffing the NRM program and in being able to support quite large operational costs for both the long-term trials and the on-farm research. At the same time staffing of the commodity programs also declined. The 2001 EPMR Panel "identified the current main dilemma characterizing CIAT's research: a rising role for NRM research, but with insufficiently well-defined methodology and uneven results, and a decline in commodity research, with a consequent slowdown in outputs – when it has been the mainstay of CIAT research."[94]

The 1990s were the beginning of the move from a set of autonomous IARCs to a more interactive CGIAR research system. Starting in 1993, inter-Center eco-regional programs were formed based on varying NRM themes and these were followed in 1996 by systemwide programs in other areas. By 2002 there were eight eco-regional and nine systemwide programs. Of these, 17 CIAT participated in nine of which it was a convener or co-convener in three: the Eco-regional Programme for Tropical Latin America, Systemwide Programme on Soil, Water, and Nutrient Management (Co-convener), and the Systemwide Initiative on Participatory Research and Gender Analysis. As the 2001 EPMR noted, "CIAT is one of the most "connected" centers within CGIAR – in the sense of its collaboration with other CGIAR centers."[95] The Eco-regional Programme for Tropical Latin America, approved by the CGIAR in 1995 was an inter-institutional platform for supporting CIAT's eco-regional strategy, but did not receive the funding that would allow it to develop sufficiently and was closed.

This period of CIAT's history can be characterized as one of expanding and developing an innovative range of institutional partnerships with other CGIAR Centers, with NARS, with the private sector, and with an increasing number of research consortia. CIAT's "connectedness" in the

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92 Urrutia E; Figueroa E. 2002. Convenio Colombia-CIAT: Un negocio de amplios horizontes para el Llano, con ciencia y tecnología, esta región se convierte en la despensa agrícola del país. CIAT, Cali, Colombia.

93 Rivas Ríos L. 2004. Resultados, adopción e impacto en los Llanos Orientales de Colombia. CIAT, Cali, Colombia. p 9.

94 TAC of the CGIAR. 2001. op. cit.

95 Ibid.

1990s positioned it well to participate fully in the CGIAR Challenge Programs that were launched in 2001. These were precursors to the CGIAR Research Programs (CRP) that would come later in the decade. CIAT participated in all four of the Challenge Programs and was instrumental in developing the Challenge Program on Climate Change that evolved into the CCAFS CRP on Climate Change. CIAT used its core strengths in biotechnology and plant breeding in both the Generation Challenge Program and Harvest Plus and in participatory research and rural innovation in the Sub-Saharan Challenge program. In the area of public–private partnerships, CIAT developed an institutional innovation in the creation of the Latin American Fund for Irrigated Rice (FLAR) in 1995, followed in 1999 by the creation of the Latin American Consortium for Support of Cassava Research and Development (CLAYUCA) – (see p. 108). Both are membership based, with annual contributions by participants coming from both the public and private sector across a significant number of Latin American countries.

At the same time, over this period CIAT developed strategic research capacity in a number of areas, including biotechnology, GIS, and spatial analysis, IPM, and farmer participatory research. As Center research became more project-driven, the central organizing question was what were the principal lines of integration? Should the units seek to be self-supporting in competing for funding or should they integrate around broader project themes? During the last half of the 1990s, CIAT organized its research around 16 aggregated project themes supported by several research units. Both the 2000 and 2008 EPMRs would focus on the logic of thematic project groups but particularly on the overall structure as a framework for integrative research. The project groups tended to be insular, focusing on generating and implementing projects in their area, but with little in terms of integration with other themes.

Joachim Voss was appointed the next Director General in 2000. He had previously been with CIAT's Bean Program in Rwanda and then went on to represent IDRC in CGIAR. He led the development of a new strategy in 2001 in which CIAT moved to a research for development (R4D) approach within the framework of rural livelihoods. This was a response to what the 2008 EPMR characterized as "a shift from philanthropic donors supporting science to alleviate global hunger to one of development–focused investors targeting poverty alleviation." (p. 1).[96] As Figure 2 above indicates, there was a significant growth in project funding at the same time as unrestricted funding plateaued at a historically low level for CIAT. The prospect of a continuing annual increase in Center budget with a structural change in the type of funding was in turn not matched by a requisite change in internal financial management. This was characterized by an ex-post assessment as "Beginning in 2002, CIAT's core expenses were consistently higher than its unrestricted revenue and the Center was living beyond its means. In that year, CIAT adopted an unconventional method of 'full cost recovery' (FCR) to balance its books at the end of each financial reporting period"[97] which was essentially

96 CGIAR Science Council. 2008. Report of the 6th External Program and Management Review of the Centro Internacional de Agricultura Tropical (CIAT). Science Council Secretariat. Rome, Italy. p 1.

97 Field L; Özgediz S. 2008. CIAT's institutional crisis: Lessons learned. Unpublished manuscript. CGIAR Secretariat, Washington, DC, USA.

based on borrowing from project funds to finance core costs.[98] The financial crisis, triggered by such practices and other drivers, led to the resignation of the Director General and an unprecedented decision by the Executive Committee of CGIAR to replace the Board of Trustees.

This was to prove to the major crisis in the history of CIAT that threatened its very survival. CIAT was able to generate emergency based on its science, its systems approach, and its innovation. The ex-post assessment concludes as follows:

> *CIAT is one of the most innovative Centers in the CGIAR System. Being innovative requires risk taking, boldness and some degree of opportunism. The CIAT crisis is, in part, a reflection of the Center's drive for innovative solutions. This drive led to unchecked growth. It also led to careless management of the assets entrusted to the Center by the donor community. The lesson from the CIAT experience should NOT be to curb innovation, but to promote it strategically, taking into account the full circumstances of the Center.*[99]

The time from the 2001 strategy to the institutional crisis in 2008 was a period of continual reorganization of the research programmatic structure. It was not so much strategy as financial constraints that fed such reorganization, and it is interesting to consider whether such innovation as described above was in part sparked by this continuing organizational flux rather than leading to institutional implosion. The 2008 EPMR describes in detail the continual reworking of program structures at headquarters while the regional programs moved toward a more integrated, systems-based research strategy. Strategic focus often gave way to an expanding scope of the research agenda in order to attract funding. Building a coherent and strategic research framework around core capacities developed over time and which underlay CIAT's reputation was difficult, much less the potential synergies from integrative, cross-program research planning and implementation.

During the period 2001–2008, CGIAR faced increasing demands from donors for impact from project investments while at the same time as the Science Council (the renamed TAC) was focusing on strategic research and international public goods. Donor support to agriculture continued to be stagnant and the apparent incompatibility between funding sources and research priorities was filled by the development of integrated natural resource management (INRM) research programs and its extension into R4D. INRM encapsulated CIAT's research approach since 1991, namely integrating productivity and NRM research within a farmer participatory approach. INRM had its fullest application in some of the eco-regional and system-wide programs in which CIAT participated, for

98 The ex-post assessment described the system this way: "CIAT's FCR (full cost recovery) method consisted of: (a) transferring part of the excess expenditure that could not be met by unrestricted funding to special projects, to the extent that these costs could be legally covered in accordance with projects agreements; (b) "internal borrowing," whereby the Finance Department and Project Leaders would "negotiate" passing certain expenditures which were not absorbed by unrestricted funding to special projects in one financial period with the understanding that these funds would be repaid to projects in the following year from unrestricted resources. The cumulative internal debt to special projects reached close to US$4 million in 2005. CIAT's inability to pay its unconventional internal debt was compounded by the strength of the Colombian Peso against the US dollar, which resulted in increases in local costs, and by the cancellation of expected funding in 2005 from a major donor. This triggered the financial crisis." Ibid. p 5.

99 Ibid. p 2.

The integration in 2001 of the Tropical Soil Biology and Fertility (TSBF) Program greatly enhanced CIAT's research capacity in soils.

example the African Highlands Initiative (AHI) and the Africa Challenge Program. CIAT could draw on a range of program competencies in participating in such programs, which would serve it well in the CGIAR Research Programs in the next, more radical reform of CGIAR.

CIAT's programs in Africa and Asia were originally built around CIAT's global crop mandates, particularly beans in Africa and cassava in Asia, but the two regional programs had the locus for systems research. The African program was built around research networks that evolved into institutions that facilitated joint African–CIAT coordination. This institutional innovation is best expressed in the development of the Pan-Africa Bean Research Alliance (PABRA) which was launched in 1996 and provided CIAT with the principal vehicle for undertaking bean research, testing and delivery in the region (see p. 52 and 108). The Tropical Soil Biology and Fertility (TSBF) Program was developed in Africa outside of CGIAR but was integrated into CIAT in 2001 (Tropical Soil Biology and Fertility Institute of CIAT). TSBF was in many ways an institute within an institute and generated its own sources of funding. The addition of TSBF greatly enhanced CIAT's research capacity in soils, augmenting the work done on management of acid soils in Latin America.

The Asia program, while initially focused on cassava, developed as an integrated systems program for the upland areas of the poorer areas of Southeast Asia – Laos, Cambodia, and Vietnam. In addition to adding significant elements of forages and NRM research, the Asia program integrated some of the elements of today's value chain work in developing rural enterprises beyond cassava. Like the Africa program, the Asia program was relatively independent of headquarters, and reflected the regional decentralization evident in many of the commodity and eco-regional CGIAR Centers. The next phase of CIAT's institutional and programmatic evolution would build on these foundations.

BOX 5

Agricultural research and security

CIAT had a number of advantages with its location in Colombia, particularly financial support from the Colombian Government, strong institutions with which to partner with, well- trained human capital to staff its programs, and a wide variety of agroecologies within which to undertake research. At the same time, during the last 50 years, Colombian society has been plagued by periods of violence and insecurity manifested in a long standing guerilla war in the rural areas led by the Revolutionary Armed Forces of Colombia (FARC), an urban guerilla group, the M-19, which was particularly prominent in the 1980s, the expansion of the illicit drug trade and the prominence of the Cali drug cartel – which during the 1990s was estimated to control 90% of the world cocaine trade, and the development of paramilitary groups as self-defense groups. Such interplay of armed groups with the Colombian military created a marked insecurity in the countryside, with particular problems in Cali and the Valle de Cauca.

For much of the 1980s and 1990s, the bulk of CIAT's research was done in Colombia, either on the main station or in various research sites distributed throughout the country, from the Caribbean coast to higher elevations in Popayan to the Carimagua station in the Eastern Plains. The regional varietal trials and on-farm research in the 1980s took CIAT researchers to virtually the four corners of the country. There was a sense that in FARC-held areas that CIAT researchers were allowed to work because of the potential help they were providing to small farmers, who were the FARC's constituency. That changed in September 1987 when the FARC commandeered 17 vehicles and held the station and airstrip hostage at the Carimagua station for 30 hours.[100] As retribution, paramilitary groups entered El Porvenir where the workers were housed and killed two members of the union. CIAT then withdrew its staff members based in Carimagua.[101] One of the former Rockefeller staff members, Jim Spain and his wife Joyce, had recently been transferred to Brazil. Over the course of time, CIAT reduced significantly its research in Colombia, particularly around the turn of the century when the FARC controlled the eastern part of the Cauca Valley that virtually halted vehicular movement in and out.

Security was a major part of family life for CIAT staff living in Cali. In many ways family life adapted to the almost daily news articles on the violence in the country. Fortunately, there were very few incidents where CIAT staff members were at major risk. One author remembers the period 12–15 March 1986 when 300 FARC guerillas came down through the western cordillera of the Andes, which abutted Cali, and attacked the third brigade of the Colombian military headquartered close to Pance, where most CIAT staff lived and where schools were located. The initial attack was quite close to these schools when students were in class. The students were evacuated and one could hear for the next 3 days the sounds of artillery and gunfire.

Even so, there were at least two kidnappings of CIAT senior staff by the FARC at different times, as well as kidnappings of family of Colombian staff. Given the insecurity through a major part of CIAT's history, it is in many ways a testament to the commitment of CIAT staff and families to the work of the institution, to the very close friendships developed with Colombian colleagues, and to a strong belief that peace in Colombia would eventually prevail.

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100 García-Durán O. 2009. Carimagua: La investigación y el desarrollo en ecosistemas de baja fertilidad. Available at: http://bit.ly/2ysgquy

101 Ironically, ICA transferred 16,700 ha of the 22,500 ha in the station to the Colombian Institute for Rural Development (INCODER) in 2004 to settle displaced persons from the rural violence.

New directions and CIAT in a reformed CGIAR

The Board was reconstituted and a new Director General, Ruben Echeverría, then Executive Director, Science Council, was appointed in 2009 with the mandate to set CIAT on a new strategic course. The Center had come through a tumultuous period but was in a position to adapt to a time of unprecedented reform in CGIAR. In 2009, CGIAR began a change management process to undertake a major structural reform in which the alliance of 15 Centers would strengthen and operate more as an interdependent system focused around global strategic objectives. At the same time, donors interested in agriculture were stimulated by the prestigious World Bank's *World Development Report 2008: Agriculture for development*, and the global food price spike. Significantly, the Bill & Melinda Gates Foundation became a major donor for research on agricultural development in sub-Saharan Africa and South Asia.

Under Echeverría's leadership, CIAT quickly put in place a new strategic direction: 'eco-efficient agriculture for the poor'. However, it would require another 5 years to build up a program structure and strategy around that concept in the strategic plan produced in 2014. This strategy would build on capacities that the Center had developed over its history but would adapt them to a very different global agenda. In particular, the strategy built on a concept that was at the heart of CIAT's research since the 1990s: "Achieving eco-efficient agriculture will require unflagging commitment to the development and widespread adoption of more productive crop varieties and better practices for managing natural resources."

The integration of commodity and NRM research within a systems perspective would now be applied to the development of climate-smart agricultural systems, the process of sustainable intensification, provision of ecosystem services, and the development of sustainable food systems. This would be done through a process of system characterization and problem diagnosis, the integration of NRM and crop improvement research, and farmer participatory adaptive research. Adapting core capacities to new agendas was a hallmark of the continuing reinterpretation of CIAT's mandate, the adaptive organizational response to a changing external environment, and the continuing interplay of CIAT's eco-regional focus on Latin America and the pursuit of its global mandate.

Working within the new CGIAR Research Programs, commodity research continued to work on the three traditional crops – beans, cassava, and rice – and forages, but the focus was on breeding with a significant component of molecular methods, including marker-assisted selection and genetic transformation. A particular research line on nutritional enhancement through both genetic transformation and marker assisted selection, was developed through CIAT's participation in the HarvestPlus Challenge Program and is a core component in developing sustainable food systems. National programs had developed significant capacity and much of the breeding at headquarters was oriented to pre-breeding for particular constraints that could be easily used by national crop improvement programs. For beans, these populations fed into the PABRA research consortium that now managed research networks in Eastern, Southern and West Africa. Rice research within the FLAR network, however, included work on agronomic practices as the main way of closing the yield gap. Also, there was an eco-regional program on fruit breeding for Latin America. Together with genetic resources, this work was managed under the Agrobiodiversity research area.

The NRM research evolved from being organized around agroecologies to a focus on soil and land management as the key to eco-efficiency and ecosystem services, and the research on system characterization and spatial analysis evolved into a dedicated program – the Decision and Policy Analysis (DAPA) research area. DAPA now works on a range of topics across an expanding thematic agenda, including: "ecosystem services and benefits to the poor, climate change and building resilience into agricultural systems, designing pro-poor and equitable supply chains in a dynamic world, and impact targeting, facilitation, and assessment" (p. 1). Spatial analysis and modeling were the entry point into new areas such as climate change. The program generated a range of regional and global economic, environmental, and agricultural databases, which provided the basis for developing further capacity in big data, particularly "intelligent monitoring systems for the crops (CIAT) researches (focusing on pest and disease dynamics and variety adoption) and create a system to support site-specific crop management, which is responsive to climate, soils, and local socio-economic conditions." This work in big data would pave the way for the CGIAR Platform for Big Data in Agriculture, launched in 2017 and jointly led by CIAT and IFPRI, its sister Center.

Soil and land management is divided between research on integrated soil fertility management at the farm scale and sustainable land management at the landscape scale. This work builds on the long-standing research of TSBF in sub-Saharan Africa, which returned to the low-input approach of the 1970s, but instead of focusing on adapted germplasm, shifted to ecological approaches in the management of soils. For example, there was a large project on understanding underground biodiversity and its impact on productivity. The land management component emphasizes rehabilitation of degraded lands, which tends to focus on more marginal agricultural areas, particularly forests, and hillsides, building on its long-standing experience in these ecosystems. This refocusing of the research on soils, while essential to the eco-efficiency strategy, is still in process. CGIAR in its history has struggled to find a blueprint for organizing soils research across the system.

The challenge for CIAT was how to programmatically link the Agrobiodiversity, DAPA, and Soils Programs to achieve eco-efficiency, especially with impact on the poor. This was done through identification of problem-oriented themes around which to organize the research. This introduced an institutional flexibility to counter the development of program silos. As noted in the 2014 strategy, these strategic initiatives "are designed to boost the development impact of our work through an integrated approach that draws on all three of CIAT's research areas," i.e., Agrobiodiversity, Soils and Land Management, and DAPA. This could be thought of as an interdisciplinary approach but at an institutional, rather than program, level. Four initiatives were identified at that time: tropical forages for eco-efficient livestock production; sustainable food systems for a rapidly urbanizing world; reducing yield gaps for sustainable intensification of agriculture; and ecosystem services for human well-being. These initiatives aligned with the emerging development agenda, which would be articulated in the Sustainable Development Goals in 2015. In aligning CIAT's strategy with the SDGs the *2015–2016 Annual Report* noted a shift in strategic focus from eco-efficiency to sustainable food systems, and suggested four themes as building blocks of food systems, namely preserving ecosystem services, harvesting big data, climate-proofing agriculture, and making food systems sustainable. This again emphasized CIAT's institutional flexibility in response to a dynamic external environment. The themes could change but there was longer term continuity in the research programs.

The more fundamental change in CIAT's external environment was the major reform of the CGIAR System, especially from 2011, when the first phase of CGIAR Research Programs (CRPs) were approved and funded. CIAT's history and program structure, coupled with a strong presence in the developing regions, were reflected in its participation in 12 of the 15 CRPs. This was more than any other Center. This 'connectedness' reflected CIAT's evolving interpretation of its mandate, it ability to change research program structure, and its flexible internal organizational 'matrix'. CIAT's participation in so many CRPs could have led to significant fragmentation of its research programs, but instead, the Center was able to align its research programs with a system-level research portfolio. A major achievement was the award of the Center role to CIAT for the Climate Change, Agriculture and Food Security (CCAFS) CRP. CIAT faces the question of how closely it aligns its programs with the evolving CRP portfolio and how it evolves its own research programs and capacities. Evolving its research programs in relation to a changing external environment has been the hallmark of CIAT's history and surely will be the hallmark of CIAT's future, which will be discussed in the final section of this report.

The history and impact of CIAT's research programs

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A network approach to bean varietal improvement has led to incorporation of CIAT-bred material into a wide range of countries, ecologies, and bean markets.

The Bean Program

Grain legumes were a particular focus of the 1967 Roberts–Hardin establishment report for CIAT. Inexpensive protein sources were a particular focal point for Lewis Roberts of the Rockefeller Foundation and he produced a report on food legumes for the first meeting of TAC.[102] These first 2 to 3 years of the 1970s were a period when CIAT was deciding on which grain legumes to focus on in its research program and the TAC was considering how best to include grain legumes in the CGIAR research portfolio. Roberts had recommended that the responsibility for priority grain legumes be decentralized across the various Centers. In this formative period of CGIAR, there was an alternative view on TAC led by M.S. Swaminathan that a Center should be created with a singular focus on grain legumes i.e., "There are several basic problems of major significance which have common factors which are not highly location-specific, and thus could probably be tackled most effectively and economically with common facilities."[103] This tension between a commodity and an eco-regional approach was reflected in the creation of the first four Centers. CGIAR would come back to this idea of a common program on food legumes with the formation of the CRP on Grain Legumes, but at that second meeting, the TAC decided on a decentralized strategy, arguing that "the diverse range of ecological conditions under which the food legumes are (or could be grown) and the need thus imposed on researchers to undertake a good deal of their work on a regional

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102 Roberts L. 1970. The food legumes: Recommendations for expansion and acceleration of research to increase production of certain of these high-protein crops. See pp. 127–231 of the Bibliography for the first TAC Meeting, June-July 1971.

103 TAC (CGIAR Technical Advisory Committee) Secretariat. 1972. Food legumes position paper. TAC Second Meeting, Rome, Italy. October 1971. p 3.

or ecological zone basis."[104] The issue then was how to allocate grain legume responsibilities across the various Centers.

CIAT had put forward a proposal to TAC to work on common bean (*Phaseolus vulgaris)* and soybean. IITA had also proposed to work on soybean, but TAC was of the opinion that there was major research work on soybean in the US and that this should be the responsibility of USDA. At the same time, TAC had received proposals from IICA to create an Inter-American Tropical Pulse program based in Turrialba with a particular focus on beans in Central America. A proposal had also been received from the East African Agricultural and Forestry Research Organization (EAAFRO) for research on beans in East Africa. The IICA program built on a bean research network created in 1962 for Central America: the Central American Cooperative Network for Bean Improvement (PCCMF) in Costa Rica. The IICA proposal led to CIAT developing a paper for TAC to establish a cooperative program for bean research in Latin America and the Caribbean, PROFRIJOL,[105] with a secretariat based at IICA. The proposal built on a workshop at CIAT in early 1973, which brought together leading scientists on different aspects of bean research. PROFRIJOL was not established until 1981 with Swiss funding and coordinated regional testing and exchange of germplasm, building on the strong breeding program at CIAT and the development of varietal nurseries. This early process of defining mandate responsibilities led to a focus on regional networks in both Latin America and sub-Saharan Africa organized around crop improvement in national programs, supported by capacity development in those programs, with more pre-breeding for particular constraints carried out at CIAT headquarters. Bean breeding at CIAT was always a collaborative venture with national programs, in part driven by the complexity of the breeding enterprise.

CIAT's Bean Program in Latin America

CIAT's Bean Program had as its core varietal improvement. Organizing the breeding program was based on the very large number of traits needed to develop an adoptable variety. On the production side, these were primarily a cascading set of pests and diseases that constrained crop yield, resulted in significant seasonal yield variation and therefore risk to the farmer. The latter in turn led to limited use of purchased inputs. Moreover, many of the diseases were seed-borne. Average farm yields were often less than half a ton per hectare and varied significantly from year to year. Moreover, there was a range of different growth types running from bush to climbing beans. On the demand side, there was a large range of seed sizes and colors and consumer preferences among them varied widely across countries in the region (see Table 1). The yield standard at the start of the breeding program were small-seeded black beans that were usually grown in more marginal conditions, were more resistant to pests and diseases, and gave higher yields. However, these were primarily consumed in the Caribbean, parts of Central America and Brazil, and thus at lower altitudes compared to where the crop was domesticated. There were two centers of domestication, one in the Andes and one

104 Ibid. p 4.

105 TAC Secretariat. 1973. op. cit.

in Mesoamerica, resulting in two gene pools. Both were domesticated at higher altitudes, with better rainfall conditions in Mesoamerica than in the Andes. "Furthermore, it has often been difficult to obtain high-yielding genotypes in Andean × Mesoamerican crosses because of outbreeding depression."[106] As the 2008 EPMR noted. "The current CIAT research strategy focuses on the exploitation of the vast genetic resources of bean that exist as a complex array of major and minor gene pools, races and sister species."[107]

Table 1 Patterns of variation in growth habit, days to maturity and seed size and color in cultivated beans.

Growth habits	Bush:	I - IIa - IIb - IIIa
	Climbing:	IIIb - IVa - IVb
Seed size	Small:	15–25 g/100 seeds
	Medium:	26–45 g/100 seeds
	Large:	>45
Seed color	White-cream-yellow-brown-pink-red-purple-black	
Days to maturity	65–280 days	

Source: Voysest O. (ed.). 1998. An ecoregional framework for bean germplasm development and natural resources research. Working document, annex to a workshop on bean breeding held in October 1991. CIAT, Cali, Colombia. p 4.

The large number of traits and their heterogeneity across the countries in the region suggested a very decentralized breeding strategy. Fortunately, this could be based on the relatively strong national capacity in bean breeding in the region, compared to the cassava and forages programs. A survey of national breeding capacity in the region identified 74 bean breeders in national programs in 1979 and 88 in 1989.[108] This provided the basis for a system whereby: "Breeders and pathologists in CIAT would identify promising materials. Recombinations of these materials were made and then sent out in the early stages of selection (F3 and F4) to national programs to be selected in the regions where they would ultimately be released."[109] A fuller articulation of the Bean Program's strategy was provided by Julie Kornegay, the leader of the Bean Program in the early 1990s: "Our comparative advantage is the trusteeship of the world's largest *Phaseolus* germplasm collection; a system for evaluating germplasm under a variety of constraints in differing environments; methods to study and monitor pest/pathogen evolution; the ability to rapidly create and advance breeding populations; and networks to disseminate improved materials to national institutions and farmers."[110] For the CIAT Bean Program globally, "expenditures peaked around US$13.8 million in 1990 with

106 Broughton WJ; Hernández G; Blair M; Beebe S; Gepts P; Vanderleyden J. 2003. Beans (*Phaseolus* spp.): Model food legumes. Plant and Soil 252:55–128. p 64.

107 TAC of the CGIAR. 2008. op. cit. p 40.

108 Johnson NL; Pachico D; Wortman CC. 2003. The impact of CIAT's genetic improvement research on beans. In: Evenson RE; Gollin D. (eds.). Crop variety improvement and its effect on productivity: The impact of international agricultural research. CABI Publishing, Wallingford, UK. p 260.

109 Ibid. p 260.

110 Kornegay J. 1993. Strategic research to improve bean production: What role does biotechnology play in the next five years. In: Roca WM; Mayer JE; Pastor-Corrales MA; Tohem J. Proceedings of the Second Scientific Meeting of the *Phaseolus* Bean Advanced Biotechnology Research Network. CIAT, Cali, Colombia.

26 principal scientists and 7 internationally recruited breeders."[111] A network approach to bean varietal improvement has led to incorporation of CIAT-bred material into a wide range of countries, ecologies, and bean markets, as CIAT does not supply finished varieties. Up to the year 2000, the number of bean varieties released annually in Latin America increased significantly, and a high proportion of them were derived from CIAT's breeding program (see Figure 3).

and culinary quality would also receive increased emphasis in the breeding program. The production systems research, including the farming systems research, would shift to the agroecology programs. The result was a significant reduction in the number of scientists working on beans. By 2007, the budget allocated to beans was around US$3 million.[113] At least two EPMRs would argue that staffing was below critical levels. At the same time as the

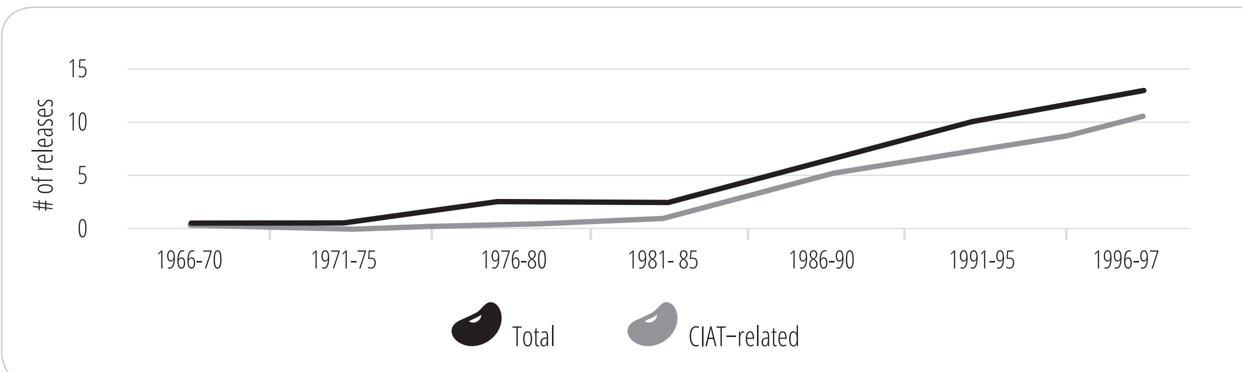

Figure 3 Average annual bean variety releases, Latin America and the Caribbean.

Source: Johnson NL; Pachico D; Wortman C. 2003. The impact of CIAT's genetic improvement research on beans. In: Evenson R; Gollin D. Crop variety improvement and its effect on productivity: The impact of international agricultural research. Wallingford, UK: CABI Publishing.

With the strategic shift to natural resource management in the 1990s, there was a shift to better targeting agroecologies, supported by spatial analysis, and increased emphasis on edaphic constraints in the breeding program.[112] Nutrition reduction in the CIAT Bean Program staff, national programs in Latin America, particularly in the small countries in Central America and the Caribbean, were reducing funding to agricultural research, in some cases completely eliminating public funding

111 Muthoni R; Andrade R. 2015. The performance of bean improvement programmes in sub-Saharan Africa from the perspectives of varietal output and adoption. In: Walker TS; Alwang J. (eds.). Crop improvement, adoption, and impact of improved varieties in food crops in sub-Saharan Africa. CAB International; CGIAR Consortium of International Agricultural Research Centers, Boston, MA, USA. p 151.

112 A 1991 workshop framed the shift in strategy: Voysest O. 1998. op. cit.

113 Ibid. p 151.

for agricultural research.[114] There have been few studies on the impact of this loss of capacity, but a study of bean research capacity in Guatemala found that CIAT materials were incorporated in 17 released varieties up to 1998 but,

> *CIATs' role in collaborative bean research has been less prominent since 2002, owing to the drop in international funding; the continuation of international nurseries and trials was made possible thanks to Zamorano's technical support, through financial contributions from USAID's bean/cowpea Collaborative Research Support Program (CRSP), together with the personal dedication of the few breeders still working in Guatemalan institutions. Indeed, from the late 1990s to 2010 it seems that not a single variety was released through international collaboration in Guatemala; following this gap, six new varieties were released within the framework of the bean/cowpea CRSP in 2010 and 2011.*[115]

CIAT's investment in national capacity and germplasm exchange through the networks in the end depends on continued investment in that capacity at the national program level.

Guatemala was something of an outlier, as several impact studies have demonstrated the wide adoption of improved bean varieties in Latin American countries. An early study "estimated that as of 1998 the the internal rate of return (IRR) for (CIAT) research in LAC was 32%", and with a lag time of 14 years before initial adoption.[116] A 2001 impact study of resistant bean varieties (RV) in Honduras found that "in the two principal bean-producing regions of the country … 41–46% of bean farmers [depending upon the season) have adopted an RV, and that adoption is neutral with respect to farm-size and market orientation… Adopters gain the equivalent of 7–16% (depending on the variety) in bean income from the yield loss averted through RV use. The ex post rate of return to disease resistant bean research in Honduras from 1984 to 2010 is 41.2%."[117] A more recent study in Honduras, El Salvador, Nicaragua, Costa Rica, and Ecuador covering the period between 1990 and 2010 focused on 54 small red and red mottled varieties developed by both CIAT and the Bean/Cowpea and Dry Grain Pulses CRSP. The study found that: "The adoption of improved bean varieties in 2010 across the five focused countries is estimated to be 67% of area planted to small red beans in Central America and 50% of area planted to red mottled beans in northern Ecuador."[118] Moreover, "The estimated average annual economic benefit per hectare planted with IVs during the period of evaluation was

114 See: Johnson et al. 2003. op. cit. p 261.

115 Méndez W; Galluzzi G; Say E. 2015. The importance of international exchanges of plant genetic resources for national crop improvement in Guatemala. CCAFS Working Paper No. 154. CGIAR Research Program on Climate Change, Agriculture and Food Security (CCAFS). Copenhagen, Denmark.

116 Johnson et al. 2003. op. cit. p 272.

117 Mather DL; Bernsten R; Rosas JC; Viana Ruano A; Escoto D. 2003. The economic impact of bean disease resistance research in Honduras. Agricultural Economics 29:343–352. p 343.

118 Reyes B. 2012. The use of improved bean varieties in Central America and Ecuador generate a steady stream of economic benefits to farmers. Impact Assessment Research Brief No 1. Bean/Cowpea and Dry Grain Pulses CRSP. Michigan State University, East Lansing, MI, USA. p 3.

highest in northern Ecuador (US$199/ha), followed by El Salvador (US$84/ha), Nicaragua (US$73/ha), and Honduras (US$64/ha.) Furthermore, the IRR was highest in Nicaragua (43%) and lowest in Honduras (34%)."[119] The return in Costa Rica was negative because the consumer preference was for light rather than dark red beans, reinforcing the critical importance of consumer and market preferences.

Given the focus on varietal improvement through a network approach, CIAT quite early on developed a network model for biotechnological research for cassava and beans, which were not receiving the research attention of the North American field crops. Following on the creation of the Cassava Biotechnology Network (CBN), CIAT in 1990 organized the *Phaseolus* Beans Advanced Biotechnology Research Network (BARN), which then led to a second large scientific meeting in 1993. Unlike the CBN, BARN could not generate the funding needed to sustain it. CIAT rather focused on biotechnology approaches that supported the breeding program, particularly reinforcing the trait-based approach to pre-breeding. Most of the bean biotechnology focused on embryo rescue to develop inter-specific crosses to introgress novel traits from wild relatives into the breeding program. Development of molecular markers for disease-related traits, particularly viruses, was also a focus. This allowed the pyramiding of resistance genes under conditions at CIAT where there was not sufficient disease pressure. "MAS was efficient for reducing breeding costs (for both viral diseases) as land and labor savings resulted from eliminating susceptible individuals."[120] A MAS system was developed more recently for CIAT's biofortification work which increases the content of iron and zinc in beans.

CIAT's Bean Program in sub-Saharan Africa

The highlands of East Africa are a secondary center of bean germplasm diversity. Varietal development in Africa faces a similar problem to that of Latin America i.e., a wide range of pest, disease and edaphic constraints and a range of sub-regional preferences in seed size and color. The Bean Program began work in the region in 1985 and followed a similar strategy to that in Latin America – decentralized breeding within a network approach – but with a significant institutional innovation in the creation of the Pan-Africa Bean Research Alliance (PABRA). This alliance was formed in 1996 as a collaborative mechanism with joint ownership for bean research between NARS, CIAT, and principal donors. PABRA consisted initially of two bean research networks in Eastern and Southern Africa joining at that stage, and another in West and Central Africa joining in 2009, making PABRA truly Pan-African.

> *All 28 member countries in PABRA implement bean R4D activities based on a common research agenda, which helps to harmonise research on beans and harnesses synergies among national bean programs on the continent. By bringing on board a range of NARS partners offering complementary*

119 Ibid. p 3.

120 See: Blair MW; Fregene MA; Beebe SE; Ceballos H. 2007. Marker-assisted selection in common beans and cassava. In: Guimarães EP; Ruane J; Scherf, BD; Sonnino A; Dargie JD. (eds.). Marker-assisted selection: Current status and future perspectives in crops, livestock, forestry and fish. Food and Agriculture Organization of the United Nations (FAO), Rome, Italy. pp 81–115.

skills and services, and often operating in different agro-ecological and social economic environments, PABRA ensures that the impacts of bean R4D are felt well beyond the specific countries or locations where activities are implemented.[121]

Capacity in bean research in the NARS has been developed over time and compared to Latin America has been maintained. In the ten countries, there was only one full-time bean breeder in 1980.[122] There were 21 by 1990 and 24 were in position in 2010.[123] Moreover, the study notes that countries with more breeding responsibilities in the networks are the recipients of more training, mentoring, and capacity building, allowing these programs to compete for larger projects from governments and donors. Within such a network approach, capacity building in individual programs strengthens capacity across the network. The result has been a sustained growth in the release of bean varieties by national programs, rising from only seven in the 1970s in the 10 DIIVA countries to 73 in the 1990s and 130 in the 2000s (see Table 2).[124]

The CIAT bean research agenda in Africa has developed some innovative research areas. The question of how to improve bean varietal mixtures and enhance the impacts on disease epidemiology was an initial important research question. The importance of women in selecting next season's

Table 2 Number of bean varieties released by decade and country.

Country	70s	80s	90s	00s	Undated	Total
Burundi	1	4	7	18	5	**35**
DR Congo	0	2	4	22	7	**35**
Ethiopia	2	1	7	22	0	**32**
Malawi	0	0	6	9	0	**15**
Mozambique	0	2	4	8	1	**15**
Rwanda	3	9	20	25	4	**61**
Tanzania	0	3	11	14	1	**29**
Uganda	1	0	11	6	0	**18**
Zambia	0	1	3	6	0	**10**
Total	7	22	73	130	18	**250**

Source: Muthoni and Andrade. 2015. op. cit. p 154.

seed for planting in turn led to the development of participatory plant breeding in beans with a particular focus on the role of women. The small farm size in Rwanda and the need for intensification led to one of the initial program successes – the introduction of climbing beans into Rwanda and eastern DR Congo. A 2001 study suggested that: "by 1998 Rwanda and the eastern areas of the DR Congo were estimated to have 16 and 48%, respectively, of their bean area

121 Buruchara R; Chirwa R; Sperling L; Mukankusi C; Rubyogo JC; Muthoni R; Abang MM. 2011. Development and delivery of bean varieties in Africa: The Pan-Africa Bean Research Alliance (PABRA) model. African Crop Science Journal 19(4):227–245. p 230.

122 Walker TS; Rathgeber EM; Dhillon BS. 2007. Report of the First External Review of the System-wide Program on Participatory Research and Gender Analysis (PRGA), CGIAR Science Council, Rome, Italy.

123 Muthoni R; Andrade R. 2015. op. cit. p 152.

124 Ibid. p 154.

planted to (climbing bean) varieties."[125] The DIIVA study only included varieties released in 1998 and after, and found in Rwanda that 34% of households planted improved bean varieties and that these were approximately equally divided between bush and climbing beans. Yield for improved varieties averaged 782 kg/ha compared to 688 kg/ha for local varieties.[126]

Although nutritional deficits in protein are no longer a major problem in Latin America, it continues to be an issue in sub-Saharan Africa. Beans are a major source of protein there and research on the crop is still a priority. The more recent breeding efforts for improving iron content has extended the nutritional dimension to micronutrients. The combination of a large and diverse germplasm collection, a trait-based pre-breeding capacity, and a set of networks that undertook breeding and adaptive research for local conditions has been central to preserving beans in farming systems in Latin America and Africa, when the area planted to grain legumes in many parts of the world has been declining. While most CGIAR Centers have moved away from research networks, usually because of lack of funding, effective research networks remain central to the research strategy of CIAT's Bean Program. This has been a well-tested model for international crop research and it should remain the basic structure on which future research will be built.

Beans are a major source of protein in sub-Saharan Africa and research on the crop is still a priority.

125 Johnson et al. 2003. op. cit. p 270.

126 Larochelle C; Alwang J; Norton GW Katungi E; Labarta RA 2015. Impacts of improved bean varieties on poverty and food security in Uganda and Rwanda. In: Walker TS; Alwang J. (eds.). Crop improvement, adoption, and impact of improved varieties in food crops in sub-Saharan Africa. CAB International; CGIAR Consortium of International Agricultural Research Centers, Boston, MA, USA. p 314–337.

The Cassava Program[127, 128]

In CIAT's first Annual Report, a potential program in plant starches was mentioned, and cassava was the focus. Unlike the other programs, the incipient Cassava Program did not have its roots in the Rockefeller Foundation's earlier Colombia program. Rockefeller drew its field staff scientists from US universities and there was little or no cassava expertise to draw on in that pool.[129] Furthermore, at the time of the program's establishment, there was only one other major multidisciplinary program working on cassava and that was the Cassava Research Program at the Central Tuber Crops Research Institute (CTCRI) in Kerala, India, which was established in 1963.[130] Although there had been research on the crop in Africa during the colonial period[131] and in Malaysia and, Indonesia, Thailand, and Brazil during the same period, there was no linked research community working on the crop. This began to change with the first meeting of the International Society for Tropical Root Crops (ISTRC) held in Trinidad in 1967, followed by a second symposium in Hawaii in 1970. IITA and then CIAT would hold the next two symposia, marking the development of an international

127 This section was co-written with James Cock.

128 This section draws on Nestel B; Cock JH. 1976. The development of an international research network. IDRC, Canada, and Clair Hershey's previous history of the Cassava Program, which is a much more detailed discussion than that presented here: Hershey C. 1994. Research for Development: The CIAT Cassava Program. CIAT, Cali, Colombia. 99 p.

129 In the *1968 Annual Report*, there is a reference to a *Manihot* Report by David Rogers, written for CIAT in 1968. Rogers was a botanist interested in germplasm conservation and had been a consultant for the Rockefeller Foundation.

130 Abraham K; Nair SG; Naskar SK. 2000. Cassava breeding and varietal dissemination in India: Major achievements during the past 25–30 years. http://bit.ly/2hoWb67

131 Jones WO. 1959. Manioc in Africa. Stanford University Press, Palo Alto, CA, USA.

research community working on tropical root crops, but particularly on cassava.[132]

The foundations of the CIAT Cassava Program began when Dr. Eduardo Álvarez Luna, Associate Director, received financial support for a major international germplasm collection in 1970. The 2,800 accessions that were collected,[133] solidified the decision to select cassava as the focus of CIAT's research on root crops. In 1971, IDRC received a proposal for a Cassava–Swine project from CIAT, which at the time saw potential synergy between the two emerging programs. At the time IDRC was focusing on less "glamorous" and perhaps more "neglected" crops and the focus changed from feed for swine to food for the estimated 300 million people for whom cassava was a staple. IDRC decided to support not only research on cassava in CIAT, but also to establish international research for cassava.[134] Within this framework, cassava researchers from around the world were invited to a conference in CIAT in 1972 to discuss future directions of the CIAT program and the overall network. In a prophetic statement for the time, Professor William O. Jones hoped "that CIAT wouldn't be too concerned with only achieving high yields and called for a total systems approach."[135]

The Cassava Program in the early years wrestled with defining a clear research strategy for the crop. Cassava had little in the way of a well-documented research history to draw on in defining such a strategy. As a crop produced only in the tropics, it fell out of the purview of research in the colonial period, which focused on export crops. Furthermore, as a perennial shrub, it differed from that of annual crops, particularly the principal cereals. Nevertheless, the experience of the Green Revolution suggested a model for international commodity research: a principal focus on crop breeding; the search for a significant yield gain that would motivate farmer adoption; and wide adaptability of genotypes. This model was appropriate for irrigated agriculture with significant use of inputs but cassava was grown by small farmers under rain-fed conditions without purchased inputs, usually under marginal soil and rainfall conditions. Three of the first Cassava Program members, James Cock who became program leader, Kazuo Kawano the breeder, and Reinhardt Howeler, the soil scientist, had all started their careers at IRRI. Now, they faced the challenge of undertaking research on a very different crop grown under very different conditions. In a world then focused on increasing agricultural productivity, the scientists were working with one of the largest existing yield gaps in any crop. Average farm level yields were around 8 tons/ha, while the conference above suggested a yield target of 80/90 tons roots/ha/annum as feasible.[136] At the same time, the fact that cassava was grown essentially by small farmers under limited rainfall and poor soil conditions put severe constraints on how much of that yield gap could be closed. The very early years of the Cassava Program had a dual strategy: one focused on understanding

132 Coursey DG. 1982. The origins and history of the International Society for Tropical Root Crops.

133 Hershey C. 1994. Research for Development: The CIAT Cassava Program. CIAT, Cali, Colombia.

134 Muirhead B; Harpelle RN. 2010. IDRC: 40 years of ideas, innovation, and impact. Wilfrid Laurier University Press, Waterloo, Ontario, Canada. 402 p.

135 CIAT Staff. 1972. CIAT Cassava Review Conference: Notes and Observations. CIAT, Cali, Colombia. p 19.

136 Ibid. p 25.

the determinants of high yield but at the same time understanding cassava's adaptation to small farm conditions. The strategy quickly evolved to the latter and would become incorporated in CIAT's minimum input research approach, namely the theme of adapting the crop to the environment, rather than the environment to the crop.

Following on from the conference, IDRC established an Advisory Committee[137] chaired by Barry Nestel to guide not only CIATs research, but also all activities in the research network.[138] The Advisory Committee guided the cassava team at CIAT as it developed its objectives which became: "to develop and disseminate information regarding systems of cassava production requiring relatively low input levels, adapted to a wide range of ecological conditions, and suitable for use by both large and small farms."[139] In the 1972 and 1973 Advisory Committee meetings, the decision was taken to develop low- to medium-input technology and distinct variety-based production technologies for distinct growing environments: "different varieties may be necessary for various ecological zones, climates, and soil types" and "...when different ecozones are considered, different production methods are required. CIAT will develop production methods that tolerate a wide range of local conditions; these systems can then be modified for any particular locality, in many cases by scientists trained at CIAT, for that specific area." and "disease and pest control is through simple cultural and sanitary practices or through varietal resistance."[140]

137 This would today be known as a steering committee.

138 For more details of this network, see: Nestel and Cock. 1976. op. cit.

139 Ibid.

140 Cassava Program Document 1973. CIAT 1973.

Production in cassava research

Due to the limited research history on the crop, fundamental research was needed to advance the scientific understanding of what was up to now considered an orphan crop. The Cassava Program became a closely knit interdisciplinary research team during the 1970s and 1980s and developed a profound understanding of the crop with fundamental research on cassava entomology (initially Aart van Schoonhoven who later moved to the Bean Program and then Anthony Bellotti), pathology (Carlos Lozano), plant nutrition (Reinhardt Howeler), and physiology (Mabrouk El-Sharkawy and James Cock). This research supported the breeding program, providing sources of host plant resistance and information on traits associated with yield under varying conditions as well as providing refined management practices including integrated pest management. This was also the period of international varietal trials. However, due to phytosanitary restrictions on the movement of vegetative material, cassava international trials were only feasible on a routine basis in the 1980s when Willy Roca developed tissue culture techniques that could eliminate pathogens. Julio César Toro initially evaluated the performance of selected germplasm over a wide range of conditions in Colombia, and later established trials in other countries. These trials confirmed the original perception that it would be difficult to identify broadly adapted varieties suitable for a range of distinct edapho-climatic zones.

The evolution of the breeding program toward germplasm adapted to specific ecologies was relatively fast. The initial systematic evaluation of the germplasm and initial hybridization started in 1973. Initial selection at CIAT was then complemented with a selection site in Carimagua on acid soils with a pronounced dry season and heavy disease incidence and soon after, a third site on the north coast of Colombia. Regional varietal trials started in 1975 and by 1978 there was a debate in the program on how many ecologies CIAT should breed for as the Center with the world mandate for cassava. The six major cassava edapho-climatic zones for cassava were defined by 1981[141] and later refined in a mapping of cassava environments by the Agroecological Studies Unit.[142] This breeding philosophy was fundamental to the question of how to generate a Green Revolution in rain-fed agriculture, especially for a series of ecologies, many of which were considered marginal for crop production. In a 1983 paper, Kazuo Kawano and Peter Jennings argued that, "A critical issue is identification of cultural practices within the reach of the farmers in each target area. Research plots for varietal selection should be managed at a level within the reach of the average farm."[143] Clair Hershey, the principal cassava breeder at CIAT headquarters during the 1980s and 1990s, described the process as "designing gene pools around eco-regional objectives (soil and climate constraints, pests and diseases). This would allow some narrowing of objectives within each particular gene pool, as compared to incorporating all resistances, adaptation traits, and quality parameters into single, broadly adapted varieties. These edapho-climatic zone descriptions became internalized as a fundamental way in which we thought about and planned research, not only in gene pool development, but also other areas of research."[144] (Fortunately, five of the six mega-environments existed in Colombia, thus facilitating the development of the ecology specific gene pools). Coupled with this was the move from finished varieties sent to national programs, to providing sexual seed from which partners would select the most appropriate varieties for their own conditions. Thus, massive quantities of sexual seed from the distinct gene pools were distributed to Africa via IITA and to Asia through CIAT's collaborative programs in Asia.

Within the framework of CIAT's leadership in the development of farmer participatory research, the Cassava Program from 1985 "began to develop simple, effective methods to evaluate new varieties not only on-farm but with close farmer participation. The methodology covers institutional involvement, trial design and management, farmer and consumer interview procedures, and data analysis and interpretation." One of the simple approaches developed by Ted Carey was to give farmers packages of cassava stakes and then simply monitor how the varieties performed.[145] This novel approach obviated laborious regional testing and rigid, often

141 CIAT Cassava Annual Report 1981.

142 Carter SE. 1986. A note on the distribution of cassava amongst different climate and soil types in South America. Unpublished manuscript. CIAT, Cali, Colombia.

143 Kawano K; Jennings PR. 1982. Tropical crop breeding: Achievements and challenges. In: IRRI. 1983. Symposium on Potential Productivity of Field Crops under Different Environments. International Rice Research Institute, Los Baños, the Philippines.

144 Hershey C. 1994. op. cit. p 35.

145 Ashby J; Quiroz C; Rivera YM. 1987. Farmer participation in on-farm varietal trials. A report on work in progress. CIAT Colección Histórica 66769.

bureaucratic, certification schemes associated with varietal release.

Throughout the 1990s and into the following decade, CIAT cassava research at headquarters increasingly narrowed to a focus on population breeding supported by the application of new molecular methods. As in other research areas, cassava compared to crops such as maize and soybean did not have the investment in the development of the basic "infrastructure" for application of the advances in molecular biology, particularly the molecular maps and markers and the transformation and regeneration procedures. In 1988, the Cassava Biotechnology Network (CBN) was formed to develop a community of scientists working on cassava biotechnology. The CBN in 2002 transitioned to the Global Cassava Partnership for the 21st century (GCP21), broadening its mandate but with a continuing focus on varietal improvement.

In the last decade or so, research has attempted to use molecular techniques to design varietal and seed systems based on that of grains. Breeder and foundation seed production and dissemination remains a challenge for a vegetatively propagated crop such as cassava and there was some research that attempted to develop a "true seed" system for disseminating cassava varieties. As with CIP's work on true seed in potatoes, a practical system faced a number of other challenges. The CIAT program then turned to the development of a breeding system based on double haploids, which would allow hybridization through the use of well-characterized, homozygous parents. This work is still under development, but recent haploid microspores have been produced from anthers.[146] Cassava research at headquarters had shifted to a focus on pre-breeding supported by biotechnology applications. The more applied research has shifted to the regions.

From supply- to demand-side research

Given the focus on food security in the 1970s and early 1980s and increasing the "pile of rice", the Cassava Program was in many ways the first CGIAR research program to ask if markets would be able to absorb the potential increases in production without catastrophic effects on farmers' incomes, and in turn what that would imply in terms of the research strategy.[147] The Green Revolution did produce dramatic falls in domestic prices, but what if the price fall was sufficient to cut off the incentive to adopt the improved technologies? Unlike rice and wheat, cassava was not seen as a strategic crop in the food basket and did not have price supports – price supports would be difficult given the lack of storage potential for fresh roots. This question would become central in research targeting poor farmers that were in turn producing primarily for other poor consumers. Whereas the Green Revolution reduced the Malthusian pall, the CIAT cassava team focused on increasing rural income as their goal. Increased income required cassava's entry into the broader market economy.

The 1972 review conference recognized the multi-market potential of cassava but without addressing the question of how best to exploit this

146 Perera PIP; Ordóñez CA; Becerra López-Lavalle LA; Dedicova B. 2014. A milestone in the doubled haploid pathway of cassava (*Manihot esculenta* Crantz): Cellular and molecular assessment of anther-derived structures. Protoplasma 251(1):233–246.

147 See Lynam JK; Janssen W. 1992. Commodity research programs from the demand side. Agricultural Systems 39:231–252.

The principal impact of CIAT's cassava research occurred in Asia and was market-led, first through cassava pellet exports from Thailand and then through the growth in the cassava starch industry throughout most Southeast Asian countries.

potential beyond the requirement to make the crop more competitive in these markets by reducing root prices. Under the auspices of the Advisory Committee, Truman Phillips, an economist at the University of Guelph, was commissioned to study cassava utilization and potential markets. The evaluation of potential markets became a recurring theme in the development context for cassava. In the early 1980s, the Cassava Program evaluated the markets for cassava products, first of all in Colombia. The 1984 EPMR of CIAT argued that there was not sufficient analytical work to demonstrate the effective demand for cassava and that such an understanding was necessary to set priorities within the program and between the four commodities within CIAT[148]. The TAC's interpretation was that the recommendation "appears to be not so much directed at the appropriateness of the CIAT research and outreach strategy in Latin America and Asia, but rather at the potential return that would accrue from CIAT investment in cassava research, particularly in terms of the resources being directed at Latin America (as compared to Asia)."[149] This recommendation came during a period of relatively tight budgets and led to reductions in the production research program, and the initiation of a 3-year set of country-based demand studies in both Latin America and Asia led by John Lynam. These later provided the basis for the COSCA study in sub-Saharan Africa, which was led by Felix Nweke from IITA. An *African Cassava Atlas* produced by CIAT provided the basis for the sampling frame used in the COSCA study.[150] To a significant extent, the TAC's hypothesis was correct, as the principal impact of CIAT's cassava research would be felt in Asia and would be market-led, first through cassava pellet exports from Thailand and then through the growth in the cassava starch industry throughout most Southeast Asian countries as well as the biofuel program that uses cassava feed stocks in southern China.[151] It was at this time that CIAT decided to reduce its program in Colombia, and transfer its resources to the Asian program.

From a very early period, there was a research component on postharvest, processing, and utilization research. Much of this work was done in collaboration with scientists seconded from the Tropical Products Institute in the UK. Several of these later joined the cassava team, and one of them Rupert Best, who later became the Cassava Program Leader and then moved on to become leader of the Agroenterprises program. The postharvest work, guided by the demand studies, was complemented by an increasing focus on breeding for quality characteristics needed for particular markets. From the late 1990s onwards, CIRAD led the postharvest research at CIAT headquarters. Initially in 1973, the Cassava Program believed that distinct varieties

148 TAC (CGIAR Technical Advisory Committee). 1985. Report of the second external program review of Centro Internacional de Agricultura Tropical (CIAT). TAC Secretariat, Rome, Italy.

149 Ibid.

150 Carter SE; Fresco LO; Jones PG; Fairbairn JN. 1992. An atlas of cassava in Africa: Historical, agroecological and demographic aspects of crop distribution. CIAT Publication No. 206. CIAT. Cali, Colombia. 85 p.

151 IITA's research strategy in sub-Saharan Africa would also shift to an understanding of market potential as critical to driving cassava development and technology adoption, primarily based on the results of the COSCA study. See: Nweke F; Spencer D; Lynam J. 2001.The cassava transformation: Africa's best-kept secret. Michigan State University Press, East Lansing, MI, USA.

were required for distinct ecologies, but not for distinct end-uses.[152] This appraisal proved to be incorrect and later breeding strategies were modified accordingly. A recent example was the identification of a mutant that produced waxy (amylose-free) starch. This moved the technology into the area of food processing and the development of an exclusive commercialization agreement with Ingredion. This example of innovation at the upper end of the value chain, which is the basis of most public–private partnerships, was opposite to where the program started, which was how market diversification would impact on the small farmer.

The Cassava Program quite early in its development recognized that access to growth markets were essential to benefit small farmers in Latin America. The program was probably the first in CGIAR to use what has since become known as a value chain approach i.e., identifying potential new markets and then organizing the production, processing, aggregation, and delivery along the value chain. The question was how to diversify markets and at the same time direct benefits to small farmers. In 1981, the program began experimenting with integrated cassava research and development projects on the north coast of Colombia. These followed on the promotion of adoption of new cassava technology by Colombia's Integrated Rural Development (DRI) program, where increased production produced a glut in the market for perishable roots and farm gate prices collapsed. A key feature of the response was to look for solutions that were not based on direct subsidies or government interventions that would influence prices. The initial scheme was based on establishing a floor price for cassava through development of expansive alternative markets. The alternative market chosen was dried cassava chips for animal feed. The projects were based on the construction of plants for solar drying of cassava for the animal feed market. Similar projects were extended to the Pacific Coast of Ecuador in 1985 and to Ceara, Brazil, in 1986. To ensure access by small farmers, the projects were organized around farmer cooperatives, although some private investors constructed plants, demonstrating that the technology and marketing strategies were viable without government support. The development of the plants is presented in Figure 4.

An impact study on the Colombian North Coast found positive economic benefits for consumers and farmers due to a more stable price.[153] Most of the benefits were skewed to poor farmers, and were primarily due to the adoption of new, improved technology with concomitant increases in production.[154] These benefits would not have occurred without the price floor created by access to the animal feed market.[155]

152 Cassava Program Document 1973. CIAT 1973.

153 Gottret MV; Raymond M. 2003. An analysis of a cassava integrated research and development approach: Has it really contributed to poverty alleviation? In: Mathur S; Pachico D. (eds.). Agricultural research and poverty reduction: Some issues and evidence. Economics and Impact Series No. 2. CIAT, Cali, Colombia. p 205–226.

154 Gottret MV; Ospina Patiño B. 2004. Twenty years of cassava innovation in Colombia: Scaling up under different political, economic, and social environments. In: Pachico D; Fujisaka S. Scaling up and out: Achieving widespread impact through agricultural research. Volume 3 of CIAT Economic and Impact Series. CIAT, Cali, Colombia.

155 Later the production of dried chips declined due to the economic opening of Colombia in the early 1990s, and cheap imports of maize from the US coupled with a revalued Colombian peso due largely to high world prices for petroleum.

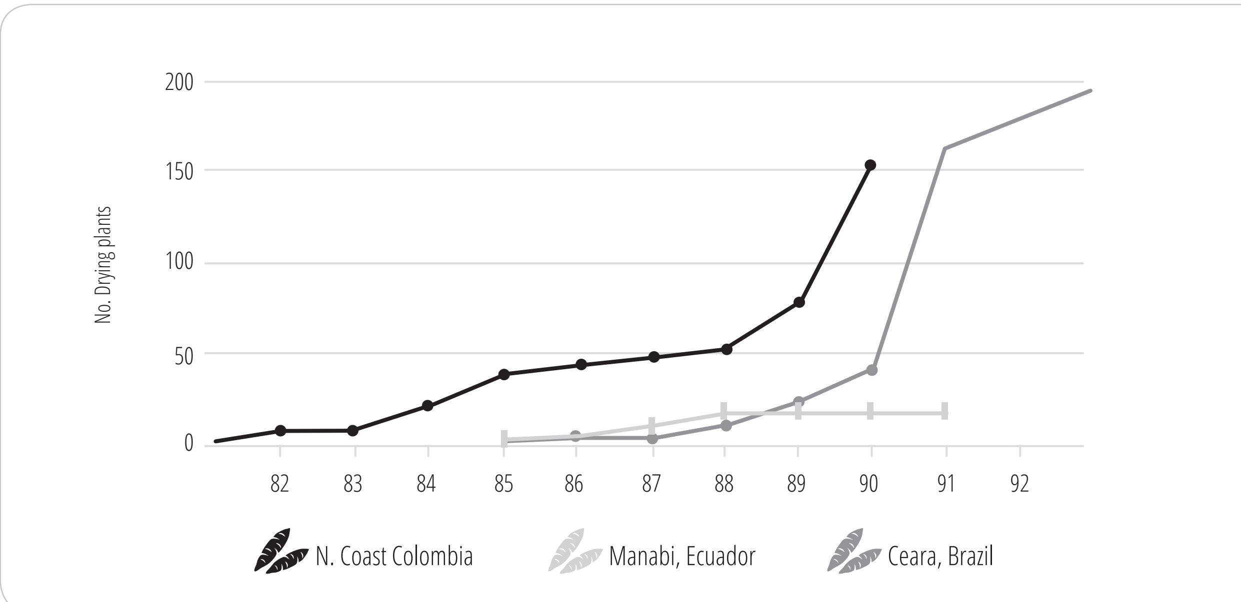

Figure 4 Number of cassava processing plants operational in Colombia, Ecuador, and Brazil.
Source: Hershey C. 1994. op. cit. p 61.

The Cassava Program in Asia

The Advisory Committee supported programs in Asia from its inception, primarily through national programs. In 1977, a liaison cassava scientist was stationed in SEARCA in Los Baños, Philippines. He facilitated germplasm exchange and selection of candidates for training in CIAT. Thus, in 1978, a cohort of Thai scientists participated in a long-term training program at headquarters; these professionals would later become the backbone of the national cassava research program in Thailand. Several short courses specifically for Asian scientists subsequently took place. However, there was no strong Cassava Program in the Philippines to work with and the regional office was closed in 1979. In 1982, Kazuo Kawano was stationed in Asia as a breeder and liaison officer, and the Asian regional office was opened in Bangkok in 1983. Thailand was chosen due to its strong cassava research programs and the promise of support from the Thai Government. A feature of CIAT's Cassava Program in Asia from 1983 was its total, seamless integration into local programs and institutions. Thus, the breeder did not have his own program, but worked within the framework of the national programs. Initially, work centered on Thailand, with the Thais generously agreeing to make germplasm produced in their program available for the rest of Southeast Asia. In 1986, Reinhardt Howeler joined the Asian regional office as an agronomist assisting national programs in the development of improved crop management. Compared to the headquarters program, the Asian program was more interdisciplinary, combining work on: soil and land conservation, farmer participatory research, networking of national programs, and most recently, new threats from pests and diseases. Although CIAT had initially proposed a third member of the team to handle utilization, the research on postharvest handling and processing moved into the Asian Institute of Technology in Thailand and the private sector. The CIAT research program thus focused on the production end of the value chain. With little expansion in the area planted root supplies and competitiveness depended on increasing yields. Significantly, cassava yields increased in Thailand from about 12 t/ha in the mid-1990s to close to 25 t/ha in mid-2000.

The breeding program in Thailand focused on breeding targets for an industrial market outside the center of origin. These were relatively simple, i.e., yield and starch content of the root. This built on the earlier breeding work at CIAT that focused on yield potential. CIAT headquarters continually sent crosses from appropriate gene pools to the Asian program. By 1992, a variety with significantly higher starch content and yield potential, KU50, was being multiplied for distribution. This variety would replace the existing local variety, Rayong 1, and in 1995 was introduced to Vietnam. This variety gave a small yield advantage with existing farmer practices, but when coupled with increased fertilizer usage it became the basis for a yield take-off in both countries. A 2013 impact study calculated a net present value of the economic surplus of US$243 million in Thailand and US$150 million in Vietnam.[156] A recent study in all Asian cassava-producing countries has found that "around 82.7% of the total of 4.1 million hectares of cassava cultivated in the 9 countries of the study are under improved cassava varieties. Sixty five % of this total is under CIAT-related varieties."[157] KU50 has been disseminated to five other countries in the region and is now grown in 47% of the total area under improved varieties in the region. Improved varieties cover virtually all the area where there is an industrial market, which is primarily for starch production.[158] Traditional varieties are still grown in those countries, such as Indonesia and the Philippines, where cassava is still important for direct human consumption.

The evolution of the Cassava Program from its negligible knowledge base could have been a series of false starts. Although the program at the very early stages hedged its bets on a research strategy, the focus on adaptation to ecological constraints proved to be the most appropriate approach. However, within this larger strategy, several excellent pieces of research produced very little impact. These included research on: somatic fusion as a tool for genetic engineering; cassava production from true seed; mycorrhiza inoculation; photosynthetic pathways of cassava; fresh cassava storage technology; intercropping with grain legumes to improve land-use efficiency; and artificial drying, as opposed to natural, drying systems. In the Cassava Program, there was, from the beginning, a portfolio of projects which made up

156 Robinson J; Srinivasan CS. 2013. Case studies on the impact of germplasm collection, conservation, characterization and evaluation (GCCCE) in the CGIAR. Standing Panel on Impact Assessment. CGIAR, Washington, DC, USA.

157 Labarta R; Wossen T; Le DP. 2017. The adoption of improved cassava varieties in South and Southeast Asia. Paper presented at the Asian Association of Agricultural Economics Conference in Bangkok. p 9.

158 In 1998, Kazuo Kawano received the Royal Decoration of the "Most Exalted Order of the White Elephant" from the Government of Thailand for his work in establishing the cassava breeding system in Thailand.

the whole program, many succeeding while others were dropped. Core funding and direct support from IDRC in the early stages provided the flexibility to adapt the research portfolio to both new scientific findings and to new information provided from field and farm testing. The move to project-based funding shifts that logic to the search for synergies across existing projects (where each project has to succeed) rather than an adaptable project portfolio within an evolving research strategy. This negates the basic idea of a portfolio that balances higher risk and the potential for higher pay-off research with lower risk and clearer expectations, which is conventional.

Fifty years of cassava research has moved the crop from its role as a neglected subsistence crop to a commodity that can contribute to the economic growth of countries in the tropics. CIAT and its sister Center, IITA in Africa have led this process and contributed to the development of a system of strong national research programs working on the crop. Cassava still does not receive the research funding that goes into maize but it is price competitive with maize starch in some segments of Asian starch and feed markets.

The pioneering research on modifying the crop to the environment rather than vice versa has shown that it is indeed possible to obtain reasonable levels of productivity with rain-fed agricultural in regions previously considered as marginal and unproductive. At the same time, the low productivity of labor compared to land in cassava production currently limits its ability to compete and at the same time provide a decent living for those involved in cassava production. In the original 1972 conference, the Director General Ulysses J. Grant, then, when mechanization was being discussed commented "Is it not true that development is related to the type of work people do? One should use [your] own resources, but I wonder if we should expect people to do this type of manual labor?" The revolution in increased productivity per unit of land, and the opening up of new markets for cassava products now needs to be matched by both reduced drudgery and increased labor productivity so that the true potential of cassava to improve the well-being of rural communities in marginal, rain-fed areas can be fully exploited.

Fifty years of cassava research have moved the crop from its role as a neglected subsistence crop to a commodity that can contribute to the economic growth of countries in the tropics.

The Rice Program

The CIAT Rice Program, more than any other CIAT commodity program, has focused on Latin America and the Caribbean (LAC). The region accounts for less than 4% of the world's rice but with a per capita consumption of about 25 kg in tropical Latin America, it is an important food staple in the region.

A number of factors argued for the establishment of an international Rice Program specific to LAC. First, at the time, most rice in the region was sown in upland areas, especially in the savannahs, such as the Brazilian Cerrados. The use of direct seeding and mechanized farming in these upland systems contrasted with the labor-intensive transplanting systems used in Asia. In addition, there were regional specificities related to rice quality, tolerance to acid soils, and aluminum toxicity, and resistance to *Tagosodes* sp., rice hoja blanca virus (RHBV), and specific races of blast.

Early success

As envisaged in the design of CIAT, the CIAT Rice Program was closely linked to IRRI. The program had its origins in the Colombian Agricultural program of the RF when a severe outbreak of RHBV led the RF in 1957 to recruit, Peter Jennings, a plant pathologist. After 4 years in Colombia, Jennings moved to the newly created IRRI in 1962 where he developed the successful semi-dwarf variety, IR8, of Green Revolution fame. When CIAT was established, Jennings moved to Cali to lead CIAT's Rice Program and played a leading role in the program for much of the next two decades, including his contributions as senior rice breeder.

Logically, the Rice Program's first efforts focused on transferring IR8 and related semi-dwarfs to Latin America's irrigated and favored rice-growing regions. A strong partnership with the National Rice

Growers Association (FEDEARROZ) and CORPOICA led to CIAT's first big success when modern varieties were adopted on practically the whole irrigated rice area of Colombia by 1975 causing yields to increase from 3.5 to 5.4 t/ha or about 50%.[159] There was also significant adoption of the varieties in favored rain-fed area. By 1981, modern varieties covered 26% of the rice area in Latin America.[160]

The Rice Program soon expanded its disciplinary base to include agronomy to develop appropriate management practices for the new varieties. By 1976, national programs were releasing locally adapted semi-dwarfs based on CIAT crosses. IRRI also posted a liaison scientist to CIAT who established a regional rice-testing network in 1976. The IRRI position was to be maintained until the mid-1990s as an effective mechanism for coordinating CIAT's program with the much larger IRRI program in Asia, exchanging germplasm within Latin America, and training.

Rebalancing to upland rice in the 1980s

The early success in irrigated rice and the large share of area under upland rice in Latin America of over 70% meant that CIAT needed to pay more attention to upland rice.[161] This move was reinforced when CIAT economists Grant Scobie (a future Director General of CIAT) and Rafael Posada published what would become a classic impact analysis in 1978 that drew attention to the distribution of the benefits of rice research in Colombia. They found a high rate of return to investment in irrigated rice research in Colombia with consumers capturing the bulk of the benefits through lower prices, and with poor consumers benefiting relatively more. However, rice producers overall lost from the lower prices and small upland producers who had not adopted the technology were most negatively affected.

The shift to upland rice led in 1986–92 by Robert (Bob) Zeigler, a future Director General of IRRI, was consistent with CIAT's original mandate to conduct research to develop the extensive savannah areas of LAC with their infertile acid soils. Upland rice is relatively tolerant to acid soils and was commonly used as a 'pioneer crop' to open new land as the savannahs were steadily colonized. In Brazil, upland rice accounted for over 90% of Brazil's rice area although yields were just over 1 t/ha. However, unlike the traditional upland areas of the Andes and Central America, large, highly mechanized farmers grew much of the savannah upland rice. The CIAT program focused on developing acid soil-tolerant varieties in an effort to facilitate the establishment of improved pastures after upland rice.

During this period, CIAT's Rice Program expanded to reach its all-time high of about ten scientists[162] with two-thirds of the resources

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159 Dalrymple DG. 1986. Development and spread of high-yielding rice varieties in developing countries. Bureau for Science and Technology, USAID, Washington, DC, USA.

__Scobie GM; Posada R. 1978. The impact of technical change on income distribution: The case of rice in Colombia. American Journal of Agricultural Economics 60(1):85–92.

160 TAC (CGIAR Technical Advisory Committee). 1985. Report of the Second External Review of the Centro Internacional de Agricultura Tropical. TAC, Rome, Italy.

161 Ibid.

162 TAC of the CGIAR. 1990. op. cit.

allocated to upland rice.[163] The program became more decentralized and new partnerships were developed internationally especially for upland rice with: IITA, AfricaRice, CIRAD, and IRD, and the Japanese International Research Center for Agricultural Sciences. EMBRAPA became a major partner within the region with significantly more resources devoted to upland rice than CIAT. The breeding work for upland rice focusing on blast resistance and tolerance to acid soils resulted in at least seven upland cultivars being released from CIAT crosses for the savannas.[164]

Under the leadership of Marc Chatel of CIRAD and Elcio Guimarães of CIAT, the program pioneered methods of population improvement through pedigree and recurrent selection within a network that involved collaborators in 15 countries. The Rice Program used shuttle-breeding approaches at disease hot spots across the region (Peru and Central America) for screening. The establishment of the biotechnology unit in 1985 also facilitated the introgression of new sources of diversity from wild relatives for combating biotic and abiotic stresses (Figure 5). César Martínez led this work; he worked in the program from 1981 to 2012 and became program leader in 2007. Given the significant losses from weeds, insects and diseases and the high use of chemical inputs in irrigated rice production, a program of integrated pest management was also initiated – this was an important step toward more sustainable production systems.

Restructuring and downsizing in the 1990s

The CGIAR-wide budget downturn and the shift of resources within CIAT to NRM in the early 1990s hit the Rice Program especially hard. The core budget for rice fell from US$4 million in 1990 to US$1 million in 1998;[165] the number of staff positions was reduced by about half and the remaining staff were expected to focus more on upstream research in accordance with CIAT's 1991 strategic plan.[166] Indeed, at one point, CIAT management decided to close the program and it was only rescued by support from the Government of Colombia and new funding arrangements (discussed below).[167]

In addition, the modest progress in upland rice yields, efforts to halt deforestation on the forest margins, and the shift away from upland rice to the more profitable soybeans in the savannahs meant that by 1986–88, an estimated 70% of LA rice production was irrigated (or favorable rain-fed) from 45% of the rice area. In Colombia, upland rice's share of rice output fell even more dramatically from

163 TAC of the CGIAR. 1985. op. cit.

164 Martínez CP; Torres EA; Chatel M; Mosquera G; Duitama J; Ishitani M; Selvaraj M; Dedicova B; Tohme J; Grenier C; Lorieux M. 2014. Rice breeding in Latin America. Plant Breeding Reviews 38:187–278.

__Breseghello F; de Morais OP; Pinheiro PV; Silva ACS; Da Maia de Castro E; Guimarães EP; de Castro AP; Pereira JA; de Matos Lopes A; Utumi MM. de Oliveira JP. 2011. Results of 25 years of upland rice breeding in Brazil. Crop Science 51(3):914–923.

165 Beintema N; Raitzer D; Dobermann A; Pray C; Sanint L; Wopereis M. 2010. Positioning rice research globally: Investments, institutional arrangements, and emerging challenges. In: Pandey S; Byerlee DR; Dawe D; Dobermann A; Mohanty S; Rozelle S; Hardy B. (eds.). Rice in the global economy: Strategic research and policy issues for food security. International Rice Research Institute, Los Baños, the Philippines.

166 CIAT. 1991. CIAT in the 1990s and beyond: A strategic plan. CIAT, Cali, Colombia.

167 Interview, Luis Sanint.

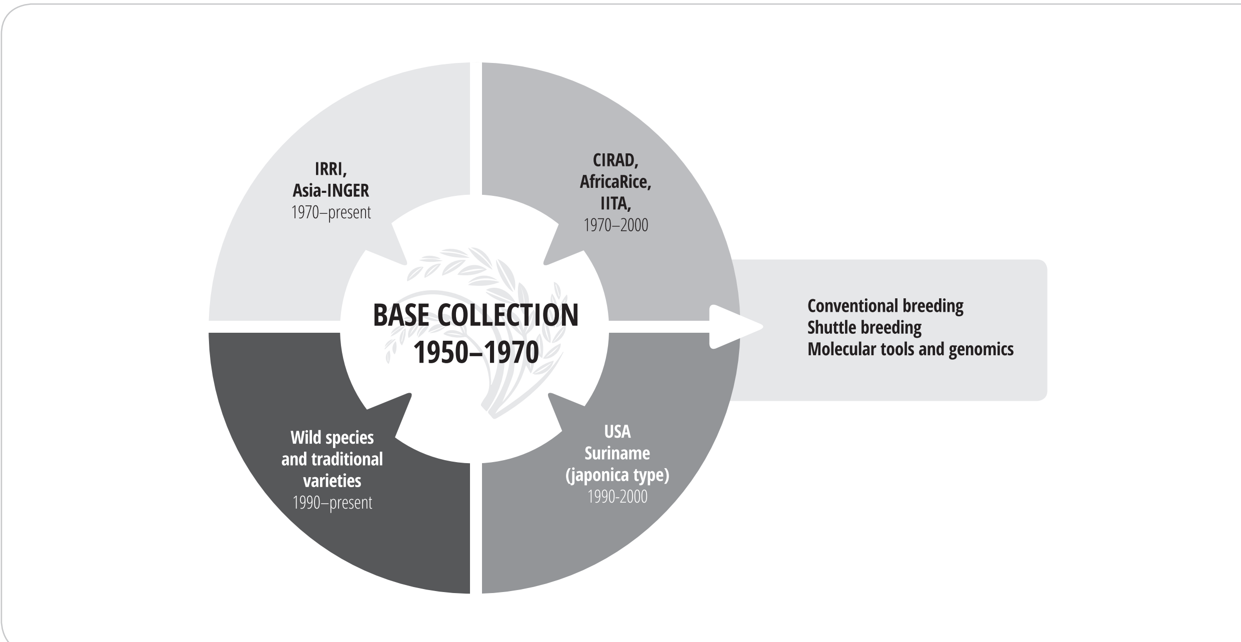

Figure 5 Sources of germplasm diversity for CIAT's Rice Program over time.

Source: Guimarães EP. 2015. Hacia dónde vamos con nuestra investigación en arroz – La visión del CIAT. LX Reunión Anual PCCMCA, Ciudad Guatemala, Guatemala, 4 May.

50% in 1966 to only 10% in 1974. Accordingly, CIAT reversed its emphasis on upland rice although some work on upland rice-pasture systems was initiated under the Savannah program in natural resources management.

The funding crisis and the shift back to irrigated rice, led to an innovative partnership, the Latin American Fund for Irrigated Rice (FLAR), a new fund established in 1995 by public and private rice stakeholders in the region (see p. 108). This fund supported applied breeding for the region and allowed CIAT to focus on upstream research such as new tools for molecular-assisted breeding, gene discovery, and pre-breeding. Through FLAR, the Latin American public and private research programs were able to retain and even strengthen the network of rice scientists with strong inter-institutional collaboration in germplasm development, agronomy, and training.

New technologies, competitiveness and eco-efficiency in the 2000s

Since 2000, the Rice Program has emphasized eco-efficiency to enhance competitiveness in the Latin American era of free trade agreements, as well as to meet sustainability goals. This has involved increased use of new tools starting with molecular markers and then advancing to sequencing of major genotypes, coupled with phenomics for gene discovery for traits related to rice adaptation and yields. Partly because of the generic biosafety approval granted to CIAT in 2007 by the Government of Colombia, CIAT has become a leader within CGIAR in rice transformations, with emphasis on improved nitrogen and water-use efficiency to enhance eco-efficiency (see p. 96). New biofortified varieties high in zinc released in six countries also offer nutritional benefits. CIAT through FLAR has engaged extensively in reducing yield gaps in rice through good agricultural practices and extension demonstrations. Also in conjunction with FLAR, members created a separate membership group led by Edgar Torres, to promote the development of hybrid rice in Latin America in 2009 that has already produced promising hybrids that are being evaluated in farmers' fields.

Finally, linkages with IRRI, AfricaRice, and advanced research institutes were strengthened from 2011 through participation in the Global Rice Science Partnership (GRiSP) − the CGIAR Research Program focused on rice (now the Rice AgriFood Systems Program). GRiSP has facilitated the use of CIAT research results and products in Asia and Africa, especially as those regions are now moving to direct seeded rice.

Large but uneven impacts

Rice research at CIAT has over the last 5 decades contributed scientifically as well as materially to food supply and poverty reduction in LA. The early success with modern semi-dwarf varieties was followed by the release of nearly 300 varieties based on CIAT crosses or a parent.[168] Under FLAR, 48 varieties have been released through the network, mainly based on crosses made at CIAT.[169] In the tropical parts of the Andean and Central American regions, the majority of rice varieties can be traced to CIAT crosses.

Equally important as its research products has been CIAT's contribution to building rice research capacity in Latin America. CIAT has trained over 1,300 rice scientists that in many cases went on to initiate rice research programs in their countries and have constituted the core of Rice Programs up to today.[170] The scientists trained by CIAT have contributed to a strong rice research network that has greatly enhanced scientific collaboration across the region.

Practically all irrigated and favorable rain-fed rice area is now sown to modern varieties based on CIAT or IRRI parentage. The most recent estimate from eight Andean and Central American countries is that 63% of the rice area in those countries is sown to varieties based on CIAT crosses.[171] Direct impacts of CIAT irrigated rice have been less in Brazil that produces half the rice of Latin America under temperate conditions in the south. Nonetheless, about half of Brazilian varieties include some CIAT parentage.[172]

Documented benefits from CIAT's investment in upland rice have been less but still significant.

168 CIAT. 2017. CIAT Rice Program: Outcome and next steps. Powerpoint presentation.

169 Martínez et al. 2014. op. cit.

170 Ibid.

171 Yamano T; Arouna A; Labarta RA; Huelgas ZM; Mohanty S. 2016. Adoption and impacts of international rice research technologies. Global Food Security 8:1–8.

172 Martínez et al. 2014. op. cit.

EMBRAPA, with a much larger rice research program made little progress in improving yields of upland areas up to 2000, but growth in yield potential accelerated due to investment by EMBRAPA and collaboration with CIAT.[173] One study estimated that an average of 15% of the Brazilian seed market for upland rice in the 1990s was made up of CGIAR varieties, very likely based on CIAT's Rice Program.[174] CIAT germplasm was especially important in upgrading grain quality of upland varieties. In addition, CIAT upland materials have been used extensively in Asia and Africa.[175]

Release of newer generations of semi-dwarf varieties has increased yield potential in irrigated areas by 31 kg/year, or about 0.6%, in line with genetic gains in yields globally.[176] Over the past 50 years, on-farm rice yields in Latin America have increased at 2.3% annually, significantly above the global average of 1.5% (Figure 6). This reflects both the investment in rice research as well as the shift from upland to irrigated rice induced by that investment. Yield stability has also been enhanced through more durable disease resistance, especially for blast.[177]

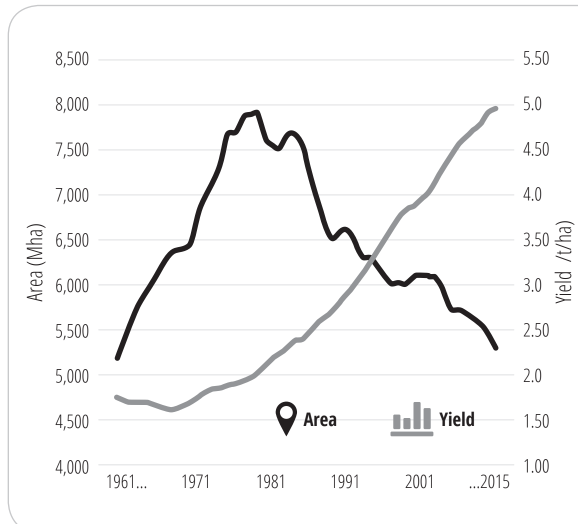

Figure 6 Rice area and yields in Latin America, 1965–2015 (5-year moving average)
Source: FAOSTAT. Accessed online 1 August 2017.

Benefits of investment in rice germplasm improvement have been placed at between US$0.85 billion and US$2 billion per year.[178] An assessment in the early 1990s concluded that benefits from investment in rice research were

173 Ibid.

174 Macedo J; Porto MCM; Contini E; Ávila AFD. 2003. Brazil country paper for the CGIAR Meta-Evaluation. OED Working Paper. World Bank, Washington, DC, USA.

175 Martínez et al. 2014. op. cit.

__Lamo J; Tongoona P; Sie M; Semon M; Onaga G; Okori P. 2017. Upland rice breeding in Uganda: Initiatives and progress. In: Jinquan Li (ed.). Advances in international rice research. InTech Openscience.

176 Fischer RA; Byerlee D; Edmeades G. 2014. Crop yields and global food security. ACIAR: Canberra, ACT.

177 Cuevas-Pérez FE; Berrío LE; González DI; Correa-Victoria F; Tulande E. 1995. Genetic improvement in yield of semidwarf rice cultivars in Colombia. Crop Science 35(3):725–729.

178 Sanint LR; Wood S. 1998. Impact of rice research in Latin America and the Caribbean during the past three decades. In: Pingali PL; Hossain M. (eds.). Impact of rice research. pp 405–428.

__TAC of the CGIAR. 1990. op. cit.

higher than for any other crop research by CGIAR in Latin America.[179]

Studies of the impacts of CIAT's rice research have attributed most of the benefits to consumers, especially poor consumers, due to lower prices.[180] Higher yields in irrigated areas and lower prices also helped save land and forests, as some of the upland rice was sown on fragile forest margins.[181] These impacts through lower prices were probably a reasonable conclusion in the early days of the program when rice sectors were highly protected and prices were determined domestically. However, after the liberalization of markets from around 1990, prices in all countries in the region (with the possible exception of Brazil) were largely determined by world prices, and producers (mostly commercial farmers) were the main beneficiaries of productivity gains from research.[182]

This suggests that in the future, farmers and seed companies should play an even greater role in research funding. CIAT's public investment in rice research must be justified by objectives that go beyond food security and equity. The Rice Program continues to contribute to global sustainability goals such as saving forests, reducing greenhouse gases, and restoring degraded land, and to global rice knowledge, such as systems of rice production based on direct seeding. The challenge for the program under the leadership of Fernando Correa since 2015, is how to finance the full cost of rice research from regional stakeholders, especially the private sector, while at the same time ensuring that it contributes to global public goods.

179 Janssen WG; Crissman C; Henry G; López Pereira MA; Sanint LR; Walker T. 1992. CIAT, CIMMYT and CIP: Their role in the agricultural research in Latin America and the Caribbean. CIAT Publication No. 213. CIAT, Cali, Colombia. p 49. http://hdl.handle.net/10568/69585

180 e.g., Sanint and Wood. 1998. op. cit.

181 Ibid.

182 The farm size distributional impact of improved rice varieties has not been rigorously studied since the 1976 - study by Scobie and Posada. However, census data reveals that half of rice producers in Colombia and South Brazil have less than 10 ha and 70% of them are renters in relatively highly productive lands. This suggests that benefits do go to small farmers as well. (Sanint, pers. comm.).

Over the past 50 years, on-farm rice yields in Latin America have increased at 2.3% annually, significantly above the global average of 1.5%.

The Tropical Forages Program

Program evolution

At its inception, CIAT recognized that exploiting the huge potential of the tropical lowlands of Latin America would require a strong focus on beef production as the most important commodity produced in the tropics and the one with the strongest market potential. Added to this was the global priority in the 1960s and 1970s on addressing perceived protein deficiencies in diets and early CIAT surveys that showed the critical role of beef in the diets of the poor of Latin America. Further, the Rockefeller Foundation's Colombian Agricultural Program as well as its Mexican Agricultural Program had invested substantially in research on beef and dairy. Since these programs had given significant attention to the tropical lowlands, they provided a base for the CIAT program.

Over 50 years, CIAT has given priority to improving productivity and sustainability of cattle production, initially for beef and later for dual-purpose meat–milk systems and for dairying. The initial plan for CIAT was to develop both a beef production and a forages program. In 1967, the design team for forage research at CIAT, led by Loy Crowder of Cornell University noted that: "the best prospects for improving livestock production per animal and per land unit are with sown pastures".[183] The beef and forages units were soon combined into a Beef Production Systems program under the leadership of Ned Raun, an animal nutritionist who had already spent 8 years with the RF programs in

183 Crowder LV; Blaser RE. 1968. A proposal for a pasture-livestock research and training program. CIAT, Cali, Colombia.

Mexico and Colombia.[184] Forages, and in particular pastures, were initially a relatively small part of a large and complex program dealing with almost all aspects of beef production – animal health, breeding and reproduction, herd management, nutrition, economics and markets, and production systems – as well as multiple dimensions of pastures and their management. A 1973 CIAT-commissioned external review, again led by Loy Crowder, and a major 1974 conference on beef cattle production systems in Latin America,[185] reinforced this broad orientation of the program.

A critical turning point was an internal review prepared by the staff of the Beef program in September 1975, which recommended a greater focus on pastures and a scaling back of other areas, especially animal health.[186] The same review also called for a reorientation away from fertile areas such as the Colombian north coast to the acid soil savannas. CIAT quickly acted to implement these changes with the appointment of Pedro Sánchez, a soil scientist and later the 2002 World Food prizewinner, as leader of the program for 1977–79, with a particular focus on management of acid soils for beef production in the lowland savannas. By 1980, with the appointment of forage scientist, Jose (Pepe) Toledo as leader, the program was squarely focused on pastures. With what would be its peak number of senior staff of 20, it changed its name to the Tropical Pastures program in 1979, while other livestock research in animal health was phased out.

At this stage, the program was the largest in CIAT. Even with a narrower focus on pastures, the research process was a more complex, time-consuming, and costly exercise relative to the single commodity orientation of the other programs as it involved grasses and legumes of different genera and species.[187] At the founding of CIAT, there was little existing base of knowledge to build on, largely from the more subtropical environments of southern USA, Queensland, Australia, and Sao Paulo state, Brazil. Much of CIAT's research over the 50 years has been to establish fundamental knowledge on tropical forages. With scores of potential species, the program had to develop appropriate methods for their evaluation under the widely varying stress conditions of the major environments and sub-systems for cattle production in the tropics. Given that the program adopted from the beginning a low-input approach that included legumes as well as grasses, candidate varieties also had to be evaluated in grass–legume mixes and needed to resist the effects of grazing.

Following the 'Australian school', the program sought sustainable grass–legume systems that fixed their own nitrogen and provided nitrogen for crops grown in rotation with forages in crop–livestock systems. As observed by CIAT forage breeder John Miles in 1991: "The merits of permanent,

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184 Crowder LV; Estupiñán J; Gregory K; Hutton EM; Costa Lemos R; Plaxico JS. 1973. External review: Team report on the Beef Production Systems Program. CIAT, Cali, Colombia.

185 CIAT. 1974. Potential to Increase beef production in tropical Americas. Proceedings of a seminar. 18–21 February. Cali, Colombia.

186 CIAT. 1975. Beef cattle production program. Staff Working Paper.

187 CIAT. 1984. Background paper on the Tropical Pastures Program prepared for the External Program Review 1984. CIAT, Cali, Colombia.

__Miles JW. 2001. Achievements and perspectives in the breeding of tropical grasses and legumes. In: Proceedings of the XIX International Grassland Congress, Sao Paulo, Brazil. pp 509–515.

grass/legume tropical pastures became something of a dogma among tropical pasture researchers and the 'Australian pasture legume school' was subsequently adopted in tropical Latin America. Pasture research in the American and Australian tropics has had a remarkably strong focus on discovering and domesticating novel legume species." A first step was the collection of the diversity of wild species, especially in Latin America (see p. 92). Early work emphasized the characterization, evaluation, and selection of suitable grass and legume species and cultivars for the acid soils of the savannas. Although the emphasis was on evaluation and selection from wild species, selective breeding was also initiated in the 1970s. As breeding started from wild species, it was necessarily exploratory with much of it focused on the legume, *Stylosanthes guianensis*. In addition, since the value of legumes is only realized in association with nitrogen-fixing *Rhizobium* species, additional research and associated skills in microbiology had to be employed – although it turned out that most legumes were able to use indigenous *Rhizobium* species already in the soil.

In the grasses, breeding work focused on *Brachiaria* and was initiated in 1988 with the transfer of sexual germplasm and interspecific hybridization methods from EMBRAPA and further adaptation in CIAT.[188] *Brachiaria* improvement aimed to develop: resistance to spittlebug (a major pest problem), tolerance to acid soils, drought and excess water, better forage quality and improved seed yields. As *Brachiaria* breeding became a priority, *Stylosanthes* breeding was phased out as Brazilian scientists were undertaking this research.

The production of forages was not an end in itself but one input into a livestock production system. These systems are in turn highly diverse in terms of agroecology, management intensity, animal breed, and output (beef and/or milk), making recommendations on pasture species and their management quite site specific. Pastures had to be ultimately evaluated in costly grazing experiments that should extend over the life of a pasture of several years. Delivery of improved pastures through seed systems was challenged by low seed yields of most species and the lack of private sector interest in an infant industry. Finally, the adoption of improved pastures depended on multiple factors, including secure land tenure and access to credit to finance the long-term investment required.

Recognizing these challenges, CIAT decided on a strategy of developing low input–low risk systems that would be suited to the capital-short producers on the frontier. The development by the new Land Resources Unit enabled a more precise definition of the major cattle production ecosystems on the Latin America frontier based on a review of soil and climatic data from 251 locations.[189]

1. Well-drained isohypothermic savannas (mainly the Plains) with 6–8 wet season months
2. Well-drained isothermic savannas (mainly Cerrados) with 6–8 wet season months
3. Poorly drained savanna under various landscapes and soils

188 Ibid.

__And Miles JW. 2007. Apomixis for cultivar development in tropical forage grasses. Crop Science 47:S-238.

189 TAC of the CGIAR. 1985. op. cit. All were defined as wet season mean temperatures above 23.5 °C.

4. Tropical semi-evergreen seasonal forests with 8–9 wet season months
5. Tropical rain forest with over 9 months of wet season

Within these ecosystems, the clear priorities for CIAT from the beginning were the first two savanna systems – the Cerrados of Brazil and the Plains of Colombia and Venezuela, which together were estimated to cover 250 million ha. They represented both the most important beef production systems and those with the greatest opportunity for improved productivity. The savannas presented multiple challenges of soil acidity, Al toxicity, poor fertility, pasture degradation, soil compaction and erosion, and build-up of pests and diseases. Research in the Plains was centered at Carimagua in Colombia in collaboration with CORPOICA after the construction of the experiment station there in 1972. Research in the Cerrados was initiated in collaboration with EMBRAPA and CIAT staff were in Planaltina near Brasilia from 1979.[190]

A secondary priority was pasture research in the forest zone with a strong focus on sustainable soil management, starting with a site in Pucallpa, Peru in 1985, and in Costa Rica in 1987. A smaller activity was initiated for the hillsides of Central America in the early 1990s.

Research priorities for forages were influenced by the overall program structure of CIAT and the different growth dynamics between the Cerrados and the Plains. Initially, the focus was on testing options for pasture establishment and management that would be ecologically sound and sustainable over the long term. As infrastructure improved, and with advances in crop technology, the program shifted to demonstrate the benefits of crop–pasture systems in the establishment and renovation of pastures as well as on the productivity of crops sown after pastures, especially pastures that included legumes. In the 1980s, research in the savannas centered on upland rice as the first crop after clearing natural pastures or forests as a step toward the establishment of improved pastures. This system was widely used at the time, and upland rice benefited from the collaboration within CIAT in developing rice varieties suited to upland acid soils (see p. 72). In the 1990s, this agro-pastoral research evolved to include soybean and maize that were increasingly grown under higher inputs and management as upland rice was phased out.

Much of the program's research on natural resource management and systems was re-organized as CIAT restructured toward NRM programs in the early 1990s, and along with a sharp reduction in funding to CIAT, the Pastures program was downsized to 5 scientific staff in 1997, including only one breeder. This change eliminated the large-scale evaluation of germplasm under grazing conditions, much of the nutritional evaluation, and the seed production component. Breeding was increasingly emphasized in the germplasm program and much of the research on sustainable soil management and pasture establishment was taken over by the systems programs. Accordingly, the program changed its name again to the Tropical Forages Program in 1992.

The complexity of production systems and pasture research put a premium on partnerships to meet the aims of the program. An important step in this process was the founding of the International

190 CIAT. Annual Report 1980. CIAT, Cali, Colombia.

Tropical Pastures Evaluation Network (RIEPT) in 1979 to test forage species and cultivars with similar methodology in a wide range of environments. This effort generated an invaluable and unique database on those forages and distributed germplasm to the emerging cadre of pasture scientists, most of whom had taken training courses at CIAT. The RIEPT network was critical in developing strong and lasting collaboration between institutions and researchers in the region. By 1986, RIEPT had 3 staff in average linked with testing at over 100 sites in 15 countries and was transforming pasture science in tropical Latin America. The information generated became the basis of the database and software *Tropical Forages* released in 2005, available on www.tropicalforages.info.

In the 2000s, the global livestock industry came under increasing criticism for its role in climate change through greenhouse gas emissions, accounting for about half of all emissions from agriculture and land use, and the loss of valuable biodiversity through its expansion into the forests. Although the CIAT program maintained attention to productivity and plot level sustainability issues, it increasingly turned its attention to landscape issues such as restoration of degraded lands and global environmental issues of reduced greenhouse cases and conservation of biodiversity. These were encapsulated in its LivestockPlus approach launched in 2015 (Figure 7).[191]

In addition to the work in Latin American, the program started modest research efforts in Southeast Asia in 1991, and Eastern and Southern Africa in 2009.[192] These programs initially focused on germplasm evaluation but then expanded the scope to other methods of forage management beyond pastures, especially cut and carry systems in crop–livestock, with attention to NRM. CIAT's long experience with a diversity of species was especially valuable to the work in Asia.

Brazil had a long tradition in research on tropical forages, and with over 100 pasture scientists was a major player in pasture science and a critical

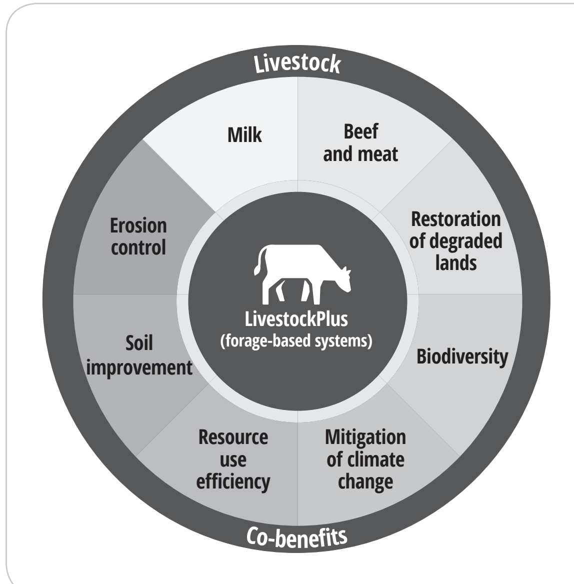

Figure 7 CIAT's conception of the LivestockPlus approach to eco-efficiency.
Source: Rao et al., 2015. op. cit.

191 Rao IM; Peters M; Castro A; Schultze-Kraft R; White D; Fisher M; Miles J; Lascano CE; Blümmel M; Bungenstab DJ; Tapasco J. et al. 2015. LivestockPlus: The sustainable intensification of forage-based agricultural systems to improve livelihoods and ecosystem services in the tropics. Tropical Grasslands–Forrajes Tropicales 3:59–82.

192 Spain JM; Ayarza MA. 1992. Tropical pastures target environments. In: CIAT. (ed.), Pastures for the tropical lowlands: CIAT's contribution. CIAT, Cali, Colombia. pp 1–8.

partner for CIAT.[193] Strong partnerships in more basic research were also developed early on with the Technical University of Berlin in 1979–81, Bayreuth University in the 1990s, University of Hohenheim from the 1990s, ETH Zurich, North Carolina State University in soils as well as CIRAD, IFDC, IRD (then ORSTOM), and many others. Last but not least, CIAT has partnered from the beginning with Australia's research programs in tropical pastures, notably CSIRO that had long experience in tropical pastures and had successfully integrated legumes in grazing systems.

Although CIAT had the first livestock program, the International Livestock Centre for Africa (ILCA) was formed in 1973 (later merged into ILRI). CIAT initially forged links through forage germplasm collection and exchange, given that most commercial grasses were from Africa and most of the legumes were from the Americas and Asia. In the late 1980s and early 1990s, a link was developed to germplasm evaluation in West and Central Africa with ILRI and French-led networks. In the 1990s, the CGIAR Systemwide Livestock Program and the Tropileche project led to further but still limited collaboration with ILRI.

In 2012, CGIAR launched the CGIAR Research Program (CRP) on Livestock and Fish that incorporated much of the Tropical Forages Program of CIAT. In 2011, CIAT's new eco-efficiency strategy also provided the opportunity for the forages program under the leadership of Michael Peters to explore the link between tropical forages and global environmental services, focusing on the reduction of greenhouse emissions through for example, biological nitrification inhibition and reduction of methane emissions and building on work in the 1990s on carbon accumulation of forages. This in turn logically linked the forage work to the CGIAR Research Program on Climate Change, Agriculture and Food Security (CCAFS), led by CIAT.

Associated with all these changes has been an evolution of the disciplinary mix in the program. Various forage germplasm activities have been a constant throughout the 5 decades starting with collecting and agronomic evaluation. Pasture management, including control of pest and diseases by cultivar selection and breeding as well as management was soon added initially to enhance productivity and quality and increasingly for sustainable natural resource use. In the late 1980s and in the 1990s, systems research moved from mere pastures to the integration of crops and livestock.

Currently the program has 10 IRS working specifically on tropical forages, linking with other programs in CIAT and external partners. Since January 2017, CIAT is coordinating the Feeds and Forages flagship of the Livestock CRP. Four of the program's staff are now based in Africa and one in Asia, indicating that the research is truly global.

Program achievements

Germplasm

Any assessment of achievements must start with germplasm collection, conservation and evaluation. From around 3,000 accessions in 1977 the collection quickly grew to 11,500 in 1984.[194] Today, with nearly 24,000 accessions, over 90% of which are legumes,

193 TAC of the CGIAR. 1985. op. cit.

194 Ibid.

CIAT has the world's largest forage germplasm base for forage species for the tropical lowlands acid soils (see p. 92).

The germplasm evaluation program led to national program releases from the early 1980s of both grass and legume cultivars largely through RIEPT, largely based on selections from wild species. For example, by 2004, 11 grasses and 16 legumes had been released in Mexico and Central America resulting from the evaluation and selection work under RIEPT.[195] In total, national programs have released 64 tropical grass and legume cultivars based on germplasm accessions provided by CIAT.[196] Unfortunately, as noted by the CGIAR Standing Panel on Impact Assessment (SPIA), there has been little effort to document the uptake of these cultivars and assess their impacts.[197]

Although most of the breeding effort was on legumes, by CIAT's own assessment, the germplasm work has not been very productive as measured by adoption. It has been a long-term, complex and expensive process whose "impact is not proportional to investment."[198] Measured by uptake, "the record of success of tropical forage plant breeding is frankly dubious".[199] Adoption of legumes has been constrained by the management skills and capital needed to maintain grass–legume pasture mixtures, anti-quality factors in legumes, and the need to work closely with farmers to adapt legumes to their specific needs.[200] Even so there have been successes in particular niches. With strong local champions among scientist and farmers, the legume, *Arachis pintoi* was adopted in the 2000s Acre State of Brazil.[201] A *Stylothanses* species mixture, locally named Estilosantes Campo Grande, has been sown on about 150,000 ha in the southern Cerrados of Brazil and a spillover of the program has been the use of *S. guianensis* as a cover crop and feed meal in China.[202]

A major success was in the *Brachiaria* grasses, where by the early 2000s adoption on over 3 million ha had been documented in Mexico and Central America.[203] CIAT, in collaboration with EMBRAPA, also achieved another success with *Andropogon*

195 Holmann F; Rivas L; Argel PJ; Pérez E. 2004. Impact of the adoption of *Brachiaria* grasses: Central America and Mexico. Livestock Research for Rural Development 16(12):1–6.

196 Peters M. 2011. Tropical Forages Program [brief]. CIAT, Cali, Colombia. 2 p. http://bit.ly/2xlxZvs

197 Jutzi SC; Rich KM. 2016. An evaluation of CGIAR Centers' impact assessment work on livestock-related research (1990–2014). Standing Panel on Impact Assessment, CGIAR. http://impact.cgiar.org/evaluation-cgiar-centers-impact-1

198 Shelton HM; Franzel S; Peters M. 2005. Adoption of tropical legume technology around the world: Analysis of success. In: Proceedings of the XX International Grassland Congress: Offered papers, Dublin. pp. 149–166.

199 Miles. 2001. op. cit.

200 Miles. 2001. Ibid.

201 Valentim JF; Andrade CMS. 2005. Forage peanut (*Arachis pintoi*): A high-yielding and high-quality tropical legume for sustainable cattle production systems in the Western Brazilian Amazon. In: Proceedings of the XX International Grassland Congress: Offered papers. Dublin. p 329.

202 Fernandes CD; Grof B; Chakraborty S; Verzignassi JR. 2005. Estilosantes Campo Grande in Brazil: A tropical forage legume success story. In: Proceedings of the XX International Grassland Congress: Offered papers. Dublin. p 330.

__Guodao L; Kerridge PC. 1997. Selection and utilization of *Stylosanthes guianensis* for green cover and feed meal production in China. In: Proceedings of the XVIII International Grassland Congress. Canada. pp 49–50.

203 Holmann et al. 2004. op. cit.

gayanus with an estimated 1.5 million ha sown by 2000 in Brazil.[204] *Brachiaria* cultivars developed by EMBRAPA from the germplasm shared by CIAT fostered a partnership with the private seed sector (31 seed companies associated as UNIPASTO), which pivoted extensive adoption of the new releases, which is estimated to cover around 10 million ha since 2003.[205] Likewise, in Colombia, surveys in 2017 in the Eastern Plains suggest that about one-third of improved pastures is sown using *Brachiaria* cultivars selected or bred by CIAT.

Under the leadership of Carlos Lascano, *Brachiaria* hybrids were released in 2002, and in Mexico a partnership with a private seed company, Grupo Papalotla, helped overcome the problem of seed production and distribution. The partnership with the private sector was further expanded through licensing by Dow Agrosciences in 2011. Today enough seed of *Brachiaria* hybrids has been produced to sow an estimated 0.7–0.8 million ha of sown pastures in Latin America.[206]

Brazil has by far the largest area of improved tropical and subtropical pastures in the world, again largely grasses. By mid 1980s, there were an estimated 16 million ha of improved pastures in Latin America, almost all *Brachiaria* spp.[207]and today an extraordinary 115 million ha is sown to improved cultivars with some 50 million ha to *B. brizantha*, cv Marandu, selected by EMBRAPA.[208] Together with better breeds and animal health, the impact on cattle intensification in Brazil has been one of the major successes in global agriculture over the past 30 years with an overall four-fold increase in productivity from around 12 kg of carcass equivalent per ha per year in 1985 to 54 kg today, partitioned equally between a higher stocking rate and improved animal performance per head (Figure 8).

It is impossible to estimate CIAT's contribution to Brazilian beef production but CIAT's sharing of germplasm and training programs have played a significant role. EMBRAPA is the leading forages programs in Latin America and up to the early 1990s, CIAT worked in close partnership in collaborative research and exchange. The CIAT–EMBRAPA joint program in the Cerrados provided some of the early successes in adoption of new pasture cultivars and many of the forage scientists received training in CIAT.[209] CIAT´s spittlebug methodologies are still very much in use and not only for *Brachiaria*

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204 Rivas L. 2002. Impacto económico de la adopción de pastos mejorados en América Latina Tropical. Paper presented at the Simposio Internacional sobre Rentabilidad en las Empresas Ganaderas. 23 November. Veracruz, Mexico.

205 Cacilda Borges do Valle (pers. comm.).

206 Michael Peters (pers. comm).

207 Toledo JM; Nores GA. 1986. Tropical pasture technology for marginal lands of tropical America. Outlook on Agriculture 15(1):2–9.

208 These data are not specific to the tropics although the bulk of beef production is carried out there. In the Cerrado in 1990, adoption was 40 million ha of improved pastures. See: Spain JM. 1990. Neotropical savannas: Prospects for economically and ecologically sustainable crop-livestock production systems. Paper presented at the Seminario Internacional Manejo de los Recursos Naturales en Ecosistemas Tropicales para una Agricultura Sostenible. ICA, Bogotá, Colombia. 19–22 November.

__See also Rao et al. 2015. op. cit.

__And Jank L; Barrios SC; do Valle CB; Simeão RM; Alves GF. 2014. The value of improved pastures to Brazilian beef production. Crop and Pasture Science 65(11):1132–1137.

209 Macedo et al. 2003. op. cit.

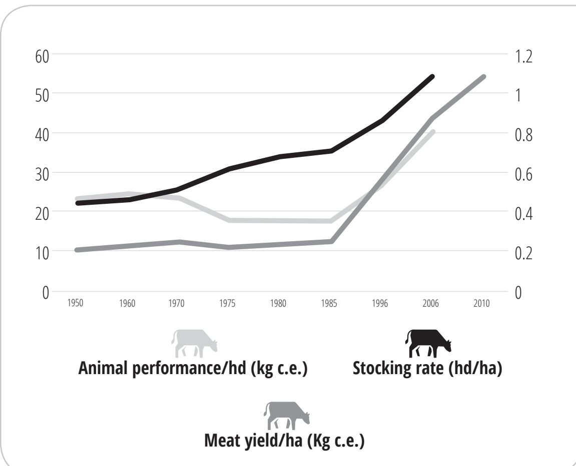

Figure 8 Livestock productivity in Brazil.

Animal performance and meat yield are plotted on the left axis and stocking rate on the right axis.

Source: Calculated from data in Martha GB; Alves E; Contini E. 2012. Land-saving approaches and beef production growth in Brazil. Agricultural Systems 110:173–177.

in Brazilian grass-breeding programs.[210] At the same time, CIAT has benefited from collaboration with EMBRAPA, especially in using EMBRAPA's breeding and laboratory methods for interspecific hybridization in *Brachiaria*.[211]

Knowledge and training

Beyond germplasm, the more fundamental research captured in a wide range of knowledge products combined with training programs (see p. 114) have been important contributions. In the 1990s, CIAT produced a number of major knowledge products such as *Centrosema: Biology, Agronomy, and Utilization* (1990), *Pastures for the Tropical Lowlands: CIATs Contributions* (1992), *Brachiaria Biology, Agronomy and Improvement* (1994), and *Biology and Agronomy of Forage Arachis* (1994). The journal *Pasturas Tropicales* published continuously by CIAT since 1979 (now merged with the Australian Tropical Grasslands and published in both English and Spanish) has been a major global source of scientific publishing and exchange in tropical forages that receives 90,000 visits annually (www.tropicalgrasslands.info). In the 2000s, CIAT also contributed to the successful development of databases and searchable tools, such as the Feed Assessment Tool (FEAST) led by ILRI, and the Selection of Forages for the Tropics (SoFT Tool) lead by CSIRO. SoFT is now visited 250,000 times annually.

Throughout the first two decades of operation, until budgets were slashed in the 1990s, CIAT made major contributions through training a cadre of pasture scientists. In the period 1977–83 alone, some 255 scientists received training at CIAT, most of them through in-service training and included 32 postgraduates and 18 postdocs.[212] Given the infancy of pasture science in Latin America, these training programs may have been as important as the research in CIAT's contribution to the region.

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210 Lapointe SL; Serrano MS; Arango GL; Sotelo G; Córdoba F. 1992. Antibiosis to spittlebugs (Homoptera: Cercopidae) in accessions of *Brachiaria spp*. Journal of Economic Entomology 85(4):1485–1490.

__Cardona C; Miles JW; Sotelo G. 1999. An improved methodology for massive screening of *Brachiaria spp*. genotypes for resistance to *Aeneolamia varia* (Homoptera: Cercopidae). Journal of Economic Entomology 92(2):490–496.

211 Valle CD; Glienke C; Leguizamon GOC. 1993. Breeding of apomictic *Brachiaria* through interspecific hybridization. Proceedings of the XVII International Grassland Congress, New Zealand: NZIAS 1: 427–428.

212 TAC of the CGIAR. 1985. op. cit.

Systems and NRM

The program recognized early on that much of the work in systems and NRM would best provide the knowledge base and tools for site-specific adaptation at two key research sites (on the savannas, Uberlandia, in the Brazilian Cerrado and Carimagua in the Colombian Eastern Plains). The Agropastoral Systems Network for the Savannas created in 2000 provided the bridge between this more strategic work and its application in national programs.[213] Participatory research methods were developed to better characterize major systems and inform research design. Long-term experiments in agro-pastoral systems demonstrated the advantages of an 'arable layer' approach based on soil amendments and vertical tillage in agro-pastoral rotations to provide a productive and sustainable soil management system for both crops and pastures over three decades, mostly under the management of CORPOICA.[214] From the 1990s, the systems work expanded to agro-silvo-pastoral systems incorporating agroforestry and fodder shrubs. Nonetheless, the program has underinvested in long-term experimentation and strategic research on soil and pasture degradation and social science due to the unstable funding base in recent decades.[215]

Although much of the work in Latin America has been directed at medium-scale commercial crop–livestock systems, many of the same forage species have found valuable uses in small-scale crop–livestock systems of Southeast Asia, and more recently in Eastern and Southern Africa. Since 1992, CIAT has used participatory research approaches to introduce forages into diverse systems of several countries in the Asian region. In pilot areas, a cut and carry system of forages for penned livestock is replacing traditional systems based on grazing of communal fallow lands or feeding of crop residues that provided low-quality feeds. The range of improved systems is impressive, varying from cattle fattening, dairying, goat production, and aquaculture, to supplying commercial forage markets. The major incentive for adoption, now estimated at close to 50,000 smallholders in Southeast Asia, has been the large saving in labor of penned systems compared to open grazing systems, combined with improved productivity and environmental benefits such as reduced erosion on hillsides when forages are planted in terraces or hedgerows.[216] Similar work

213 Vera RR. 2004. Research on agropastoral systems: Background and strategies. Agropastoral systems for the tropical savannas of Latin America. CIAT, Cali, Colombia. pp 3–10.

214 Spain JM. 1990. op. cit.

__Interview with Jim Spain.

__Ayarza MA; Vilela L; Pizarro EA; Costa PD. 1999. Agropastoral systems based on legumes: An alternative for sustainable agriculture in the Brazilian Cerrados. Sustainable land management for the oxisols of the Latin American savannas. CIAT, Cali, Colombia. pp 22–36.

215 Friesen D; Ayarza MA; Thomas RJ; Amézquita E; Sanz JI. 1999. Strategic systems research for the Latin American savannas. In: Fujisaka S. (ed.). Systems and farmer participatory research. Developments in research on natural resource management. CIAT, Cali, Colombia. pp 30–49.

216 See: Connell J; Stür W; Horne P. 2010. Forages and farmers: Case studies from South-East Asia. Canberra, ACT: Australian Centre for International Agricultural Research.

__Stür PM; Horne FA; Gabunada PP; Phengsavanh P; Kerridge PC. 2002. Forage options for smallholder crop-animal systems in Southeast Asia: Working with farmers to find solutions. Agricultural Systems 71(1–2):75–98.

__Stür W; Truong TK; Duncan A. 2013. Transformation of smallholder beef cattle production in Vietnam. International Journal of Agricultural Sustainability 11:363–381. Doi: 10.1080/14735903.2013.779074 has been underway in densely populated parts of Eastern and Central Africa since early 2009. An initial success has been the use of *Brachiaria* hybrid (Mulato II) for integrated insect and *Striga* management and fodder supply by up to 100,000 farmers in Kenya.[217]

With the growing emphasis on global environment services, CIAT's strategic research has shown that well-managed *Brachiaria* grasses are especially effective in sequestering soil carbon relative to natural pastures, and that *B. humidicola* inhibits biological nitrification. Both these findings offer opportunities to reduce greenhouse gases.[218] A renewed push on introducing legumes into forage-based systems, possibly through shrub species, could also have big implications for biological fixation.[219] These positive impacts on the environment have been used to justify and pilot payments for environmental services in pasture systems in several countries of the region.[220]

Probably the greatest environmental benefit from research on tropical forages has been through intensification of cattle production, as seen in Brazil, resulting in major savings in land. In the 1990s, there was a debate that intensification would increase land rents and provide incentives for further clearing of natural forests and savannas.[221] However, recent analysis indicates that through the effects of increased productivity on beef prices combined with the better protection of forests in Brazil, intensification has indeed been substantially land saving.[222] The large areas of degraded pastures in the region offer much potential for further intensification through pasture renovation to save land. This is now a focus of the program, including policy incentives such as payments for environmental services and certification schemes that recognize the global benefits of investing in improved forages.

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217 *icipe* (International Centre of Insect Physiology and Ecology). 2015. The push-pull farming system: Climate-smart, sustainable agriculture for Africa.

218 Fisher MJ; Rao IM; Ayarza MA; Lascano CE; Sanz JI; Thomas RJ; Vera RR. 1994. Carbon storage by introduced deep-rooted grasses in the South American savannas. Nature (United Kingdom) 371(6494):236-238.

__Subbarao GV; Nakahara K; Hurtado MDP; Ono H; Moreta DE; Salcedo AF; Yoshihashi AT; Ishikawa T; Ishitani M; Ohnishi-Kameyama, M; Yoshida M. 2009. Evidence for biological nitrification inhibition in *Brachiaria* pastures. Proceedings of the National Academy of Sciences of the United States of America 106(41):17302–17307.

219 Muir JP. In process. Enhancing food security in Latin America with forage legumes.

220 Interview with Cees De Haan.

221 Angelsen A; Kaimowitz D. 2001. Agricultural technologies and tropical deforestation. CABI Publishing, Wallingford, Oxon, UK.

__White D; Holmann F; Fujisaka S; Reategui K; Lascano C; Amazónico DDP. 2001. Does intensification of pasture technologies affect forest cover in tropical Latin America? Inverting the question. In: Angelsen A; Kaimowitz D. (eds). Agricultural technologies and tropical deforestation. CAB International, Wallingford, Oxon, UK.

222 Vale P. 2015. Land use intensification in the Amazon: Revisiting theories of cattle, deforestation and development in frontier settlements. [PhD thesis.] London School of Economics and Political Science (LSE).

__Cohn AS; Mosnier A; Havlík P; Valin H; Herrero M; Schmid E; O'Hare, M; Obersteiner M. 2014. Cattle ranching intensification in Brazil can reduce global greenhouse gas emissions by sparing land from deforestation. Proceedings of the National Academy of Sciences of the United States of America 111(20):7236–7241.

Although much of the work in Latin America has been directed at medium-scale commercial crop–livestock systems, many of the same forage species have found valuable uses in small-scale crop–livestock systems of Southeast Asia, and more recently in Eastern and Southern Africa.

Genetic Resources

The rapid convergence within CIAT on four commodity programs in the 1970s immediately raised the importance of CIAT's global responsibility to collect, conserve and characterize germplasm of both cultivated species and wild relatives for these commodities. This is because Latin America is the center of origin for beans and cassava and the home of the largest diversity of tropical legume species with potential forage value.[223] For beans, CIAT held a global CGIAR mandate for germplasm conservation, while for cassava and forages, responsibility was shared with IITA and ILRI, respectively.

At its founding, there were already a few bean collections in Latin America, notably the USDA bean collection that included accessions of cultivated and wild beans collected in Mexico in 1966 and 1967.[224] Colombia also had a collection dating from the RF Colombian Agricultural Program. A major task from 1967 through the early 1970s was to assemble and organize these collections and mount new collections. Notably, 36 explorations since 1978 by Daniel G. Debouck, long-time leader of CIAT's genetic resources group, yielded 3,944 accessions of 41 wild bean species and new species as recently as January 2017. The genebank currently keeps over 38,000 accessions of beans from 110 countries.

Investment in collection was especially important for cassava as there had been little research on the crop to date and its biological origin was unknown in 1967. CIAT quickly proceeded to assemble a germplasm collection of cassava from remote areas of tropical South America, including from Colombia where this crop is grown from sea

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223 In the case of rice, IRRI had already assumed a global mandate within the CGIAR System for conservation of genetic resources.

224 Gentry HS. 1969. Origin of the common bean, *Phaseolus vulgaris*. Economic Botany 23(1):55–69.

level up to 1,800 m.[225] This collection and its variation "set the basis for the overall progress during the following thirty years".[226] From a genebank of 2,218 accessions in 1973, the cassava collection increased to 6,643 accessions from 28 countries by the end of December 2016.

Similarly, much work was required for tropical forages, capitalizing on the pioneering efforts of Australian scientists. Under the norm prevailing at that time that crop germplasm was the heritage of humankind, germplasm was initially obtained through inter-institutional agreements. The first collections of forages were donated by CSIRO of Australia, the University of Florida, and others. This was greatly increased by 9,410 accessions of forage legumes, mostly collected in South America from acid soil savannahs by 1979.[227] In the 1980s, CIAT forage scientist, Rainer Schultze-Kraft conducted numerous collecting trips in Brazil, Venezuela, and several Southeast Asian countries, yielding thousands of accessions that make up the largest part of the tropical legume collection.[228] Today, the tropical forages collection kept by CIAT's genebank consists of 23,140 accessions of 734 taxa, mostly of the legume family from 75 countries. The forage grasses and legumes are wild plants that require more attention in genebank management than domesticated crops.

The growing size of the collections then managed by each program and the challenges of characterizing and distributing germplasm led to the establishment of the Genetic Resources Unit (GRU) in 1977. Another important development by the mid-1970s was the establishment of a germplasm health lab responsible for checking the health status of each sample being exported or imported. The lab benefited from the latest advances made by the pathologists and virologists of CIAT for the safe movement of germplasm across international borders.

Cassava as a clonal crop required the development of specific methods for the safe transfer of vegetative materials across international borders. These included *in vitro* conservation technology that allowed the entire collection occupying more than 6 ha in the field to be moved into an *in vitro* genebank in the early 1980s. Using the *in vitro* technology, the genebank has distributed samples of nearly all the cassava collection to users in 84 countries.

The international Convention on Biological Diversity (CBD), agreed in December 1993, changed the prevailing norms and placed control of crop genetic resources under national laws. In 1994, CGIAR concluded an agreement with FAO to keep the germplasm collections of the countries in trust for the advance of agriculture, particularly in the tropics. Material Transfer Agreements were implemented and were made common to all genebanks of CGIAR. In 2008, CIAT genebank staff attended the opening of the Svalbard Global Seed Vault in the Norwegian

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225 Gulick P; Hershey C; Esquinas-Alcázar J. 1983. Genetic resources of cassava and wild relatives. International Board for Plant Genetic Resources, FAO, Rome, Italy. 56 p.

226 Kawano K. 2003. Thirty years of cassava breeding for productivity: Biological and social factors for success. Crop Science 43(4):1325–1335.

227 Schultze-Kraft R: Giacometti DC. 1979. Genetic resources of forage legumes for the acid, infertile savannas of tropical America. Pasture production in acid soils of the tropics. CIAT, Cali, Colombia. pp 55–65.

228 Maass BL; Hanson J; Robertson LD; Kerridge, PC; Abd El Moneim AM. 1997. Forages. In: Fuccillo D; Sears L; Stapleton P. (eds.). Biodiversity in trust: Conservation and use of plant genetic resources in CGIAR centres. Cambridge University Press, Cambridge, UK. p 321–348.

Artic and by 2016, 90% of CIAT's accessions of the in-trust collections of beans and tropical forages were safely backed up at Svalbard.

Since 1973, CIAT has distributed 576,002 samples to users in 164 countries. The CIAT breeding programs have been the major users of the collections but over the past 15 years, external users have been on the rise, especially from public sector research organizations. For cassava and forages, the numbers of countries benefiting from the conservation effort exceeds by far the numbers of depositors in the germplasm bank.

Initially, CIAT breeders logically chose to use landraces in order to deliver rapidly improved varieties that could be accepted by farmers and markets of the developing world. Over time, breeders have increasingly used the stored wild relatives for new sources of traits. Resistance to diseases (e.g. bacterial blight, common bean mosaic virus, white mold), insects (e.g., bruchids, leafhoppers), and tolerance to salinity and frost are traits that have been progressively discovered in the wild materials of beans.

The expanding size of the bean and the cassava collections led CIAT to develop core collections of the respective crops, using characterization data, and geographic and genetic information in the early 1990s. The core collections have been used to find resistance to diseases (e.g. angular leaf spot in beans), abiotic stresses such as low phosphorus tolerance, and nutritional traits such as protein quality or starch characteristics. The development of the core collections and related studies on crop gene pools showed that, in beans and cassava, genetic diversity is highly structured among races developed since domestication. These studies by scientists at CIAT and advanced research institutes through the 1990s and 2000s have profound practical consequences for plant breeding, namely for resistance to diseases (e.g. races of pathogens matching those of the host plant) and for yield (e.g. combining ability and heterosis).

Today the CIAT genebank keeps in trust the biological heritage of 141 countries, and the collections of beans, cassava, and forage legumes are the largest in the world by size and diversity. CIAT's genebank provides an invaluable conservation service that is "among the world's best".[229] In addition, since many accessions in the genebank are now extinct in the wild or in farmers' fields, CIAT has provided several national genebanks with a copy of their original collections, and supplied 'heirloom varieties' to farmers who wanted to take advantage of new market opportunities (Table 3). Finally, since 1977, the GRU, just as in other programs, has taken an active part in training: 323 professionals have had hands-on training and 68 graduate theses have been supervised. Yet a new generation of genebank curators and professionals in conservation science will need to be trained to ensure conservation of genetic resources into the future.

229 TAC of the CGIAR. 1985. op. cit. p 39.

Table 3 Distribution of germplasm from the GRU, 1973–2016.

	Beans	Cassava	Forages
No. of accessions distributed	37,390	6,492	13,692
No. of samples sent	441,225	44,153	90,624
No. of recipient countries	105	84	110
% Users from			
CIAT	71.6	61.0	45.2
NARS	15.5	14.0	26.4
Universities	10.4	8.0	11.2
Private companies	0.7	2.0	---
Farmers	0.6	---	8.9
Others	1.2	15.0	8.3

Source: Debouck D. 2017. CIAT Genebank: From a support unit to a partner in conservation of the world's crops. Draft paper. CIAT, Cali, Colombia.

Today the CIAT genebank keeps in trust the biological heritage of 141 countries, and the collections of beans, cassava, and forage legumes are the largest in the world by size and diversity.

Biotechnology Unit[230]

The acceleration in advances in molecular biology in the 1970s and 1980s prompted CIAT to explore the emerging applications of biotechnology in its crop research. This was especially important as most of CIAT crops were orphan crops where there was little interest by advanced research institutes or the private sector. Given the need for institutional capacity spanning four commodities, CIAT decided to establish the Biotechnology Research Unit (BRU) in 1985 under the leadership of William (Willy) Roca to integrate biotechnology tools in germplasm development, characterization and conservation in the Center's crop improvement programs. The BRU built on earlier work in tissue culture and virology in the Cassava Program and facilitated CIAT's participation in the Rockefeller Foundation's International Program in Rice Biotechnology, which was launched in 1984. The strategy of the BRU is to target biological constraints difficult to solve through traditional approaches by: (i) accessing and testing relevant technologies using collaborative research partnerships with advanced research institutes; and (ii) devolving resulting promising tools and technologies for use by CIAT's crop breeding programs, as well as in the national programs of Latin America and elsewhere. The BRU facilitated a structural shift in CIAT's breeding programs towards trait-based pre-breeding, which allowed research at headquarters to selectively target and provision more conventional breeding programs in networks in Africa and Asia.

The early work focused on the development and use of cell and tissue culture technologies for application to CIAT crops. This naturally emphasized cassava, a vegetatively propagated crop, which

230 This section is abbreviated from notes kindly provided by Joe Tohme and Willy Roca.

required methods for the production of virus-free clones, clonal multiplication, and *in vitro* conservation. While the emphasis was on facilitating international germplasm exchange (see p. 85), it also included applications for varietal multiplication in Colombian communities through "Low Cost Rural Labs" and the "Biotechnology in the School" program in Colombian secondary schools. During this period too, double haploid rice plants derived from anther culture improved efficiency in rice breeding by reducing the number of generations needed to produce fixed lines and accelerating generation of transgenic material for resistance to rice hoja blanca virus. This work was synthesized with the publication of a major text on tissue culture in agriculture in 1991.[231]

The biotechnology revolution transformed agricultural faculties in northern universities with the development of significant research capacity in plant biotechnology.[232] Rockefeller's Rice Biotechnology program provided something of a model on how to link advanced research institutes to emerging capacity in the developing world. BRU adopted this model in the organization of the Cassava Biotechnology Network (CBN) in 1988 that held three meetings in the 1990s. The network also established the "Ginés–Mera Memorial Fellowship Fund for Postgraduate Studies" in 2003 for students from developing countries, in honor of two CIAT scientists who lost their lives in a tragic airplane accident. A similar network, the *Phaseolus* Beans Advanced Research Network (BARN) was founded in 1990, but could not obtain the funding to continue for more than two meetings.[233] CIAT was also a main actor in the Latin American and Caribbean Agricultural and Forestry Biotechnology Network (REDBIO) from 1991. REDBIO international conferences became a major regional platform for collaboration and scientific exchange in biotechnology in Latin America and collaboration with CIAT was further strengthened when REDBIO moved its secretariat to CIAT in 2013.

By 1995, CIAT's capacity in molecular biology was well established. The EPMR of 1995 noted "excellent progress in positioning itself prominently in the field."[234] Soon after CIAT researchers developed the first cassava molecular map – the first one done completely in a CGIAR Center.[235] In cassava, and especially beans, there was also a focus on developing capacity in marker-assisted selection in breeding programs and molecular fingerprinting of germplasm collections.[236] A good example is the use of markers for a dominant gene (*CMD2*) for

231 Roca WM; Mroginski LA. (eds.). 1991. Cultivo de tejidos en la agricultura: Fundamentos y aplicaciones. Publicación CIAT No. 151. CIAT, Cali, Colombia. 969 p.

232 This included investment in independent research centers devoted to plant biotechnology, such as the Donald Danforth Plant Science Center, the John Innes Centre, and the Boyce Thompson Institute for Plant Biotechnology Research to name just three.

233 It might be argued that this was because of the difficulty of genetic transformation of the crop.

234 TAC (CGIAR Technical Advisory Committee). 1995. Report of the Fourth External Programme and Management Review of the Centro Internacional de Agricultura Tropical. TAC, Rome, Italy.

235 Fregene MA; Ángel F; Gómez R; Rodríguez F; Chavarriaga P; Roca W; Tohme J; Bonierbale M. 1997. A molecular genetic map of cassava. Theoretical Applied Genetics 95:431–441.

236 Blair MW; Fregene MA; Beebe SE; Ceballos H. 2007. Marker-assisted selection in common beans and cassava. In: Guimarães EP. (ed.). Marker-assisted selection: Current status and future perspectives in crops, livestock, forestry and fish. Food and Agriculture Organization of the United Nations (FAO), Rome, Italy. p 107.

cassava mosaic virus (CMV) resistance that were used to develop resistant varieties in CIAT where CMV does not occur. This allowed the introduction of Latin American germplasm into African breeding programs where CMV is a major problem. Markers are also used in the HarvestPlus program in biofortification of beans and cassava.

A significant number of transgenic varieties with novel traits have been developed by CGIAR Centers, many of which have gone through field testing, but none have actually been approved for release. Genetic transformation remains a potentially important part of any crop improvement program and CIAT has developed capacity and products in both cassava and rice. With the focus on eco-efficiency, more emphasis was placed on abiotic stresses such as drought, nitrogen use, and phosphorous efficiency, which are primarily multigenic. Transgenic approaches have been used in rice where transformation uses *Agrobacterium* to introduce genes already present in the rice genome more efficiently than through conventional breeding.

In 2007, CIAT received generic permission from the Government of Colombia to evaluate new gene technologies under confined field conditions that complied with national biosafety regulations. To implement these procedures, all the activities related to gene technology evaluation through the transgenic approach, "Platform for Transformation and Gene Editing" were centralized in 2010 into one building. CIAT has developed standard operating procedures as a tool to manage issues related to compliance with management of biosafety risks associated with transgenic experiments and has trained staff accordingly. Today, CIAT remains the only institute in Latin America to have expertise in genome editing techniques for agricultural crops, which have been recently applied to widely grown rice varieties.

With the signing of the Cartagena Protocol on Biosafety in 2003, CIAT undertook biosafety capacity building in partnership with the Global Environmental Facility and the World Bank in four biodiversity-rich countries: Brazil, Colombia, Costa Rica and Peru. Two of CIAT's crops, rice and cassava, were used as models for training of national scientists in biosafety issues and public communication around the Cartagena Protocol.

Given wide concerns among the public about transgenics, a pipeline of transformed rice and cassava required CIAT to develop strong biosafety protocols as a necessary step for varietal release with a strong emphasis on stewardship. In 2014, CIAT was made a member of Excellence Through Stewardship – a global, industry-coordinated organization that promotes universal adoption of best management practices for developing products through plant biotechnology – by decision of its executive Board of Directors.

The integration of the genomics activities with the breeding programs was accomplished by moving the activities into the crop improvement programs. This included gene discovery especially in water and nutrient efficiency, developing and using molecular markers and genomics tools to elucidate crop gene pools and make crop improvement more efficient, particularly for nutritional quality and biotic and abiotic stresses. To facilitate phenotyping protocols for desired traits, CIAT established modern facilities such as a semiautomatic rainout shelter for drought screening equipped with automatic system for capturing infrared images of plants in a high throughput mode, and N omission plots for nitrogen-use efficiency (NUE).

In short, CIAT has always been in the forefront of biotechnology research within CGIAR. Willy Roca, founder of the BRU, received in 1995 the first REDBIO

Award for his contributions in conservation and sustainable use of genetic resources and Joe Tohme, the current director of CIAT's Agrobiodiversity Research Area, was in 2015 named a fellow of the American Association for the Advancement of Science (AAAS). Over the past three decades, it has created a state-of-the art bioscience platform – consisting of a laboratories and field facilities – where advanced techniques are applied across diverse crop gene pools to tasks such as germplasm conservation, genomics and phenomics applications, and genetic transformation. These facilities have become a central focus for training of young scientists from the developing world. Just in the period 2009–2016, 30 PhD students, 47 MS and 22 BS students conducted their thesis work at the BRU along with many others who received specialized in-service training.

Today, CIAT remains the only institute in Latin America to have expertise in genome editing techniques for agricultural crops, which have been recently applied to widely grown rice varieties.

The evolution of natural resource management (NRM) research

Natural resource management (NRM) research is quite broad in scope and the research problem varies depending on the scale, whether it is plot, farm, landscape, or agroecology. As embedded in the Roberts-Hardin proposal, CIAT's focus on the lowland tropics of Latin America would involve agricultural systems, often combining both crops and livestock within particular agroecologies. The task for CIAT was to select the problem focus that would define the research, as set out by Roberts and Hardin: "Clearly, this gives the institute a broad latitude of ecological conditions within which to work. It would focus its efforts and resources within this wide range of conditions to make significant progress on well-defined, important problems. As the institute grows, such focusing should be left largely to the judgment of the director, the staff, and the board of trustees, with the general criteria always in mind that resources and efforts should be so directed as to have the broadest possible impact for increasing basic food production in the shortest possible time."[237] The history of NRM research at CIAT has been one of rapid shifts in its focus that has impeded the achievement of this vision.

The problem focus narrowed quite quickly in the mid-1970s to research on just four commodities as the means of increasing food production. This narrowed the NRM research approach to the plot and farm scale, or "the management of natural resources *within* agriculture."[238] For the three crop programs, this primarily focused on soil and nutrient management and adaptation to edaphic constraints.

The Tropical Pastures Program, on the other hand, targeted two of the three major

237 Roberts and Hardin. op. cit. p 16.

238 CGIAR ISPC. 2012. op. cit. p 2.

lowland tropical ecologies identified by Roberts and Hardin:[239] the savannas and the tropical forest of the Amazon and Orinoco. In 1982, with support from the Rockefeller Foundation, CIAT organized a conference on extending the agricultural frontier in the Amazonian rain forest with appropriate agricultural technologies.[240] In essence, the Roberts-Hardin mandate was being pursued with the focus on increasing food production in marginal ecologies; the conference participants noted significant differences across countries around the Amazon Basin in terms of expansionist policies into the rain forest. However, there were emerging challenges on the horizon. Deforestation had only just started to pick up with the opening of the Trans-Amazonian Highway in 1972. The 1980s were a period when a consensus among scientists was only beginning to develop on the impact of increasing CO_2 on climate change. Daniel Ludwig's billion-dollar investment in the Jari project in the Brazilian Amazon to produce pulp and rice was up for sale as conditions were found to be too difficult. Pasture establishment in the Amazon was expanding and the area under degraded pasture was expanding just as rapidly. All of this pointed to a more holistic approach to NRM than just tropical forages, at least in the rain forest of Latin America, which would become at least part of the rationale for the shift to a NRM research agenda in 1991.

The core of the Tropical Pastures Program in the 1980s was the savannas of South America, particularly the Plains of Colombia and Venezuela and the Cerrado of Brazil. The challenge was adapting pastures to the infertile soil conditions of these ecosystems, particularly very low phosphorous levels and high aluminum saturation. The assumption was that the prices of soil amendments (such as lime and fertilizer) would be too high for profitable application given the low investment in road infrastructure – a similar context that CIAT would face with their program in sub-Saharan Africa. The research focus was in adapted forage germplasm, particularly grass–legume mixtures, and yet the issue at the farming system level was the incentive that would induce investment in pasture establishment. With the move from a commodity focus to an NRM focus in 1991, the research program could begin to focus on the system and especially the integration of crop production as the basis for pasture establishment. The scale at which the research problem was defined then became a key issue in the succeeding research on NRM at CIAT.

The 1990s and the development of a Latin American eco-regional center

The 1991 strategy marked a turning point in CIAT's approach to NRM research, in that it gave primary focus to NRM over commodity research in the design of its program structure. CIAT returned to its origin as an eco-regional Center. A 1993 TAC paper on eco-regional research identified the following organizational principles: "operate on a regional basis; focus on an important agroecological zone with a serious degradation problem; combine natural resources management and production objectives; employ a multidisciplinary approach;

239 The proposal classified as favorable the coastal areas and the high selvas of the Andes. The Cerrados and Eastern Plains were classified as of unknown potential at the time of the report. The potential of the humid tropics was defined as unfavorable.

240 CIAT. 1982. Amazonia: Investigación sobre agricultura y uso de tierras. Hecht SB. (ed.). CIAT, Cali, Colombia. 448 p.

include both natural and social sciences; involve national research institutions and other partners in a synergistic way; adopt flexible systems of governance and priority setting; and ensure global coherence and flexible funding mechanisms."[241] CIAT used all of these principles in the design of its strategy and research program – except the last one – and before the TAC paper was published. A major study characterizing the agroecologies of Latin America was done to prioritize the selection of target agroecologies.[242] The research was organized around three agroecologies: the savannas characterized by oxisols and ultisols, the rain forest margins, and the mid-altitude hillsides, also characterized by acid soils. CIAT entered this program restructuring at exactly the same time as overall funding for CGIAR was declining and simultaneously the needs were increasing with the expansion in the number of Centers. CIAT would use the strategy as an organizing template throughout the decade of the 1990s but would be severely financially constrained in fully staffing and implementing the strategy.

The initial approach to the three agroecologies followed a similar methodological approach but within different socioeconomic and problem contexts. "CIAT's contribution to natural resource management in tropical America focuses on improving land management by integrating stakeholder-based land use planning and assessment with the use of sustainable, intensifying production systems which help to protect and conserve the natural resource base."[243] This approach used geospatial characterization of the agroecology, which was used to select benchmark sites for intensive study, and within those sites the application of participatory methods for problem diagnosis, in association with national institutions. Comparative analysis across the sites would produce the international public goods. The Savannas Program added an additional component – it "established large, long-term experiments in each area to investigate the strategic principles involved in more sustainable crop rotations and ley-farming systems, and the changes they induce relative to non-disturbed native savanna. These efforts are complemented with on-farm trials in nearby farmers' fields and the testing of prototype improved systems, including farmers' reactions to them."[244] Unfortunately, these systems experiments were quite early in the program curtailed due to budget constraints.

In order to manage the decline in budget over the 1991–1996 period, the Center experimented with a range of organizational models, with a continuing vision of integrating crop improvement and NRM research. To rationalize a declining scientific staff, a matrix of scientific competency (resource) groups were formed to flexibly support the two agroecology programs (rain forest margins and savannas were merged) and the four commodity programs. This led to organization around more component or disciplinary research, which culminated in 1996

241 TAC (CGIAR Technical Advisory Committee) Secretariat. 1993. The eco-regional approach to research in the CGIAR: Report of the TAC Center. Directors Working Group. TAC Secretariat Rome, Italy. p v-vi.

242 Jones P; Robison D. 1990. Data analysis for decision making in natural resource management for sustainable agriculture: Phase 1, Environmental description and classification. Agro-Ecological Studies Unit. CIAT, Cali, Colombia.

243 CIAT. 1999. Natural resource management research at CIAT. CIAT, Cali, Colombia. p 12.

244 CIAT. 1995. Charting a new course: CIAT's initiative in resource management research for Latin America and the Caribbean: A review and status report, 1991 through 1994. CIAT, Cali, Colombia. p 37.

in organization around 16 project areas and the closing of the research programs. This was motivated by the shift in funding structure and the dependence on bilateral, project funding. There were five NRM projects: IPM, soils, sustainable systems, hillsides and land use. Research mostly lost its systems orientation but achieved more flexibility in competing for project funding. The 2000 EPMR "considers that CIAT is making the transition to a new model among the CG Centers. It is working to implement an effective model for blending NRM and germplasm research. It has become a more open center and the hub of the research establishment for the region, while maintaining international presence and impact."[245] While the 1995 EPMR[246] gave the fledgling NRM programs high marks for methodological design, the 2000 EPMR found a lack of sufficient rigor in the methodology being deployed, particularly in the Hillsides program, partly reflecting the capacity constraints. With the shift in finances to restricted project funding, maintaining research coherence within sufficiently long time frames would be a challenge for NRM research across CGIAR. Undertaking NRM research with short-term project funding is a problem to date within CGIAR and is a significant reason for the inability to demonstrate broad-scale impact.

During this period, CIAT became an important participant in the expanding number of systemwide and eco-regional programs to complement the NRM research in the programs. "In contrast to the area-based eco-regional research approach, the CGIAR Systemwide programs provide a supply of expertise which exceeds that available in CIAT or any other single Center. CIAT's natural resource management research draws on the several CGIAR Systemwide programs: SWNM program, PRGA program, IPM program, and Livestock program to strengthen capacity especially in the eco-regional benchmark sites."[247] CIAT's research on the rain forest margins was essentially integrated into the Alternatives to Slash and Burn Eco-regional program. The soils research in both the Hillsides and the Savannas was consolidated in the Soil, Water and Nutrient Management (SWNM) Program. In many ways this provided a foundation for CIAT's future participation in the CGIAR Research Programs.

The impacts of this research during the 1990s can only be framed in terms of the products or research outputs that were produced. Some of these found applications in unexpected areas. The characterization work by the Agroecological Studies Unit included an atlas of Honduras that was the foundation for targeting the relief effort after Hurricane Mitch.[248],[249] Impact studies on NRM

245 TAC (CGIAR Technical Advisory Committee) Secretariat. 2001. Report of the Fifth External Programme and Management Review of the Centro Internacional de Agricultura Tropical (CIAT) - 2000. TAC Secretariat, Rome, Italy. p xxiv.

246 Ibid.

247 CIAT. 1999. op. cit. p 22.

248 See: *The Economist*. 1998: www.economist.com/node/345738. Other works pointed to the resilience provided by appropriate land management on slopes during the hurricane. See Holt-Gimenez E. 2002. Measuring farmers' agroecological resistance after Hurricane Mitch in Nicaragua: A case study in participatory, sustainable land management impact monitoring. Agriculture, Ecosystems & Environment 93:87–105.

249 The Seeds of Hope project was mounted instantly after the hurricane in Honduras. Within 72 hours, CIAT had assembled a multicentre task force led by CIAT, had organized nearly US$2 million in special funding and was using its GIS capacity to help emergency services.

during this period focus on integration of soil and land management with the commodity programs, particularly NRM with cassava in Asia.[250] As might be expected, most of these were primarily adoption studies and usually project based. As the cassava case suggested, adoption of NRM technologies diffused within project villages but not to nearby villages.

What is possibly most striking is that CIAT's research program was not positioned to participate in the principal technical innovations taking place in the Brazilian Cerrados, including the development of the input-based approaches for managing soil fertility, the expansion in soybean as the basis for pasture establishment, and most recently, conservation tillage and conservation agriculture as key to soil degradation following opening of new areas for cultivation. This missed opportunity was in part due to the strategic differences between CIAT and EMBRAPA in developing technologies for the Cerrado – a low- vs high-input approach[251]– and to the significant improvement in research capacity in EMBRAPA over the 1980s and 1990s, in part due to early training at CIAT but also due to the massive investment in PhD training, as shown in Figure 9.

The 1997 CGIAR System Review recommended that: "the CGIAR enhance its research methodology by adopting an integrated natural resource management approach." This led to a succession of four meetings across Centers, a third of which was held at CIAT, to produce a consensus on approaches to research on what was then termed integrated natural resource management (INRM) research. At the fourth INRM meeting, a set of 11 operational principles was distilled for INRM research, which became the basis for a book laying out the approach.[252] CIAT contributed to this synthesis, drawing on its past experience and ongoing work in Central America, and suggested a methodology for monitoring, evaluation, and impact assessment of NRM research – particularly arguing for a shift from a logical framework methodology to an impact pathway methodology, which would later find application in the CRPs.[253] However, at this juncture, most of CIAT's NRM research would begin to focus on sub-Saharan Africa and CIAT would be one of the few Centers to lead in the application of the INRM approach.

An increased focus on Africa

CIAT's NRM research at the turn of the century, supported by a new strategy in 2001, shifted focus increasingly to sub-Saharan Africa, particularly Eastern, Central, and Southern Africa. The foundations were provided by the increasing NRM research being carried within the PABRA consortium and the integration of the Tropical Soil Biology and Fertility (TSBF) Program into CIAT. TSBF was

250 The expected internal rate of return was estimated to be between 34 and 41%. Dalton TJ; Lilja NK: Johnson N; Howeler R. 2007. CIAT. Impact of participatory natural resource management research in cassava-based cropping systems in Vietnam and Thailand. In: Waibel H; Zilberman D. (eds.). International research on natural resource management: Advances in impact assessment. CABI, Wallingford, UK.

251 Interestingly the same differences would underlie the debate on a Green Revolution in Africa.

252 Campbell B; Sayer J. (eds.). 2003. Integrated natural resource management: Linking productivity, the environment, and development. CAB International, Wallingford, UK.

253 See: Gottret MV; White D. 2003. Assessing the impact of integrated natural resource management: Challenges and experiences. In: Campbell and Sayer. 2003. Ibid.

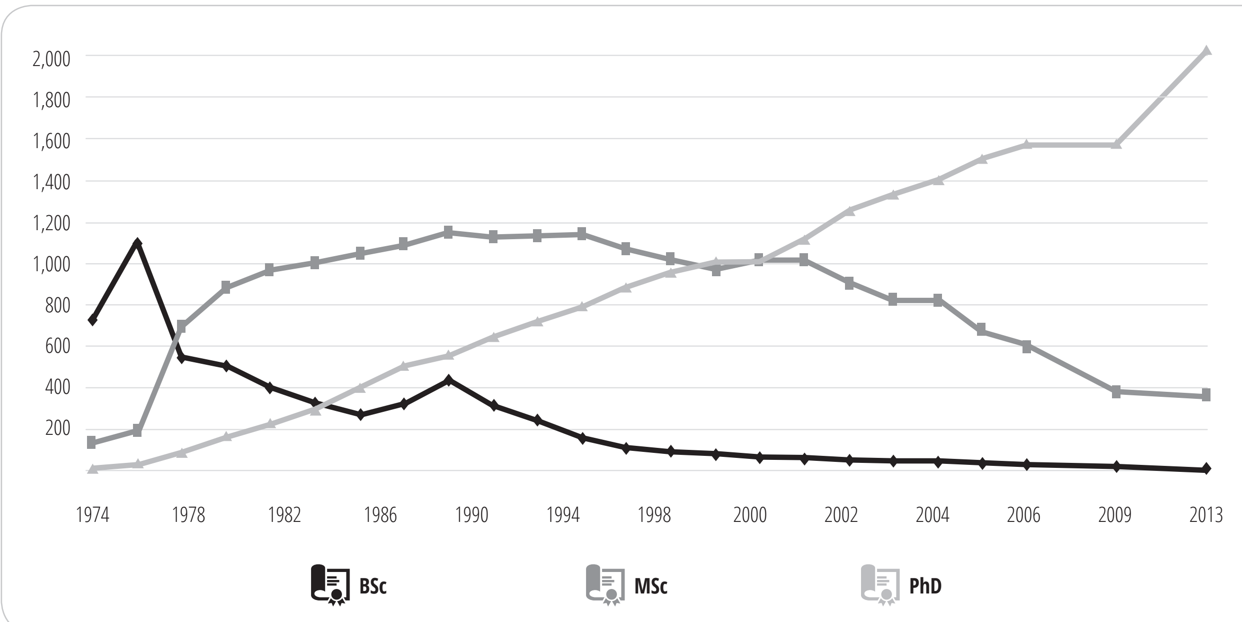

Figure 9 Trends in the degree qualifications of EMBRAPA researchers, 1974–2013.

Source: Adapted from (i) Nehring R. 2016. Global governance/politics, climate justice & agrarian/social justice: linkages and challenges: An international colloquium. Colloquium Paper No. 35. Yields of dreams: Marching West and the politics of scientific knowledge in the Brazilian Agricultural Research Corporation (EMBRAPA). 4-5 Feb 2106; and (ii) OECD. 2015. Graph 7.5. Academic qualification of Embrapa researchers, 1973/2013, in Innovation, Agricultural Productivity and Sustainability in Brazil, OECD Publishing, Paris. Doi:10.1787/9789264237056-graph49-en

incorporated within CIAT as an institute in 2001 and at a stroke added a well-developed soils research program based in Nairobi. TSBF had a principal focus on Africa. PABRA and TSBF were complemented by a new program, Enabling Rural Innovation (ERI), which built on CIAT's long experience in participatory research and agroenterprise development and whose aim was to "create an entrepreneurial culture in rural communities, where farmers 'produce what they can market rather than trying to market what they produce', and encourages them to invest in their natural resources rather than depleting them for short-term market gain."[254] The three programs were complementary and represented in many ways the INRM approach. As noted in a review of TSBF's research: "The central hypothesis is that natural resource management (NRM) research will have more leverage if the apparent gaps between investment in the natural resource base and income generation can be bridged. Therefore, TSBF-CIAT's

254 Kaaria S; Abenakyo A; Alum W; Asiimwe F; Best R; Barigye J; Chisike C; Delve R; Gracious D; Kahiu I; Kankwatsa P; Kaganzi E; Muzira R; Nalukwago G; Njuki J; Sanginga P; Sangole N. 2006. Enabling rural innovation: Empowering farmers to take advantage of market opportunities and improve livelihoods. In: Innovation Africa Symposium, Kampala, Uganda. Proceedings. CIAT, Kampala, Uganda. p 4.

new strategy has been to take ISFM an additional step forward by addressing the full chain of interactions from resources to production systems to markets and policies."[255] There was a significant degree of African ownership in these programs and they provided the basis for CIAT's participation in a number of African-based research consortia (discussed below).

TSBF in many ways defined the soils research agenda for sub-Saharan Africa. The early research focus was on understanding the biological management of tropical soils, including an understanding of microbial biomass, underground soil biodiversity, soil organic matter (SOM) dynamics through defining SOM fractions, and the intersection with soil nutrient dynamics and plant demand. In joining CIAT, this more strategic research agenda was then translated into an applied and adaptive research agenda under the banner of integrated soil fertility management (ISFM). "ISFM is a holistic approach to soil fertility research that embraces the full range of driving factors and consequences of soil degradation—biological, physical, chemical, social, economic and political."[256] Given the high rates of nutrient depletion in African farming systems, the high cost and variable access to fertilizer, and the inability to maintain traditional fallowing systems, efficient use of limited nutrients, especially in locally available organic resources, was critical in developing effective soil management strategies. This was the research focus of the TSBF Program, with a particular focus on Eastern and Southern Africa. The 2008 EPMR did a highly favorable review of TSBF, and reported: (1) "The quality of outputs and achievements at TSBF is among the highest within CIAT and a direct reflection of its historical institutional culture of collaboration (South−North and South−South), competitiveness for international funding, and excellent scientific guidance, and (2) TSBF has demonstrated that strategic and development objectives are not mutually exclusive in NRM research and can in fact have synergistic effects, including maintaining a high level of publications in international journals."[257]

CIAT, during the first decade of the century, was thus well positioned to develop a program for implementing INRM, turning theory into practice. The Africa program participated in three multi-Center initiatives that had INRM at the core of their design: the African Highlands Initiative, the East African region of the African Challenge Program, and the Consortium for Improving Agriculture-Based Livelihoods in Central Africa (CIALCA). INRM requires time and continuity and the CGIAR reform process was conceptualized around the merging of such initiatives into the CGIAR Research Programs (CRPs), starting in 2011. Much of this work was merged into the systems work of the Humid Tropics CRP. Both ERI and TSBF were closed as programs and CIAT had little participation in Humid Tropics. The potential of the INRM work was not realized due to larger changes in CGIAR; this would seem to characterize the history of NRM research at CIAT i.e. innovative in design but experiencing either time or financial constraints that curtailed execution and validation. The 2008 EPMR summarized the intent. "It is CIAT's belief

255 TSBF -CIAT (Tropical Soil Biology and Fertility Institute of CIAT). 2006. Integrated soil fertility management in the tropics: TSBF-CIAT's achievements and reflections. CIAT Publication No. 350. TSBF-CIAT Institute, Cali, Colombia. p 3.

256 Ibid. p 2.

257 CGIAR Science Council. 2008. op. cit. p 35.

and experience that many of the most appropriate tools for achieving widespread impact (both social and biophysical) need to be derived through iterative interdisciplinary research processes. Agricultural science practice cannot be successful if it is disconnected from development practice, and system-based action research is often required in order to yield innovation and robust, international public goods."[258] CIAT has contributed significantly to the methods that underlie this approach but the intent has been continually retarded by lack of program continuity, of long-term scientific and field capacity and of long-term financing. A long-term, integrative research approach that would be a leading edge in achieving development impact would devolve to research organized around a set of interrelated but focused thematic research areas that in turn relied on adaptation and integration by specialized development partners. To a very significant extent, CIAT returned to the disciplinary themes of the late 1990s, which in turn allowed for focused participation in a range of CRPs, most of which, however, lay outside the NRM area.

The quality of outputs and achievements at the Tropical Soil Biology and Fertility (TSBF) Program is among the highest within CIAT and a direct reflection of its historical institutional culture of collaboration (South–North and South–South).

258 Ibid. p 30.

Institutional Innovations

CIAT is not only associated with a 50-year record of technological innovation, but during its history, it has spawned many institutional innovations. In fact, given its broad and flexible mandate, CIAT has been on the forefront of a number of institutional innovations within CGIAR and more generally in the management of CIAT itself. This section selectively highlights some of these innovations that cut across programs.

From networks to consortia

The importance of regional networks in sharing germplasm and information was recognized at the outset and in fact, CIAT inherited regional networks in beans and maize from the Rockefeller Colombian program. All the commodity programs quickly developed networks at the regional level and some, such as the 1976 International Bean Yield and Adaptation Nursery, became global even before CIAT had outposted staff to other regions. The creation of effective networks was recognized as one of CIATs major achievements.[259] The number of networks may have peaked around 1990 when there were 16 (Table 4), which accounted for about 20% of CIAT's resources.

As with so many activities, the restructuring and budget cuts of the early 1990s took their toll on the networks. Some, such as the successful RIEPT for tropical pastures, were closed, at considerable cost to the Center's reputation with national programs.[260] Other networks found ways to reduce financial support and devolve network management to national systems to make them

259 TAC of the CGIAR. 1985. op. cit.

260 TAC of the CGIAR. 1995. op. cit.

Table 4 List of CIAT-led networks circa 1990.

Program	Network	Year initiated
Beans	Central America and Caribbean Bean Network	1979
	Central African Bean Improvement Network	1983
	Eastern Africa Regional Bean Network	1984
	Southern Africa (SADC) Bean Network	1985
	Andean Zone Bean Network	1988
	Bean Advanced Biotechnology Research Network	1990
Cassava	Asia Cassava Network	1987
	Pan-American Cassava Breeders Network	1987
	Manihot Genetic Resources Network	1992
	Southern Cone Cassava Development Network	1992
	Cassava Biotechnology Network	1992
Rice	IRR–CIAT International Network for the Genetic Improvement of Rice	1976
	Caribbean Rice Improvement Network	1987
Forages	International Tropical Pastures Evaluation Network (RIEPT)	1979
	Southeast Asia Forage Research and Development Network	1989

Source: TAC (CGIAR Technical Advisory Committee). 1995. Report of the Fourth External Programme and Management Review of the Centro Internacional de Agricultura Tropical. TAC, Rome, Italy.

more demand driven. A first step starting as early as the 1980s was the 'Steering Committee Model' that took on tasks of planning, review, and assignment of responsibilities based on national interest and comparative advantages – this would evolve into research consortia such as PABRA, as discussed below. These networks were also soon linked to the emerging sub-regional research organizations (SROs as associations of national systems) starting with PROFRIJOL in Central America and the Caribbean. In Africa two SROs, ASARECA and CORAF, developed as coordinators of all CGIAR Center networks operating in the region, including CIAT's bean network. However, donor support for networks waned, the SROs restructured along program lines, and the bean networks are one of few remaining networks.[261]

261 See: Lynam J. 2011. Plant breeding in sub-Saharan Africa in an era of donor dependence. IDS Bulletin 42(4):36–47.

The Bean Program has been consistently commended by external reviews for the quality and innovation in its partnerships. The 1989 EMPR observed that: "The Bean Program's nationally driven networks are leading the way to a closer partnership with national systems in Africa".[262] The networks increasingly brought in non-traditional partners in the private sector and civil society, as well as with end users (Figure 10). Participatory approaches such as participatory varietal selection (PVS) and participatory plant breeding (PPB) became routine practice to meet the diversity of farmer and consumer demands. New disciplines were added especially in nutrition, gender, and value chains. By 1996, a consortia approach had emerged with the Pan African Bean Research Alliance (PABRA) that linked the three sub-regional networks that by 2016 included 570 partners in 28 countries, and reaching 27 million farmers.[263] A recent favorable review of the achievements of PABRA stated that: "CIAT is the mainstay of the PABRA network and will continue to be so in the future".[264]

Financial sustainability and the orientation to user were further strengthened in rice and cassava networks where members pay the cost of the network and in return set the agenda. FLAR, the Latin American Fund for Rice, established in 1995, funds most of the regional breeding work on rice through membership contributions from over 30 public and private sector members from 18 countries, who pay annual membership fees based on the size of

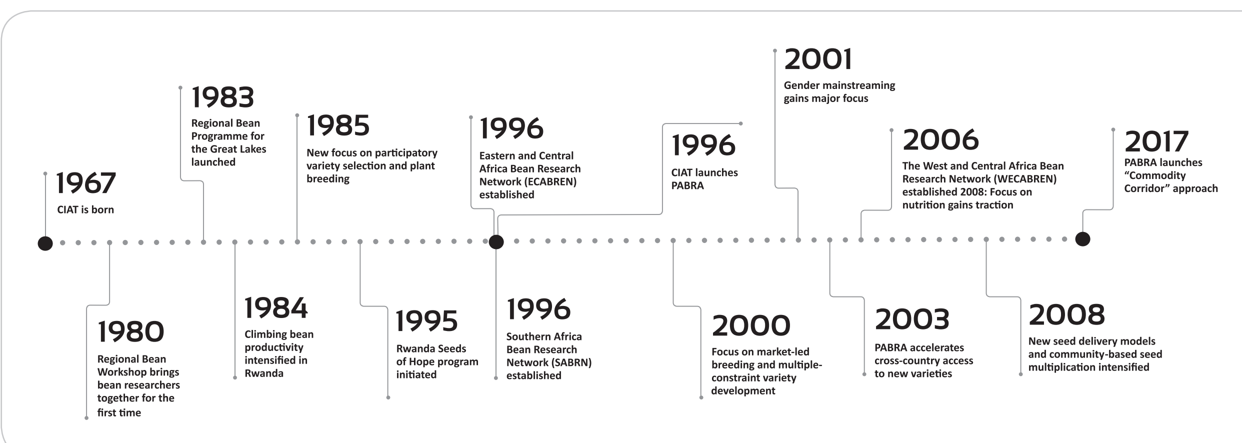

Figure 10 Time line for the bean networks in Africa.

262 TAC (CGIAR Technical Advisory Committee). 1989. Report of the Third External Review of the Centro Internacional de Agricultura Tropical (CIAT). TAC Secretariat. Rome, Italy.

263 PABRA (Pan-Africa Bean Research Alliance). 2017. Annual Report 2016. CIAT.

264 Robinson J. 2015. The role of CIAT in the Pan-Africa Bean Research Alliance. Independent External Review, CIAT.

the rice sector in their country. The sustainability of FLAR over 25 years reflects the bottom-up processes used in its establishment involving proactive support from rice producer organizations and the national and sub-national levels. Meanwhile, CIAT reoriented its rice research to upstream activities that provides traits and other discoveries to the FLAR breeding program. CLAYUCA for cassava follows a similar model involving nine countries in LAC and three in Africa and has in fact gone further in establishing a legal entity, Clayuca Corporation, to share costs, risks, and benefits. These institutional innovations are seen as a model for other commodity research programs in CGIAR, although they do raise tensions between the objectives of achieving financial sustainability and CGIAR IPR policy of open-licensing arrangements for inclusiveness.[265]

Participatory research methods

Given its early emphasis on small farmers and low-input approaches to improving productivity, CIAT instinctively developed a strong, multidisciplinary orientation to working with small farmers. The earlier Beef Production Program not only had a strong systems orientation but worked closely with producers to test interventions with integral involvement of social scientists. When CIAT moved to the four commodity programs, CIAT became a leader in the 1980s in on-farm research with a farming systems perspective, built around the commodity of interest and involving breeders, agronomists, and social scientists. Training of national program scientists in on-farm research methods was a major focus, with nearly 200 participants in 1989 alone. CIAT collaborated closely with CIMMYT in many joint activities that used a similar approach. By the end of the decade, CIAT had achieved a "worldwide reputation among professional peers for its innovative approach to on farm research methodologies".[266]

The next logical stage in participatory approaches was to empower farmers to make decisions about their experimental priorities and choice of technology. This stage also coincided with the budget crisis of the early 1990s that led to a search for more cost-effective methods for on-farm research. Two long-term social scientists, Louise Sperling and Jaqueline Ashby, led these institutional innovations in participatory research.

Sperling was a pioneer in participatory varietal selection and breeding. Her classic study of farmers' selection of bean varieties in Rwanda showed that farmers were more efficient in selecting bean varieties for their diverse environments and tastes than breeders were.[267] Participatory breeding methods progressed as farmers were introduced into even earlier stages of the breeding cycle and programs were further decentralized to the local level. Participatory breeding is now mainstreamed into CIAT programs and among national partners, especially in the African bean programs.

265 Independent Evaluation Review of the CGIAR. 2015. Evaluation of the CGIAR Research Program Global Rice Science Partnership (GRiSP). Rome, Italy.

__CGIAR Science Council. 2008. op. cit.

266 TAC of the CGIAR. 1990. op. cit.

267 Sperling L; Loevinsohn ME; Ntabomvura B. 1993. Rethinking the farmer's role in plant breeding: Local bean experts and on-station selection in Rwanda. Experimental Agriculture 29(04):509–519.

Ashby established the idea of CIALs (Committees for Local Agricultural Research) by empowering communities to run their own on-farm research programs. This not only enhanced demand perspectives for technologies but offered a way to greatly reduce costs and to integrate technology delivery mechanisms through development of community seed enterprises. By 2000, there were 250 CIALs in eight countries with significant spillovers to neighboring communities. [268] The Tropical Forages Program used a similar approach to successfully introduce forages into upland farming systems of Asia.[269]

By 2000, CIAT was recognized as playing "a crucial role in putting participatory research methods on the intellectual map."[270] This recognition was evident when CIAT was asked to the lead the systemwide program on Participatory Research and Gender Analysis (PRGA) from 1996. CIAT through its strong record on participatory approaches was already a leader in gender analysis, especially in the Bean Program in Africa where most farmers were women. The PRGA did provide a strong conceptual and methodological basis for gender analysis but progress in mainstreaming gender in a transformative way in the research programs was much slower.[271]

The science park

CIAT was the second CGIAR Center after ICRISAT to set up a Science Park, Agronatura, that not only afforded a way to tap underutilized infrastructure but also achieve a vision of providing a dynamic platform for start-up, science and technology firms, and for more civil society organizations a platform for cross-sectional alliances in agricultural research and NRM in Latin America, and especially in the Valle de Cauca. Agronatura included a number of CIAT spin-offs, such as CLAYUCA and FLAR, regional offices of CGIAR Centers such as CIMMYT and Bioversity International, BIOTEC Corporation (a Colombian start-up), and civil society organizations from Colombia (Alexander von Humboldt Institute and others). Since this vision of creating an environment to foster synergetic effects was slow to develop, CIAT created – in 2010 – its own Foundation (FUNDACIAT)[272] to promote public-private research for development partnerships in Colombia, with the intent of scaling up the experience of Agronatura.

A key contribution from FUNDACIAT was to consolidate a long aspiration in the region, which was to promote private sector and civil society organizations to benefit from public research and training while strengthening the collaboration of CIAT with them. The organizations involved were: CORPOICA Palmira (the nearby research station of the Colombian Corporation for Agricultural Research), the National University of Colombia

268 Ashby J; Braun AR; Gracia T; Guerrero MDP; Hernández LA; Quirós CA; Roa JI. 2000. Investing in farmers as researchers. Experience with local agricultural research committees in Latin America. CIAT, Cali, Colombia.

269 Connell et al. 2010. op. cit.

270 TAC of the CGIAR. 2000. op. cit.

271 Walker et al. 2007. op. cit.

272 Arango Nieto L; Trigo EJ. 2010. Consultancy report on the current situation of AGRONATURA and FUNDACIAT. CIAT, Cali, Colombia.

(Palmira campus), ICA (Colombian Agricultural Institute – the country's agriculture phytosanitary agency), the Chamber of Commerce of Palmira, and several other organizations. In many ways, this was the original institutional configuration outlined in the Roberts-Hardin proposal. As a result of this, in 2012 a new science park – Biopacific Park was created (1,000 ha, combining the area of CIAT and CORPOICA; and 400 PhDs combining CIAT, CORPOICA, and the National University of Colombia) to scale up the original aspirations of Agronatura and FUNDACIAT. Since the main office of the new Park was based at CIAT, FUNDACIAT staff joined the Park, and FUNDACIAT was closed.

CIAT as an institutional innovation

Finally, the many changes in CIAT have been a type of institutional innovation to adjust to a changing CGIAR and changing regional priorities and financial contexts. CIAT has over its history redefined its mandate multiple times. In turn, these have tackled complex research problems; how CIAT has organized its research program around these problems has been an institutional innovation in itself. CIAT's development of the interdisciplinary crop research program in the 1970s and 1980s was in many ways unique within CGIAR and a model for national research programs. The transformation in the 1990s to an eco-regional Center with a focus on sustainable development in marginal areas of Latin America again defined a model for research organization around this concept, although financial constraints limited its full development. The critical fall in unrestricted funding in the mid-1990s and the shift to reliance on bilateral funding was the rationale for elimination of a research program structure and organization around major project clusters instead. The attempt by CIAT in the early 2000s to organize research around products, as it was being done for example at CIMMYT, was unsuccessful because of the systems focus of much of the research. All of these changes have provided the foundations for the current organization around sustainable food systems in a reformed CGIAR around CRPs. This organizational model rests on areas of excellence that have been developed over the years and that can be brought together in the regions or the CRPs to address problems under the eco-efficiency framework.

Capacity Development

Capacity development has been a central plank of CIAT's strategy over the half century but in many ways it has been forced to continuously adapt to changing financial, institutional, and development contexts. The Roberts-Hardin paper put particular emphasis on this component in the initial design of CIAT: "Latin American scientists and technicians will be needed in large numbers to carry research results into frontier areas of the various countries as they are opened up, to apply and interpret new findings as development proceeds, and ultimately to staff the institute." As stated in the paper, there were no universities in Latin America offering a PhD in agricultural sciences and only a few offering an MSc at the time. The constraint was having enough qualified personnel to staff national research programs.

Training was from the start the principal thrust of capacity development. Only 1 year after becoming operational, the 1969 Annual Report reported that 11 postgraduate interns, 17 production specialists, and 7 MSc candidates were being trained at CIAT. Training for the production specialists aimed to produce a 'generalist' in a particular commodity or theme (such as multiple cropping) rather than focusing on the trainee's discipline. With the program reorganization into four commodity programs, the training program was integrated into the commodity programs and training was differentiated into multidisciplinary production training based primarily on in-country short courses covering all aspects of research in that crop and longer term discipline-specific research training where the trainee was attached to a CIAT scientist. The focus was on building interdisciplinary crop research programs in national research institutes, in a sense replicating the research model at CIAT. This was based on either an explicit or implicit needs assessment in the program and the potential for investment in the commodity program by national governments. For commodities such as cassava and forages, the aim was to build new research capacities in 'orphan' crops and for beans and rice to strengthen existing capacities.[273] The Seed Unit was established purely as a capacity development program. This approach to capacity development (of targeting crop research programs) was strengthened by the development of commodity research networks, based primarily on germplasm exchange and developing breeding capacity. This was particularly striking in the bean research networks in both Latin America and Africa. Cassava, however, was limited by the difficulty of germplasm exchange of a vegetative crop. An indication of the investment in human capital development during the period of the 1980s is training of 2,551 national scientists and 72 MScs, and just those from Latin America.[274]

With the shift in the 1990s to NRM, both the content and the target of capacity development changed quite significantly. NRM research had little in the way of an identifiable home, apart from the research stations in three eco-regions targeted by CIAT. In many ways, Roberts and Hardin suggested the establishment of such a network of research stations in the lowland tropics of Latin America. What was less clear was the capacities that were needed to carry out what was an emerging research agenda. At the same time, the budget cuts fell heavily on training programs, to the point that the program was closed in 1995 only to be reopened in 1996, but with a focus on training in research methodologies, developing training tools for training of trainers, and a move away from institutional development of NARIs to NGOs and universities, primarily within a project modality. Although the limitations of this approach were recognized in the importance "to move from a focus on training to one of capacity development, from short-term, one-off actions to long-term relations based on dialogue and collaboration,"[275] the reliance on project-based funding did not allow such a pathway.

The application of NRM research was knowledge intensive, which naturally incorporated communication strategies, which in the last decade have evolved into knowledge management strategies. This linkage was recognized as early as 1974,[276] but only effectively developed with the shift in focus to NRM. An initial innovation in this regard was the development of learning alliances, "a process undertaken jointly by R&D agencies through which research outputs are shared, adapted, used, and innovated upon. This is done to strengthen local capacities, improve the research outputs, generate and document development

273 See: Domínguez CE; Fernández F; Pina M Jr. 1984. Developing scientific manpower for root and tuber crops research and extension. In: Proceedings of the Sixth Symposium of the International Society for Tropical Root Crops. Lima, Peru: International Potato Center (CIP). p 47–53.

274 Janssen WG. 1992. CIAT, CIMMYT, and CIP: Their role in agricultural research in Latin America and the Caribbean. Centro Internacional de Agricultura Tropical (CIAT); Centro Internacional de Mejoramiento de Maíz y Trigo (CIMMYT); Centro Internacional de la Papa (CIP). CIAT, Cali, Colombia. p 49.

275 Lundy M. 2004. Learning alliances with development partners: A framework for scaling out research results. In: Pachico D; Fujisaka S. (eds.). Scaling up and out: Achieving widespread impact through agricultural research. Volume 3 of CIAT Economic and Impact Series. CIAT, Cali, Colombia. p 229.

276 Fernández O; Fernando O. 1974. New trends in training of agricultural production specialists as development communicators. In: Crawford RH; Ward WB. (eds.). International Symposium on Communication Strategies for Rural Development (1974, Cali, Colombia). Proceedings of the Cornell-CIAT International Symposium, 17–22 March 1974, CIAT Headquarters, Cali, Colombia, New York State College of Agriculture and Life Sciences; Centro Internacional de Agricultura Tropical (CIAT), Ithaca, NY, USA. p 175–185.

outcomes, and identify future research needs and potential areas of collaboration."[277] Learning alliances eventually folded into broader approaches to integrated natural resource management. As such, capacity development became more institutionally diffuse, more project based, and framed within what became "knowledge into action." The overall approach was generalizable across a range of institutional context but at the same time focused on adaptation to local conditions.

This evolution in approaches underlies the current strategy for capacity development in eco-efficiency, particularly an evolution from "a relatively narrow focus on training for improved food production, mainly through plant breeding, to a more systemic approach for rural innovation."[278] The approach to capacity development combines a number of elements which CIAT has developed over the years, including: "(1) partnership strategies, (2) participatory research, (3) learning alliances, (4) monitoring and evaluation, and (5) knowledge management and sharing."[279] However, as with NRM, eco-efficiency raises a challenge in terms of how to develop institutional capacity i.e.,"As agricultural research organizations begin to mainstream eco-efficiency, they can start by examining their internal capacities, policies, administrative processes, incentive structures, and other organizational arrangements."[280] This brings capacity development full circle with a focus on institutional capacity but compared to targeted crop research programs argues for a quantum leap to organizational change at the institute or system level. Developing organizational and management capacity in national research institutes that in turn supports the development of systems research and rural innovation capacity remains the challenge going forward.

277 Lundy M. 2004. op. cit. p 229.

278 Staiger-Rivas S; Álvarez S; Ashby J; Lundy M; Muthoni R; Victoria PA; Quirós CA; Sette C, Rajasekharan M; Russell N. 2013. Strengthening capacity to achieve eco-efficiency through agricultural research for development. In: Hershey CH; Neate P. (eds.). Eco-efficiency: From vision to reality. Issues in Tropical Agriculture series. CIAT, Cali, Colombia. p 228.

279 Ibid. p 228.

280 Ibid. p 244.

Capacity development has been a central plank of CIAT's strategy over the half century.

Programmatic evolution of the Decision and Policy Analysis (DAPA) Program

This second part on the history of program development ends in an analysis of one of the three current research programs at CIAT, the Decision and Policy Analysis (DAPA) Program. DAPA was created following the program restructuring after the 2008 EPMR and as a component of the resultant 2014 strategic plan that was framed around eco-efficiency. This plan was built on the three program pillars: DAPA, Agrobiodiversity, and Soils. While the Agrobiodiversity Program consisting of CIAT's four mandate commodities has been a constant throughout CIAT's history – although operating within quite different strategic frameworks – DAPA is a new program area but builds on several research lines that go back through much of CIAT's history. This flexibility in research program design and organizational structure that has been a hallmark of CIAT's history is in many ways well represented by DAPA. Research programs in an institute such as CIAT are not created de novo but build on capacities that have been created under other strategic frameworks and find a role in new strategic and programmatic structures. DAPA is thus a perfect case to close out this review of the programmatic history of CIAT.

DAPA is in part formed from research areas that never quite found a rationale to develop as a program and in part on more recent research themes and capacities. Those historical programmatic threads include: (1) data and spatial analysis, evolving from the early work in the Agroecological Studies Unit (AESU); (2) value chains evolving from early postharvest research and then agroenterprise development; (3) soil, land and water management work that provided an entry point into ecosystem services; and (4) social sciences which have been integrated to varying degrees in major program areas over its history. DAPA is currently organized within a matrix structure of themes and cross-cutting, mainly disciplinary groups that then undertake the thematic research – a research structure found at many points in CIAT's history, including the present strategy, and which usually is a result of a systems approach. The last DAPA strategy presents this program organization:

> *The new organizational structure consists of three main research themes and various cross-cutting research groups. DAPA's research themes are thematic areas of work where we believe DAPA can deliver scaled outcomes and impacts, where we have competitive advantage, and where we can contribute effectively to the CGIAR objectives/outcomes through the CRPs: (1) Climate change adaptation and mitigation, (2) Ecosystem services, and (3) Linking farmers to markets. All three thematic areas require multi-disciplinary teams working together towards a common goal. Those teams are to be formed from DAPA's cross-cutting themes which will deliver world-class science and expertise on: (1) Gender analysis, (2) Policy analysis, (3) Impact and strategic studies, (4) Knowledge management, (5) Spatial and agricultural modeling, and (6) Big data.*[281]

The three themes build on previous capacities, as do the cross-cutting research groups. This section will briefly review the history of each of the four research "threads" outlined above with some final remarks on how they currently are framed within DAPA's overall program structure.

Data and spatial analysis

Data and spatial analysis is a central foundation to the work of DAPA and CIAT's work in this area started in the mid 1970s with Thomas Cochrane's agroecological characterization of the land systems in the Amazon Basin. This study led to the creation of the AESU and the extension of agroecological characterization to the commodity programs. This work was the first venture into what has now become known as knowledge management – information and analysis that support decision-making and research design within the commodity programs. This tracks very closely DAPA's current mission, which is "to facilitate and improve decision making in the private and public sectors (i.e. agricultural and environmental sectors) by ensuring that decision makers are well informed and engaged, through the provision of reliable information and easy-to-use analytical methods to assess the likely outcomes of policy, research, development and management options."[282] The difference is that the AESU supported decision-making within CIAT, whereas DAPA's target audience lies outside the Center. The scope of the research has in turn also expanded significantly.

To undertake this work at a continental scale the AESU began the development of critical databases. This formed the beginnings of CIAT's work on what is now termed big data. In particular, Jones constructed a climate database of thousands of weather stations across the tropics with the aim of constructing spatial climate surfaces for targeting of agricultural technologies. After a decade of data collection, Jones's research then generated decades of research outputs in support of CGIAR's mission.

281 CIAT. 2013. DAPA general strategy 2013–2020. Unpublished paper. CIAT, Cali, Colombia. p 2.

282 Ibid. p 1.

This helped CGIAR and its partners identify priorities, set crop improvement targets geographically, and better understand how to tailor solutions to site-specific problems. Jones's data set eventually fed into WorldClim, a suite of global gridded climate surfaces, which was made freely available online and has been downloaded by hundreds of thousands of users, paving the way for open-access culture within CGIAR. The paper published on WorldClim is the second-most cited paper in CGIAR's history, according to a citation analysis commissioned by the CGIAR Consortium Office in 2013.

The AESU provided the analysis on the zonation and prioritization of agroecologies for the 1991 strategy. As a result of the shift to NRM research, the AESU was integrated into the new Land Use Program in 1992, building on the agroecology prioritization work, to a focus on NRM and particularly to policy work supporting land-use strategies. This was the initial work in CIAT on policy research. Although spatial analysis had been key to the work of the AESU, a separate GIS Unit was created in 1994 and then reintegrated back into what was then the Land Use project in 1998. This was an interesting case where program structure was changed in order to accommodate the hiring of scientific talent.

The period 2003–2010 was a period of programmatic flux at CIAT and after a 2003 CCER on spatial analysis, a research group on Spatial and Economic Analysis for Decision and Policy Support was created in what was then the People and Agro-ecosystem Challenge. As the CCER had noted, "the real objectives of the (what was then) LUP, and indeed of CIAT, are moving in the direction of helping communities adapt and cope with the impacts of global change, whether the result of climatic and associated environmental factors, or economic and social drivers."[283] This report argued for the move into assessing the interaction between climate change and impact on productivity of the mandate crops. The research group was again reorganized in 2006 into Market, Institutions and Livelihoods and then in 2007 into Agroecosystem Resilience, one of the smaller programs in CIAT at the time. DAPA, as a fully fledged research program was created from the Agroecosystem Resilience project in 2009 in the post-EPMR restructuring. In the 2010–2012 Medium Term Plan, DAPA was one of four project areas in the Latin America Regional Program and its research focus at that stage was on that region. With the new strategic plan in 2014, DAPA became one of the three principal program areas of CIAT and over the course of that period the program leader, Andy Jarvis, has developed DAPA into the largest program in CIAT. DAPA is in many ways a product of this history of program recombination, being able to respond to changing global agendas, as well as the opportunities within the CGIAR's CRP process.

Agroprocessing and value chains

CIAT was an early leader in CGIAR in using a value chain methodology. This approach arose out of the Cassava Program where effective demand and uncertain markets were major issues and the program emphasized product development for new markets through research on processing and postharvest technologies. Experiences in the Seed Unit that operated throughout the 1980s also

283 CIAT. 2003. Center-commissioned external review of spatial analysis at the International Center for Tropical Agriculture (CIAT). Unpublished report. CIAT, Cali, Colombia.

helped CIAT achieve expertise in seed enterprise development and alternative business models for seed delivery involving private firms, seed associations, and communities. Research in these areas was highly constrained in the early 1990s when the focus shifted to NRM. With the shift to a project structure, the value chain work was formalized in the creation of the Rural Agroenterprise Development project in 1996. The initial focus was on reinvigorating the research on cassava processing and market development but with the intent to expand the scope of the work, especially with the creation of CLAYUCA in 1999. By 1998, the research scope had broadened to high-value products such as horticulture and dairy as they often presented better opportunities for poverty reduction.

The Rural Agroenterprise Development project retained its integrity over the 1996–2007 period. The challenge was in aligning its program with other projects within a rapidly changing program structure during that period. The research tended to focus on the development of methods, tools, and models within an adaptive, participatory approach. Application of these tools required decentralization to the regions. The Hillsides program in Central America and the Uplands program in Asia, in particular, emphasized value chains as necessary to promote NRM practices and system sustainability. There was also a major initiative in partnership with Catholic Relief Services (CRS) in sub-Saharan Africa.

The formation of the Rural Agroenterprise Development project was at end of the period of structural adjustment and market liberalization when value chain work expanded rapidly among Centers and NGOs. CIAT developed some innovative approaches in the emergence of equitable 'local innovation ecologies' in value chain governance, including collective action to empower communities and entrepreneurs, especially women and learning alliances, to share experiences across communities and value chains. The most recent of these value chain tools is the LINK methodology,[284] which aims to enhance smallholder access to markets within private-sector-led market development and which has recently been extended to work on nutrition.

While the value chain work has continued for over three decades, it has always been challenged to balance the research versus the development dimensions, and within research, the international public good dimension (methods and tools). This challenge, of course, was not unique to CIAT but rather has been the hallmark of much of the project-based work on value chains in CGIAR more generally.

Ecosystem services

Ecosystem services is a relatively new area of research for CIAT, but only in the sense that it has provided a conceptual and integrative framework across the water research done in the hillsides program and the soil organic carbon (SOC) research done in TSBF and the management of acid soils. The work has essentially been biophysical in nature and has assessed changes in the "stocks" of water and SOC, principally in relation to land-use change from community to landscape level. At the same time, there is an interface with the research on climate change in both assessing the impacts of climate change on provision of those services and the impact of sequestration of SOC on

284 Lundy M; Amrein A; Hurtado JJ; Becx G; Zamierowski N; Rodríguez F; Mosquera EE. 2014. LINK Methodology: A participatory guide to business models that link smallholders to markets. CIAT Publication No. 398. CIAT, Cali, Colombia. Available at: http://hdl.handle.net/10568/49606

climate change mitigation. As in the past, existing research is brought together under a new strategic framework.[285] The provision of ecosystem services such as water and SOC are provided at a landscape level but are based on decisions of individual land users. Improvements in the provision of ecosystem services depend essentially on improvements in crop and NRM practices. The research of TSBF-CIAT based farmer investment in those practices on the improvements in crop productivity. There is often a lag in such productivity improvements, which limit farmer investment. Payment for ecosystem services (PES) is a framework that provides such incentives, by essentially creating a market for those services. PES potentially provides a vehicle for that long sought-after goal of integrating commodity and NRM research.

Social sciences

Social sciences and agricultural economics[286] have from the beginning been a principal component of CIAT's research but there has never been a social science program or one that focused on social science topics, such as rural poverty, except very briefly at the beginning when there was an agricultural economics program. Social scientists have been integrated into multidisciplinary teams, apart from the Impact Assessment Unit formed in 1993, which has included primarily agricultural economists. This pattern began with the inclusion of an agricultural economist in each of the original four commodity programs, where they worked primarily on cropping and farming systems. To a significant extent, social science and economics has been integrated into the systems-based research of CIAT. Moreover, there has been a tendency for economists to be more concentrated in particular program areas, primarily at headquarters, such as Impact Assessment and the Land-Use Program, and other social scientists have been more distributed both across programs and outposted within regions.

CIAT has had in its history more non-economist social scientists than most other CGIAR Centers. This has in part been due to CIAT's leadership in the area of participatory research, the development of the Rural Innovation Institute, and the work it has done in gender analysis, particularly within the PRGA. The numbers of social scientists reached a high point in 1999.[287] As noted in the review of social sciences at CIAT:

> *The acceptance of new social science technologies in CIAT has been led by the development of practical field skills, more than by the development of theoretical concepts. For example, the determining factor in the creation and evolution of CIALs, cassava cooperatives, and watershed-level consortia has been the practical skills to*

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285 See: Quintero M; Sachet E; Wyckhuys K; Cordingley J; Kizito F; Cruz-García GS; Winowiecki L; Rajasekharan M; Valbuena D; Chirinda N. 2015. Ecosystem Action – CIAT's Ecosystem Services Strategic Initiative. CIAT, Cali, Colombia. 30 p.

286 Economists consider themselves to be social scientists while social scientists consider economists to be outside that particular gambit and only including anthropologists, rural sociologists, geographers, and political scientists.The section will maintain the distinction between economists and social scientists.

287 See: Holland D; Ashby J; Mejía M. 2002. Growing social research in CIAT, 1968–2002. Paper presented at the Social Research in the CGIAR conference: "Looking to the Future, Learning from the Past," 11–14 September 2002, CIAT, Cali, Colombia.

create such structures and demonstrate their impact, not the ability to conceive of them.[288]

This approach was reviewed by the 2006 CCER on the Rural Innovation Institute, which led in 2006 to the closing of that program and a major restructuring whereby Rural Agroenterprise Development (SN−1), Participatory Research Approaches (SN−3), Systemwide Program on Participatory Research and Gender Analysis (SW−3), and Spatial and Economic Analysis for Decision and Policy Support in Agriculture and the Environment (BP−2) were all integrated into Market, Institutions and Livelihoods (PA1) with a resultant loss of social science capacity and a shift from field-based work. As the 2008 EPMR noted: "The CCER−RII made many references to the weakness or lack of research output of the RII and recommended moving from a method driven to an issue driven approach and focus more on outputs (research leading to new insights) rather than inputs (development action plus manuals)."[289] This issue continues as a principal debate within CGIAR and has found expression in the design of the Sub-Saharan Africa Challenge Program, which CIAT led in the Eastern Africa site, and in the three CRPs structured around systems.[290]

Social science and economics currently at CIAT are located essentially in DAPA, with a balance towards agricultural economics, particularly in the work on impact assessment, valuation of ecosystem services, value chains, and policy. This is very close to an economics and geography research agenda although done within a multidisciplinary team approach and reflects CIAT's historical systems approach and the recent strategic frame of eco-efficiency.

DAPA and organizational natural selection

DAPA is a product of historical antecedents, changes in Center strategy and external context, continuity in research capacities, and the near institutional extinction of CIAT in 2008–2009. As suggested above, the analogy would be that of programmatic natural section and evolution within a rapidly changing environment. This again highlights the institutional flexibility that has been a hallmark of CIAT's history and argues for a continuing adaptive response to a changing CGIAR, development agendas, and resource flows. This provides the context for a consideration of CIAT's future evolution in the following section.

288 Ibid. p 10.

289 CGIAR Science Council. 2008. op. cit. p 31.

290 See for example the approach of the Aquatic Agricultural Systems CRP: Douthwaite B; Mayne J. 2017. Evaluating complex interventions: A theory-driven realist-informed approach. Evaluation 23(3):294–311.

3

The past as a prologue: CIAT's evolving R4D Program

(This section is based on extensive discussions with Ruben Echeverría, the current Director General of CIAT).

The agricultural research for development agenda has shifted from the idea of "more, better, faster, cheaper" to "more, better, fairer, cleaner."

CIAT's 50-year history has been one of continuing institutional change, adapting to both a dynamic external environment as well as responding to emerging internal constraints. Among CGIAR Centers, CIAT has had one of the broader mandates, which it has reinterpreted at various points in this history. This has allowed CIAT to continually redefine itself, promoting periodic institutional innovation. In many ways the process of institutional change has speeded up over the 50 years, giving CIAT an institutional flexibility in adapting to higher level reform processes in the CGIAR System. Some staff members and the record on impact of its research have argued that continually adaptation of the research program structure undermines the long-term problem orientation needed in agricultural research. However, CIAT's history has to date been built on a foundational core of four commodity programs, which have been adapted to changing program architectures at a Center level. This has allowed CIAT to maintain an innovative "leading edge" to its research while continuing to explore long-term problems within its core.[291] This history provides the framework within which CIAT will continue to evolve and adapt into the future.

Global agendas with direct relevance for agricultural research have increased in number and complexity over the course of the last 50 years. Today, over half of the land used for agriculture is moderately or severely degraded; millions of people have an abundance of calories but suffer from poor nutrition; vital ecosystem services are undervalued and at risk; and climate change threatens many of the world's most vulnerable people. The complexity of these issues cuts across scientific disciplines and requires a flexible research program structure.

These global challenges require global action and are now enshrined in the United Nations' Sustainable Development Goals, and the Paris Agreement on climate change. These have far-reaching implications for agricultural research, and CIAT. They reflect the fact that the agriculture-for-development agenda has shifted from the idea of "more, better, faster, cheaper" to "more, better, fairer, cleaner." The global community is asking the agriculture sector to do more than just produce; it is asking it also to be a steward of the landscapes in which it generates its economic returns.

CIAT and its partners have never been in a stronger position to help achieve the SDGs. That's partly because, in the 50 years since CIAT was established, new tools, techniques, and technologies that have helped research keep pace with the challenges have revolutionized science. These innovations mean CIAT can aspire to impacts that previously it could only dream of. For example, until recently, it was inconceivable to undertake research to improve entire landscapes, or quickly bundle multiple traits into crops through gene editing; soon the data revolution will enable the breeding crops *in silico* – using computers and DNA information. These developments will enable researchers to quickly develop new varieties of beans, rice, cassava, and tropical forages that are targeted to

291 Lowell Hardin at CIAT's 30th anniversary made the same point as follows: "CIAT recognized that for it to sustain donor support while pursuing its long-term, somewhat visionary, goal (on developing Latin America's agricultural frontier), the Center would need rather promptly to show results from at least part of its work. So CIAT adopted a two-tier strategy. The first tier would include its strong commodity programs, which were designed to yield an impact in the short term, and the second tier would involve overall farming systems that integrated commodity work with long-term agroecological objectives." Hardin L. 1998. Conceptual and philosophical bases for CIAT's founding. In CIAT. 30 Anniversary of the foundation of CIAT, 1967–1997. CIAT, Cali, Colombia. p 55–63.

specific environments, markets, and nutritional requirements. Big data approaches will help them refine and deliver site-specific advice to farmers about what to plant, when to plant, and how to best manage their crops.

But critically, there is another reason as to why CIAT is well-placed to play a part in the new development agenda; as documented in earlier chapters of this book, it has always been a "systems center". Over the years it hasn't just focused on improving key crops, but also the ways in which they are produced, bought, sold, and how these activities affect the environment, different social groups and human health.

This multidisciplinary systems approach has seen CIAT's work evolve from research on crops adapted to particular agro-ecologies (1967–1990) to the integration of NRM and commodity research in target agro-ecologies (1991–2007), to the unifying concept of eco-efficient agriculture, which has been its guiding principle for the last decade or so. Eco-efficient agriculture: (1) uses resources more effectively to achieve sustainable increases in productivity; (2) can help reduce the degradation of natural resources; and (3) helps creates opportunities for boosting incomes and employment in rural areas. The eco-efficiency paradigm has helped CIAT integrate those three key pillars of sustainable intensification. CIAT's research has evolved to and been organized around increasingly higher system levels. Each stage has required a more flexible program structure organized around priority problem areas, in many ways realizing the original conception of CIAT as focused on farming systems in the lowland tropics.

Building on this diverse research base, it's now time to further expand CIAT's vision, to one focusing on sustainable food systems as a whole. That's because the global development agenda requires integrated responses; food security or nutritious diets, for example, are no longer simply about agricultural productivity or even the availability or affordability of food. They are also about: quality, utilization and distribution of food; rural and urban consumers' behaviors and preferences; the incentives and disincentives that food processors and sellers respond to; and the stability and resilience of food supply chains in both cities and rural areas. These, in turn are closely linked to – and affect – the way we manage our natural capital i.e., the soils, water resources and landscapes. One of the central challenges for the coming decades will be to deliver healthy diets, and to ensure the sustainability of the systems that deliver those diets. In particular, it will enable CIAT's research to respond to the needs of the growing number of poor consumers in urban areas.

CIAT's extraordinarily rich and evolving blend of disciplines is indispensable to fully understanding the different dimensions of food systems. Its expertise in areas ranging from genetics, soil sciences, and nutrition, to economics, policy analysis, social sciences, and ecology will play a role in meeting the growing demand for food and boosting incomes, while reducing agriculture's environmental footprint and achieving greater social equity. The challenge for CIAT will be to make it a reality in all of the regions in which it operates.

Adopting a sustainable food systems framework is also a unique opportunity for CIAT to align its research agenda – and its 14 research themes – with global priorities on food, agriculture, the environment, equity, and health. These bring together key elements of the Center's current portfolio, such as conservation and use of agrobiodiversity, nutrition and health, ecosystems services and land restoration, markets, adaptation and mitigation to climate change, use of big data, and many others.

It means that with 50 years of research on agricultural systems behind it, CIAT's future portfolio may closely resemble its original vision i.e., a Center focusing on food systems research for a growing urban population.

As it continues to pioneer new research areas, CIAT will also remain firmly on track in implementing its research-for-development (R4D) strategy based on its three current research areas – policy analysis, soils and landscapes, and agrobiodiversity. It will continue to pursue an integrated global approach to agricultural R4D that combines a sharp focus on agricultural biodiversity with the cross-cutting themes of tropical soils and policy analysis. CIAT's R4D approach is done within a sub-regional approach, with programs designed around the different development contexts found in Latin America, Southeast Asia, and sub-Saharan Africa. It will also allow CIAT to develop new research themes, reframe existing programs and further explore the interconnectedness between different research areas and themes. In the coming years, CIAT will aim to strengthen its capacity in social and environmental sciences too, and it may consider expanding its crop research portfolio to move beyond its traditional focus on rice, beans, cassava, and tropical forages. These kinds of changes will again be possible as CIAT is a systems Center with an ambitious and relatively open mandate.

The Center's continued involvement in many CGIAR programs, platforms and initiatives reflects its unequivocal commitment to collective action at the CGIAR System level as well as the unique character of its individual contribution. CIAT has evolved in step with CGIAR over the years, supporting its transition to become one of the world's largest networks of agricultural R4D organizations. CIAT's innovative work in areas such as participatory gender research, biofortification, genotyping and phenotyping, geographic information systems, public private partnerships, linking farmers to markets, ecosystem services, climate change, and big data – to name a few – have significantly influenced CGIAR research and helped expand its development impact.

To help further strengthen its global presence, CIAT has in recent years focused strongly on broadening its partnership strategy and its multiple spheres of collaboration, nationally, regionally, and internationally. These include its strategic relationship with its host country, Colombia. CIAT's work with national research systems (including public, private, and civil society organizations) will continue to be the key mechanism by which it implements its research, and makes its results more accessible and useful. At the same time, its long-standing presence in several regions of the developing world – especially Eastern Africa, Southeast Asia, and Central America, and its significant contribution to the global research portfolio of CGIAR allows it to work from local to global level. Past successes illustrate the need for CIAT to continue to build these multi-level partnerships, including the strengthening of South–South networks. Moreover, the process has already given rise to new research agendas, based on shared interests and compatible knowledge, experience, and capacities.

At the same time, there are important shifts taking place in the way CIAT's partners and donors operate, which the Center is already responding to. For example, some "traditional" donors would like to become partners; some traditional partners would like to become donors; and there is now a stronger focus on research and impact at the regional and national levels than ever before. As a result, CIAT will see the emergence of more bilateral partnerships, new relationships with national agricultural research organizations (NAROs), universities and other advanced research institutions, new agreements with governments and development agencies, and new public–private partnerships. To nurture these, CIAT will need to build on its diversified resource mobilization strategy, while continuing to strengthen its results-based programmatic focus, monitoring progress towards achieving concrete outcomes. It will also seek engagements with donors and partners for high-level policy dialogues, and become more involved in the design, implementation, and evaluation of donors' lending operations.

CIAT's "systems culture" will continue to evolve in support of this work, enabling the Center to find the best ways to translate donors' investments into tangible benefits. In particular, it will aim to balance the need for near-term impacts, while ensuring sufficient expertise is dedicated to issues that require longer term research and engagement. An additional challenge will be to ensure that the many global programs in which CIAT is involved align with the regional priorities of the Center and international policy processes, while also ensuring local impacts.

One strategic undertaking to which CIAT is giving special attention – and which combines global, regional and local dimensions – involves the creation of a new plant genetic resources hub at its headquarters in Colombia. For decades, CIAT's genebank has been at the heart of its efforts to make tropical agriculture more productive and resilient. By creating a new state-of-the-art facility, known as *Future Seeds*, CIAT will continue to conserve, study, and share valuable seeds for crop improvement work, while expanding this work into new areas. In addition, it will share digital genetic information that researchers around the world can use to help them unlock the value of crop diversity – the biological foundation of tropical food systems. Colombia – considered the second most biodiverse country in the world after Brazil – stands to gain significantly from the new facility and is actively involved in its planning.

As the vision for *Future Seeds* takes shape, CIAT might consider expanding the range of crops conserved, beyond cassava, beans, and tropical forages. Another area in which CIAT expects to expand its genebank work relates to training and information exchange, in which the Center will build the capacity of others to play their part in the global conservation agenda.

Staying the course

These are all exciting new developments that will help ensure that as CIAT celebrates its 50th birthday, it maintains a healthy, youthful vigor. It has strong organizational, scientific, and financial foundations upon which to pursue these new research directions and partnerships over the next decade, and is well prepared to carry out its mission of reducing hunger and poverty and sustainably improving human nutrition in the tropics.

In addition, as we look to the future, five decades of experience tell us that some things definitely won't change. Agriculture will continue to be an important driver of economic and social development in many parts of the world – and this will continue to have profound implications for the environment, equity and human health. That means that CIAT will remain committed to producing independent scientific research that policy makers can use to boost the productivity, competitiveness and sustainability of farming. It will also remain committed to innovative research that is targeted, inclusive, resilient, and that improves both lives and landscapes. In short, the Center will continue to demonstrate the enormous potential of its science in helping achieve a sustainable food future for all.

As the current Director General Ruben Echeverría noted:

> *I'm immensely proud to look back at five decades of CIAT research, and equally excited about the emerging opportunities. CIAT's achievements are a great testament to the dedication, ingenuity, and perseverance of its research and administrative staff, and its partners all over the world. I would personally like to thank everyone who has contributed to CIAT's success, and join the global development community in looking forward to the work ahead.*


GIAR

Annex 1: The long and difficult road to the birth of CIAT

Date	Report or event	Comment
30 Oct 1961	USAID Report, *Proposed initial program for support of science and technology in Latin America*, USAID.[292] The report was commissioned to design a program for the Alliance for Progress. The team was chaired by **Frank Press**, California Institute of Technology and member of President J.F. Kennedy's Science Advisory Council. **Will M. Myers**, University of Minnesota was the agricultural science member of the team.	The report mainly recommends support to six country-level projects to build capacity in agricultural research and education. However, one of its largest programs is a regional program for tropical forages and livestock to be located in Costa Rica, Colombia, or Brazil. It further recommends that a team including **Ken Turk** from Cornell and a member of the RF Colombia program develop more detailed plans for this program. The team also recommended support for expanded research and education at Turrialba under IICA.
11 Oct 1963	Address by **President John F. Kennedy** to the NAS Centennial celebration. Calls for *"the establishment of a series of international agricultural research institutes on a regional basis. I can imagine nothing more unwise than to hoard our knowledge and not disseminate it and develop the means of disseminating it throughout the globe."*[293]	The inclusion of this paragraph in a relatively short speech has all the fingerprints of **George Harrar**, President, RF.[294] The materials for the speech were sent to the president's office by **Detlev Bronk**,[295] chair of the Centennial Committee, member of the Presidents Scientific Advisory Committee, and past president of the NAS. Bronk, a biophysicist with little knowledge of agriculture, was a long-time RF Trustee while Harrar had led the NAS Committee on Inter-American Cooperation established under Bronk so they knew each other very well.
Oct 1964-Mar 1965	*Proposal for the creation of a Tropical Research Foundation*, NAS Task Force.[296] Report commissioned by USAID as part of support to the Alliance for Progress. Review conducted under the Latin America Science Board, NAS, chaired by **Will M. Myers**, U of Minnesota, future founding DG of IITA, and future vice-president of the Rockefeller Foundation. The Task Force was a team of mostly mid-level scientists under no official leadership. **David Timothy**, ex RF Colombian Agricultural Program was a member of the Task Force.	The TORs called for the team to review the feasibility of establishing research Centers along eco-regional lines. The report recommended a Tropical Research Foundation (TRF) to be funded by the US Government with a governing board in Washington, a central research facility in Puerto Rico and three regional stations based on ecological zone, two in Brazil and one in Peru.

292 Press F. 1961. op. cit. 162 p.

293 Kennedy JF. 1963. op. cit.

294 Harrar did in fact meet with President Kennedy twice in 1962, once in relation to an inter-American meeting of national research councils, and once with only Jerome Wiesner, the president's science advisor.

295 Janice Goldblum, pers. Comm.

296 NAS (National Academy of Sciences). 1965. http://pdf.usaid.gov/pdf_docs/Pnadq461.pdf

Date	Report or event	Comment
27 May 1965	Latin American Science Board meets in Rio de Janeiro under **Will M. Myers**, and issues clarification to NAS Task Force proposal.	Clarification provides more flexibility on Board composition and multiple sources of funding including the Foundations. Also allows for the creation of eco-regional-based Centers under the TRF governed by a Board from that region. The clarification likely reflects initial criticism of the original proposal.
15 Jul 1965	Letter from **Jack Vaughn**, Coordinator Alliance for Progress, USAID, to **Frederick Seitz**, President of NAS, responding to the NAS Task Force report.[297]	USAID critical of lack of sufficient partnership with Latin American institutions and lack of capacity development and involvement of US universities. Also 'political sensitivities' voiced especially from Brazil on setting up a US-governed, financed and staffed foundation.
9 Sep-9 Dec 1965	*Report of the Ad Hoc Review Panel on the "Proposal for the Creation of a Tropical Research Foundation"*, NAS.[298] Distinguished panel chaired by **G. Harrar** and including **Frosty Hill** of Ford Foundation, **P. Mangelsdorf** (Harvard U. and advisor to RF), **T. W. Schultz** (U of Chicago and adviser to RF and future Nobel Prize winner), **T. Hesburgh**, (RF Trustee and President of Notre Dame), **George Beadle** (maize geneticists, and 1958 Nobel Prize winner, President, U. of Chicago), and **Milton Eisenhower**, President, Johns Hopkins University and Latin Americanist.	Critical of the NAS Task Force report, with respect to the lack of partnership with Latin American institutions, the Washington and Puerto Rico bases, and dependence on US public funds. Recognizes Latin America's huge potential in food production not only to improve domestic supplies but to supply the world. Recommends the creation of a major research Center on tropical agriculture with international staffing and governance, and initial funding from the Foundations and USAID. Location of the new Center is left open. Recommends that the Foundations take the lead rather than US Government.
29 Nov-3 Dec 1965	International conference at Cornell University, "Potentials of the Hot Humid Tropics in Latin American Rural Development" organized by Cornell professors **Ken Turk** (member of the NAS LA Science Board) and **Loy Crowder**, ex RF Colombia.	Attended by **Lowell Hardin** (FF), **Lewis Roberts** (RF), **T. W. Schultz, Armando Samper** (IICA and Colombia) and seven scientists associated with the Latin American Science Board and Task Force.
Jan 1966	**Lewis Roberts** and **George Harrar**, RF, visit Colombia.	It is presumed that the new Center was discussed with the Colombian Government.

297 NAS Archives, Folder on International Relations. 1965. Latin American Science Board Task Force on Agriculture Tropical Res: Proposed.

298 NAS Archives, Folder on International Relations. 1965. Latin American Science Board Panel to Review Proposal of a Tropical Research Foundation.

Date	Report or event	Comment
17 Mar 1966	High-level meeting of heads of USAID (**David Bell, Lincoln Gordon, Albert Moseman, Thomas Todd**), Rockefeller (**Harrar**), Ford (**Hill**), and NAS (**Harrison Brown,** others).[299]	**David Bell**, Administrator, USAID argues that funds for the new Center could not effectively flow through NAS or OAS, and an IRRI-type model was needed. **Harrar suggests Palmira as the site of the Center**. USAID agrees to fund initial capital costs, and the Foundations the operating costs.
22 May–4 Jun 1966	International meetings of the problems of agriculture in the humid tropics of Latin America, in Peru and Brazil.[300]	The invitation was sent by **Ken Turk** of Cornell so they are a follow-up to the Cornell conference. They were 'stakeholder consultation' meetings to get buy-in to the idea of a CIAT.[301] They may have also aimed to reduce expectations that the new Center would be located in Peru or Brazil as proposed by the report on the TRF.
Oct 1966	*Proposal for Creating an International Institute for Agricultural Research and Training to Serve the Lowland Tropical Regions of the Americas*, by **Lewis Roberts**, RF, and **Lowell Hardin**, FF.[302]	The first detailed design document for CIAT located in Palmira. Proposes a Center to focus on a specific ecological region but with strong commodity orientation.
12 May 1967	*Memorandum of Understanding* signed by **Harrar** from the RF and **Armando Samper** (Minister of Agriculture), **Jorge Ortiz Méndez** (DG ICA) and other Colombian officials.	
16 May 1967	First allocation of enabling funds by the RF.	
17 Oct 1967	*Act of Foundation* agreement by RF (**Ulysses J. Grant**) and Colombian officials including **Ortiz Méndez**, and **Virgilio Barco Vargas**, ex Minister of Agriculture and future President of Colombia.	This is the official date for the establishment of CIAT as a legal entity.
29 Nov 1967	First allocation of enabling funds by the FF.	
4 Dec 1967	CIAT established as a corporation under Colombian law.	

299 Memorandum of Conversation. 24 March 1966. NAS Archives, Folder on International Relations, 1965. Latin American Science Board Panel to Review Proposal of a Tropical Research Foundation.

300 Invitation letter from Ken Turk to Harrison Brown, Foreign Secretary, NAS. NAS Archives, Folder on International Relations. 1965. Latin American Science Board Panel to Review Proposal of a Tropical Research Foundation.

301 Agricultural Study Asked. The *Cornell Daily Sun*, Volume 82, Number 150, 26 May 1966. p 16.

302 Roberts and Hardin. 1966. op. cit.

Date	Report or event	Comment
Feb 1968	Proposed site at Palmira of 520 ha reviewed, approved, and purchased by the Government of Colombia under the leadership of ICA director, **Jorge Ortiz Méndez.**	
4 Jun 1968	CIAT Board of Trustees elected and installed.	
28–30 Jun 1968	First Board meeting. **Enrique Blair** elected Chair of BoT, and **U. J. Grant** appointed Director General.	
30 Jun 1969	Kellogg Foundation becomes third donor.	
12 Oct 1973	Newly constructed headquarters at Palmira inaugurated.	
18 Mar 1988	Legal status of CIAT changed to an "international entity."	

Note: For a detailed time line and future information on the period of establishment from 1966–73, see: Samper Gnecco A. 1973. Five steps in the establishment of CIAT, 1966–1973. In: CIAT. 1998. 30 Anniversary of the Foundation of CIAT, 1967–97. pp 29–54.

Acronyms and abbreviations

AESU	Agroecological Studies Unit
AHI	African Highlands Initiative
ASARECA	Association for Strengthening Agricultural Research in Eastern and Central Africa
BARN	*Phaseolus* Beans Advanced Biotechnology Research Network
BRU	Biotechnology Research Unit
CAP	Colombian Agricultural Program
CATIE	Tropical Agricultural Research and Higher Education Center
CBD	Convention on Biological Diversity
CBN	Cassava Biotechnology Network
CCAFS	CGIAR Research Program on Climate Change, Agriculture and Food Security
CCER	Center-Commissioned External Review
CGIAR	'CGIAR' was originally the acronym for the 'Consultative Group on International Agricultural Research'. In 2008, CGIAR redefined itself as a global partnership. To reflect this transformation and yet retain its roots, 'CGIAR' was retained as a name. CGIAR is now a global research partnership for a food-secure future
CIAL	Local Agricultural Research Committees
CIALCA	Consortium for Improving Agriculture-Based Livelihoods in Central Africa
CIANO	Northwestern Agricultural Research Center
CIMMYT	International Maize and Wheat Improvement Center
CIP	International
CIRAD	French Agricultural Research Centre for International Development
CLAYUCA	Latin American and Caribbean Consortium to Support Cassava Research and Development (now Clayuca Corporation)
CMV	Cassava Mosaic Virus
CORAF	West and Central African Council for Agricultural Research and Development
CORPOICA	Colombian Corporation for Agricultural Research
COSCA	Collaborative Study of Cassava in Africa
CRP	CGIAR Research Program
CRS	Catholic Relief Services
CRSP	Collaborative Research Support Program
CSIRO	Commonwealth Scientific and Industrial Research Organisation
CTCRI	Central Tuber Crops Research Institute
DAPA	CIAT's Decision and Policy Analysis Research Area
DG	Director General
DIIVA	Diffusion and Impact of Improved Varieties in Africa Project
DR Congo	Democratic Republic of Congo
DRI	Colombia's Integrated Rural Development Program
EAAFRO	East African Agricultural and Forestry Research Organisation
ECABREN	Eastern and Central Africa Bean Research Network
EMBRAPA	Brazilian Agricultural Research Corporation
EPMR	External Program and Management Review

ERI	Enabling Rural Innovation
FAO	Food and Agriculture Organization of the United Nations
FARC	Revolutionary Armed Forces of Colombia
FCR	full cost recovery
FEAST	Feed Assessment Tool
FEDEARROZ	Colombian National Rice Growers Association
FF	Ford Foundation
FLAR	Latin American Fund for Irrigated Rice
GCP21	Global Cassava Partnership for the 21st Century
GIS	geographic information systems
GRiSP	Global Rice Science Partnership (now the CGIAR Rice AgriFood Systems Program)
GRU	Genetic Resources Unit
IARC	International Agricultural Research Center
ICA	Colombian Agricultural Institute
ICRISAT	International Crops Research Institute for the Semi-Arid Tropics
IDB	Inter-American Development Bank
IDRC	International Development Research Centre
IFDC	International Fertilizer Development Center
IFPRI	International Food Policy Research Institute
IICA	Inter-American Institute for Cooperation on Agriculture
IITA	International Institute of Tropical Agriculture
ILCA	International Livestock Centre for Africa
ILRI	International Livestock Research Institute
INCAE	Central American Institute of Business Management
INCORA	Colombian Institute of Agrarian Reform
INRM	integrated natural resource management
IPG	international public goods
IPM	integrated pest management
IPM	CGIAR Systemwide Program on Integrated Pest Management
IPR	intellectual property rights
IRD	Research Institute for Development
IRR	internal rate of return
IRRI	International Rice Research Institute
IRS	internationally recruited staff
ISFM	integrated soil fertility management
ISTRC	International Society for Tropical Root Crops
IV	improved variety
LAC	Latin America and the Caribbean
LUP	Land-Use Plan
MADR	Ministry of Agriculture and Rural Development of Colombia
MAS	marker-assisted selection
NARI	national agricultural research institute
NARO	national agricultural research organization

NARS	national agricultural research system
NGOs	non-governmental organizations
NRM	natural resource management
NUE	nitrogen-use efficiency
OAS	Organization of American States
PABRA	Pan-Africa Bean Research Alliance
PCCMCA	Central American Cooperative Program for the Improvement of Crops and Animals
PCCMF	Central American Cooperative Program for Bean Improvement
PES	payment for ecosystem services
PPB	participatory plant breeding
PRGA	CGIAR Systemwide Program on Participatory Research and Gender Analysis
PVS	participatory varietal selection
R&D	research and development
R4D	research for development
REDBIO	Latin American and Caribbean Agricultural and Forestry Biotechnology Network
RF	Rockefeller Foundation
RHBV	rice hoja blanca virus
RIEPT	International Tropical Pastures Evaluation Network
RII	Rural Innovation Institute
RV	resistant variety
SABRN	Southern Africa Bean Research Network
SADC	Southern African Development Community
SDGs	Sustainable Development Goals
SEARCA	Southeast Asian Regional Center for Graduate Study and Research in Agriculture
SOC	soil organic carbon
SoFT	Selection of Forages for the Tropics Tool
SOM	soil organic matter
SPIA	CGIAR Standing Panel on Impact Assessment
SRO	Sub-regional Research Organization
SWNM	CGIAR Systemwide Program on Soil, Water and Nutrient Management
TAC	CGIAR Technical Advisory Committee
TOR	terms of reference
TPRF	Tropical Plant Research Foundation
TRF	Tropical Research Foundation
TSBF	Tropical Soil Biology and Fertility Program
UN	United Nations
USAID	United States Agency for International Development
USDA	United Stated Department of Agriculture
WECABREN	West and Central Africa Bean Research Network

Design and layout **Daniel Gutiérrez**

Graphs and figures **Ximena Hiles**

Editing **Anne Downes, Victoria Rengifo, and Stéfanie Neno**

Printing **Libre Expresión Creativos, Cali, Colombia**

October 2017

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ISBN: 978-958-694-173-0