FLOWS UNDER STRESS: AVAILABILITY OF PLANT GENETIC RESOURCES IN TIMES OF CLIMATE AND POLICY CHANGE

Working Paper No. 18

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

Isabel López-Noriega
Gea Galluzzi
Michael Halewood
Ronnie Vernooy
Enrico Bertacchini
Devendra Gauchan
Eric Welch

CLIMATE CHANGE AGRICULTURE AND FOOD SECURITY

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Contact:

CCAFS Coordinating Unit - Faculty of Science, Department of Plant and Environmental Sciences, University of Copenhagen, Rolighedsvej 21, DK-1958 Frederiksberg C, Denmark. Tel: +45 35331046; Email: ccafs@cgiar.org

Abstract

There is growing recognition that successful adaptation of agricultural production systems to changes in climate will depend upon the improved access to, and use of, genetic diversity. In order to facilitate this adaptation, new forms of interdisciplinary research, new technologies, novel partnerships and effective policy instruments are considered essential. Given their mandate, history and expertise, the centres of the Consultative Group on International Agricultural Research (CGIAR Centres) are expected to play an important role in developing novel agricultural research strategies required to respond to climate change challenges. This report describes how eight of the CGIAR Centres whose research is focused on plant genetic resources, are (re)organizing their conservation and improvement activities in light of climate change adaptation. The report also analyzes how the collection, use and distribution of plant genetic resources by CGIAR Centres are influenced by international and national policies, treaties and agreements.

The study concludes that climate change has not radically changed CGIAR gene bank and plant-breeding priorities and approaches, although it has added some urgency to changes already occurring in the CGIAR system. In recent years, the CGIAR Centres have broadened their operational strategies through closer co-operation with the private sector and through more direct interactions with farmers, national extension agencies, non-government organizations and aid agencies. Explicit climate change adaptation efforts related to plant genetic resources can be found in the operational strategies of some of the centres and for some crops, but, to date, no specially developed system-wide strategy has been developed. The most significant changes that are occurring are more strongly influenced by demand from the donor and international development community for more impact 'on the ground.'

Some concerns exist among CGIAR scientists about continued access to plant genetic resources, including crop wild relatives. Such access is important for the discovery and use of climate-relevant traits. CGIAR scientists also expressed concerns about the distribution of plant genetic resources which in recent years has become subject to new rules and regulations. Study findings point to an increasing influence of international and national policies and legal frameworks on all of the operations of the CGIAR Centres from upstream to downstream levels.It appears that, broadly considered, despite recent developments in the policy environment, the centres and their research partners continue to face challenges accessing plant genetic resources as inputs to their crop improvement and research activities. This situation may, in the longer term, have a serious impact on the development of (new) strategies to adapt to climate change that are based on the use of plant genetic resources.

Key climate change adaptation efforts deployed by the CGIAR Centres

The CGIAR Centres have been breeding improved materials in response to climate change-related stresses for a long time. Breeders have identified only a few *new* breeding activities that are directly linked to recent climate change stresses, such as increased drought, more extreme temperatures, more widespread flooding, higher levels of salinity and shifting patterns of pest and disease occurrence. They have also mentioned that in some cases they are making use of new technologies (such as molecular and modelling) to respond to increased climate change pressure. Some of the centres are using participatory crop improvement to directly address farmers' constraints related to recent climate changes.

In some of the CGIAR Centres, breeders have expressed concern about the small portfolio of crop species being improved and disseminated, particularly those that are hardier and more resilient to climate extremes. Some of them are working on the development of alternative variety release, dissemination and seed quality assurance schemes to deal with this problem. Such efforts involve small-scale seed producer groups and the use of informal channels of multiplication and exchange.

CGIAR gene bank managers and breeders have observed that many of the traits they have traditionally been interested in are related to abiotic and biotic stresses due to climate change factors. Only some of their work is directly linked to recent or predicted climate changes in particular areas and countries of the world.

One particular area of interest expressed by both gene bank managers and breeders concerns the collection and characterization of wild relatives of some crops in the hope of finding useful, and so far undiscovered, traits with particular climate change adaptation potential – for example, a tolerance to extreme heat or cold.

Some CGIAR Centres are experimenting with new approaches to linking both CGIAR and national gene banks directly to farmers who are facing climate change challenges. The International Centre for Maize and Wheat Improvement executes the Sustainable Modernization of Traditional Agriculture project in Mexico, while Bioversity International introduced the Seeds for Needs project in Ethiopia and Papua New Guinea. Both of these projects involve farmers who are the direct recipients and evaluators of gene bank germplasm.

Key words: climate change, gene banks, genetic resources policies, interdependence, plant breeding, plant genetic resources.

About the authors

Enrico Bertacchini is a post-doctoral researcher in the Department of Economics at the University of Turin, Italy. Since completing his PhD in Law and Economics, one of his main research interests has been the international governance of plant genetic resources for food and agriculture. In 2009, he worked as a consultant for the Instituto Agronomico per l'Oltremare on a research project concerning the analysis of the implementation of the International Treaty on Plant Genetic Resources for Food and Agriculture in Italy.

Gea Galluzzi is an agronomist with a PhD in agro-biodiversity from the Sant'Anna School of Advanced Studies, Pisa, Italy. For her doctoral research, she studied the genetic diversity in wheat species at the molecular level. She also researched climate change policy issues with the support of the Coalition for Rainforest Nations (an intergovernmental organization). She is currently working in Bioversity International's regional office for the Americas in Cali, Colombia, on policy aspects affecting conservation and the use of plant genetic resources for food and agriculture with a special interest in underutilized species.

Devendra Gauchan is an agricultural economist who has specialized in the conservation of agrobiodiversity. He has a PhD from the University of Birmingham. He is currently a senior scientist and the head of the Socioeconomics and Agricultural Research Policy Division at the Nepal Agricultural Research Council in Kathmandu, Nepal. He recently conducted post-doctoral studies at the International Rice Research Institute from 2008 to 2010, focusing on technology adoption, household livelihoods and impact assessment.

Michael Halewood is a senior scientist and head of the Policy Research and Support Unit at Bioversity International in Rome. His research focuses on the impact of policies on the use and conservation of agricultural biological diversity. He holds degrees in political science and law from the University of Toronto and a doctoral degree in law from Osgoode Hall Law School.

Isabel López-Noriega is a legal specialist in the Policy Research and Support Unit at Bioversity International in Rome. She studied law at the Complutense University of Madrid, Spain, and has a MA in environment management and a MA in international law. Her area of expertise is in international biodiversity law, and she works on international and national policies and laws dealing with access to, and the use of, genetic resources. Prior to joining Bioversity International, she was at the UNESCO chair for the environment at the Universidad Rey Juan Carlos in Madrid.

Ronnie Vernooy is a rural development sociologist with a MSc and PhD degree from Wageningen Agricultural University. He joined Bioversity International's Policy Research and Support Unit in October 2011. Before coming to Rome, he was a natural resource management program specialist at the International Development Research Centre in Canada from 1992 until 2010. He has conducted research on agricultural biodiversity management in Costa Rica, Cuba, Honduras, Nicaragua, China, Mongolia and Vietnam.

Eric Welch is an associate professor in the Department of Public Administration at the University of Illinois at Chicago (UIC). He also directs the Science, Technology and Environmental Policy Lab and co-ordinates the PhD program in Science and Technology Policy at UIC. His research focuses on environment policy, genetic resource policy, science and technology policy, information management and research and development performance evaluation. He teaches courses on technology and innovation theory, science and technology policy, decision analysis and environmental policy.

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Contents

1.0. Introduction

1.1. Using plant genetic resources to adapt to climate change: Biological, institutional and policy issues

A growing body of literature asserts that the successful adaptation of agricultural production systems to changes in climate will depend upon higher levels of access to, and use of, genetic diversity than is currently the case (Yadav et al. 2011). This assertion has been clearly recognized by the international community in the revised Global Plan of Action for the Conservation and Sustainable Use of Plant Genetic Resources for Food and Agriculture (FAO 2011) and the Nagoya Protocol on Access and Benefit Sharing and the Fair and Equitable Sharing of Benefits Arising from Their Utilization (Secretariat of the Convention on Biological Diversity 2011).[1] Commentators make the case that to optimize the contribution of genetic resources to climate change adaptation, new forms of interdisciplinary research, the use of new technologies, novel combinations of partnerships and effective policy instruments are considered essential. They argue that such contributions would ensure that genetic materials with useful traits are timely identified, efficiently included in crop improvement programs and effectively delivered to farmers' fields (Reynolds 2010). Supportive policies and laws could create an enabling environment for the use of technologies and plant genetic resources for climate change adaption, but, to date, detailed discussion of the content of such policies has been sparse (Pinstrup-Anderson and Watson 2011).

Given their nature, the centres of the Consultative Group on International Agricultural Research (CGIAR Centres) occupy important, nodal positions in internationally co-ordinated efforts to conserve, improve and use plant genetic resources. Their networks with national agricultural research organizations (NAROs) all over the world and with advanced, international and national research institutes in selected countries, and, more recently, with private sector and civil society organizations, including farmer associations, are unique. They are clearly well situated to make important contributions to climate change adaptation, and the way in which they will do this will have a global impact.

In recognition of these facts, the Commission on Genetic Resources for Food and Agriculture (CGRFA) of the Food and Agriculture Organization (FAO) lists the CGIAR Centres, along with the Secretariats of the United Nations Framework Convention on Climate Change (UNFCCC), the Convention on Biological Diversity (CBD) and the International Treaty on Plant Genetic Resources for Food and Agriculture (ITPGRFA), as the key partners for developing a roadmap to exploit the potential of genetic resources for climate change adaptation (CGRFA 2011).[2] The experiences of the CGIAR Centres in terms of the challenges they have faced and the lessons they have learned concerning partnerships, germplasm diffusion and use strategies, as well as the impact of different policies on their own and their

1 Nagoya Protocol on Access and Benefit Sharing and the Fair and Equitable Sharing of Benefits Arising from Their Utilization, 29 October 2012, <http://www.cbd.int/abs/text/>.
2 UN Framework Convention on Climate Change, 31 I.L.M. 849 (1992). Convention on Biological Diversity, 31 ILM 818 (1992). International Treaty on Plant Genetic Resources for Food and Agriculture, 29 June 2004, <http://www.planttreaty.org/texts_en.htm>.

partners' efforts, are clearly relevant to other organizations in the process of identifying how they can contribute to adaptation to climatic changes.

However, the CGIAR Centres do not operate together as a monolithic entity. Each of the 15 centres has an independent legal identity and has traditionally pursued relatively autonomous research and development programs. These programs are developed to respond to the characteristics of the priority crops or species they work with, the capacities of their partners, and the needs of the people whose interests they are serving. Such efforts have changed in recent years, with the centres agreeing to operate under the overall framework of the CGIAR consortium, with a common strategy and results framework and research programs that have been approved by the Consortium Board and Fund Council.[3] The Climate Change, Agriculture and Food Security program (CCAFS) represents such a reorganization and concentration of the efforts of the centres. The CCAFS aims to overcome the threats to agriculture and food security in a changing climate, which is faced in particular by vulnerable communities around the world. However, the CCAFS does not include gene banking or breeding per se within its focus.

To date, there has not been a collective stock-taking of how the CGIAR Centres are (re) organizing their management of plant genetic resources to respond to the challenge of climate change adaptation and the impacts of international and national policies on their work. This report aims to address this 'gap' through an analysis of how the collection, use and distribution of plant genetic resources for food and agriculture (PGRFA) by the CGIAR Centres may be changing in response to the changes in climate and policies. The key questions this report addresses are:

- Has the need to respond to climate change influenced the kinds of plant genetic resources that the CGIAR Centres seek to collect, conserve and use?[4]

- Has it influenced their plant breeding priorities? Their partnerships? Their strategies for ensuring that adapted plant genetic materials are made available to farmers?

- What policies support or impede the efforts of the CGIAR Centres and their partners to use plant genetic resources in climate change adaptation?

- What kind of policy support could be beneficial to make adaptation strategies more effective?

- How do the experiences of the CGIAR Centres concerning these issues compare to what has been predicted or observed in the relevant literature?

Subsequent research and related papers will analyze the options that the CGIAR Centres can themselves adopt in both short-term practices and policies to respond to the challenges identified in this report and in longer term national and international policy reforms to support the more efficient use of genetic resources to adapt to climate change.

3 CGIAR. 2011. Changing agricultural research in a changing world. A strategy and results framework for the reformed CGIAR. <http://www.cgiar.org/consortium-news/agricultural-research-to-make-a-difference-our-strategy-and-results-framework/>

4 Beyond the scope of this study are microbial, animal and tree genetic resources.

1.2. Analytical framework

For practical reasons, we conceptually divide our analysis of the uses of PGRFA according to the patterns of flow into, within and out of the CGIAR Centres as visualized in Figure 1. For the purposes of our analysis, we differentiate between the experiences of gene banks acquiring, analyzing, conserving and distributing germplasm and the flows and uses of germplasm by the breeders and breeding programs. The gene banks and breeding programs are guided by a newly developed common strategy and results framework as well as numerous research programs, as earlier mentioned.

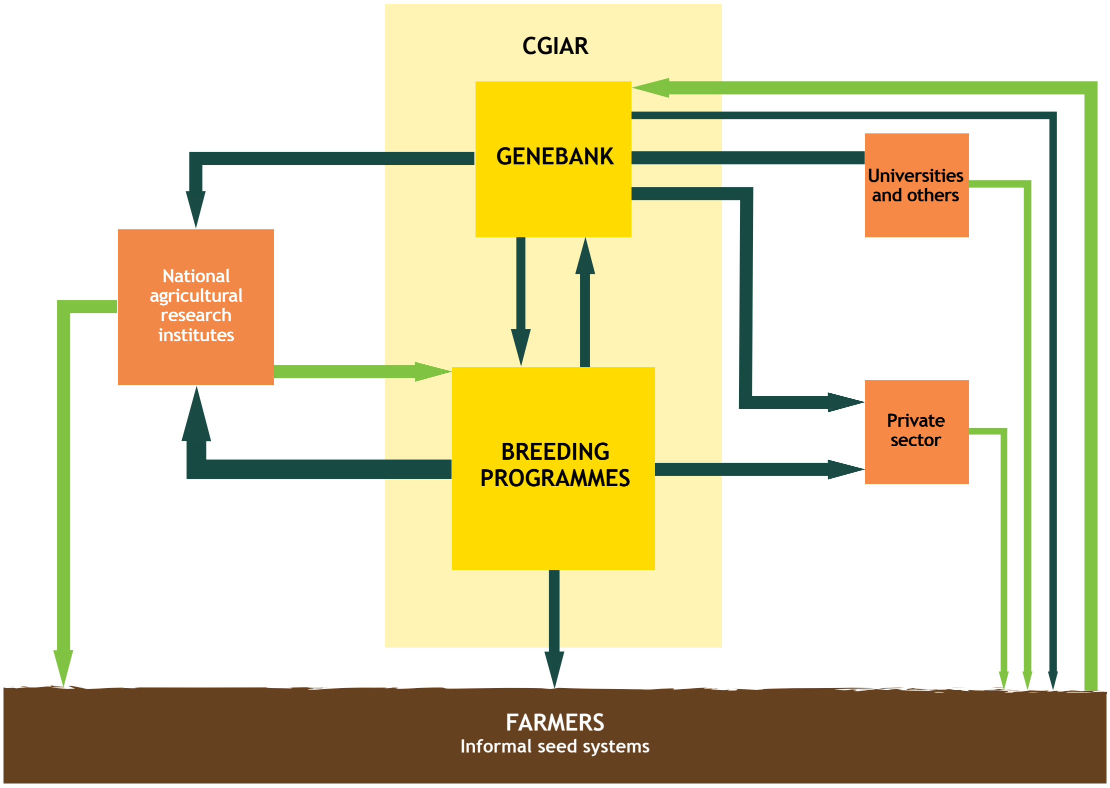

Figure 1: Germplasm flows in and out of the CGIAR.

Source: the authors

The CGIAR centres operate in a wider, external institutional context that includes international and national policies and laws (for example, those concerning agricultural biodiversity, plant genetic resources, seed systems, trade, technology and intellectual property rights), funding priorities, capacities and rules of donor agencies and programming agendas of development agencies. This wider context is also influenced by forces, events and changes in the global biophysical environment (for example, natural disasters), on which climate change has had an increasing impact.

Different perspectives have been adopted to conceptualize the processes of technology development and diffusion (Biggs 1990; Rogers 2003). In the field of agricultural technology development, including crop improvement, models tend to be divided into two groups. The first include those models that respond to a classic, linear and functionalistic approach where innovations are seen to move progressively from advanced agricultural research institutions, to national agricultural systems, to national extension systems and, finally, to farmers. The second group include models that do not assume that innovation systems naturally exist and function smoothly in a top-down and linear manner. Rather, they focus on how different actors make use of different sources of information, relationships and technologies to actively construct (or hinder) the process of innovation, including farmers, community organizations and non-government organizations (NGOs) (Leeuwis 2004; Snapp et al 2002). Some studies have combined both models and analyzed how actual crop improvement processes are being organized in terms of management rules, responsibilities and roles, decision-making processes and the division of labour (Biggs and Smith 1998), including the relatively new field of participatory plant breeding (Vernooy et al. 2009). Our study will also make use of a combination of these two models known as knowledge systems and social actor approaches (Vernooy and Song 2004). We will analyze the institutional and organizational structures and mechanisms through which knowledge and germplasm are generated and disseminated among the actors at various levels and locations. This assessment will be combined with an analysis of how the key social actors – in this case, gene bank managers, breeders, intellectual property right (IPR) specialists, extension agents, NGO staff and farmers – actively take part in, and make decisions about, the use, management and conservation of germplasm. We will also analyze if and how the CGIAR Centres or certain actors within them are shifting operational strategies to strengthen their own and their partners' climate change adaptation capacities.

1.3. Methodology

Our first step was to identify the groups of actors in the CGIAR Centres most directly involved in germplasm management: gene bank managers, breeders, research directors, regional directors, uptake specialists and intellectual property and contract managers. We developed a draft survey document for semi-structured, personal interviews. It included common questions for all respondents and focused questions for the different users. Eric Welch in the Faculty of Public Administration and Policy at the University of Illinois at Chicago assisted in the design of the survey. The survey document was tested through interviews with scientists at the International Centre for the Improvement of Maize and Wheat (CIMMYT) in Mexico and subsequently revised. The survey document is included in Appendix 1.

Thereafter, additional visits to the headquarters of the International Center for Tropical Agriculture (CIAT), the International Potato Center (CIP), the International Crops Research Institute for the Semi-Arid Tropics (ICRISAT), the International Institute for Tropical Agriculture (IITA) and the International Rice Research Institute (IRRI) were organized for personal interviews. Telephone interviews were conducted with the scientists at the International Center for Agricultural Research in the Dry Areas (ICARDA) in Aleppo, Syria and at Bioversity International in Leuven, Belgium and Montpellier, France. A total of 70 personal interviews with scientists from 8 CGIAR Centres were conducted from July to November 2011. Interviewees included 29 breeders, 8 policy and legal specialists, 8 gene bank managers and 25 other scientists (natural resource management scientists, geographic information systems specialists and social scientists). Interview notes were recorded in a common comparable Excel format and complemented by summaries (provided by the interviewers) of the most salient issues that arose over the course of the interviews with scientists in the same centre. In addition, we collected journal articles, reports and other documents that were pointed out by the interviewees as being relevant. To complement the interviews and compare field findings with other sources, we conducted literature reviews (including grey literature) regarding issues initially identified as being important or that were highlighted in the course of the interviews. These documents included CGIAR Centres' breeding programs; strategies and channels for the dissemination of improved germplasm from the CGIAR Centres; factors influencing the uptake of crop technologies, such as subsidies; the impact of intellectual property rights and access and benefit-sharing policies on agricultural research and the CGIAR Centres' collaboration with the private sector.

Finally, to obtain an overview of the extent and geographical coverage of CGIAR-facilitated germpasm flows (in the context of possible adaptation to climate change), we accessed data on germplasm acquisitions and distribution by the CGIAR gene banks and breeding programs from two sources: data from the CGIAR's System-Wide Information Network for Genetic Resources (SINGER) (for gene banks) and data that the centres had amalgamated for the purpose of reporting their activities to the Governing Body of the ITPGRFA for 2007-09 (for both breeders and gene banks). There are insufficient time series data from breeders to be able to identify trends, but the data are nonetheless useful for capturing a yearly snapshot of the quantities of materials acquired and distributed for different crops, the types of recipients and in what parts of the world they originated. We chose the most recent year, 2009. The quantitative data complements the mostly qualitative data from the survey interviews.

In the next phase of research, which is to be conducted in 2012-13, we will survey a range of non-CGIAR respondents from about 20 countries around the world to obtain additional perspectives, including scientists who have received and used improved germplasm from the CGIAR Centres as part of their climate change adaptation strategies or regular crop improvement activities. In addition, we will analyze the policy implications of the overall research findings and identify a range of possible policy changes that could be considered at organizational, national and international levels to make it easier to realize the potential of PGRFA to adapt to climate change.

Chapters 2-4 in this report present the main field research findings of the study, Chapter 5 offers a synthesis of the main findings and Chapter 6 concludes and looks ahead.

2.0. Operations of the CGIAR gene banks and breeding programs in the last decade

2.1. CGIAR gene banks

2.1.1. Origins and evolution

Most of the international *ex situ* collections currently hosted by 11 of the CGIAR gene banks began as working collections used by teams of scientists both inside and outside the CGIAR. Over time, the centres accepted responsibility for maintaining the collections on behalf of the international community, subject to internationally recognized standards. They agreed to provide global-facilitated access to these collections for the purposes of agricultural research and development, conservation and breeding. The CGIAR collections currently include 693 766 accessions of PGRFA (SINGER website March 2012). According to the SINGER database, the *ex situ* collections hosted by the centres include materials that were originally collected from 195 countries. Between 1979 and 2009, the centres' gene banks distributed materials to 178 countries.[5] Table 1 shows the top 30 source countries which contributed slightly over 50% of the total number of accessions conserved in gene banks of the CGIAR system.

Table 1. Top 30 countries of source for the materials conserved in CGIAR gene banks.

Top 30 source countries	N. accessions in CGIAR gene banks	Top 30 source countries	N. accessions in CGIAR gene banks
India	66864	Syria	10952
Mexico	34603	Ivory Coast	10019
Ethiopia	22763	Bangladesh	9126
Iran	22049	Taiwan	6244
USA	21977	Nepal	6240
Turkey	17505	Zimbabwe	6043
China	16813	Japan	5900
Laos	16212	Malaysia	5744
Brazil	15606	Cameroon	5644
Peru	15488	Cambodia	5550
Nigeria	15245	Afghanistan	5277
Indonesia	13308	Mali	5073
Colombia	13039	Niger	5029
Thailand	12083	Jordan	5022
Philippines	11089	Korea (Republic of)	4924

Source: SINGER (2012)

5 System-Wide Information Network for Genetic Resources (SINGER), <http://www.singer.cgiar.org>

The gene banks redistribute samples of the materials they received (and keep as accessions) to countries all over the world. Figure 2 shows the number of samples that the gene banks distributed, from 1979-2009, of materials originally sourced from different countries. Data exclude distributions within the CGIAR (from gene banks to CGIAR breeders) and transfers to Norway which are destined to the Svalbard seed vault and took place in 2008-2009. Darker shades represent larger numbers of samples of materials collected from those countries.

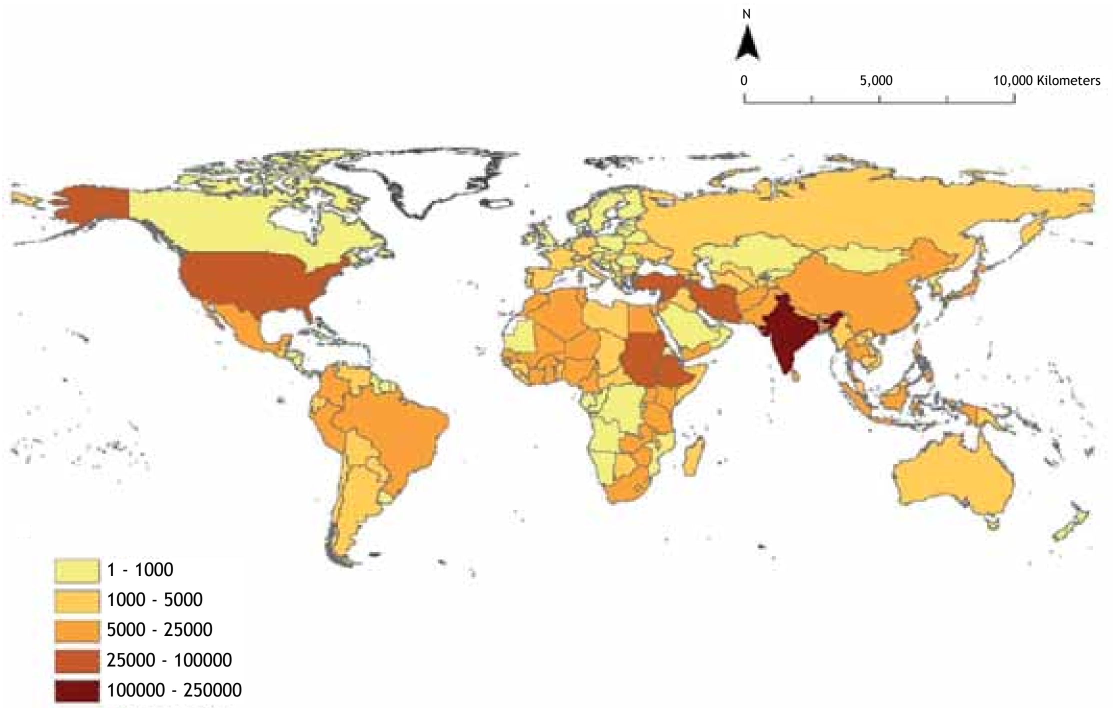

Figure 2: Number of samples distributed by the CGIAR gene banks (1979-2009) that were originally sourced from indicated countries.[6]

Source: SINGER (2012)

By contrast, the map in Figure 3 shows the equally broad range of countries that have received samples of material through the CGIAR gene banks over the 1979-2009 period. Data exclude distributions within the CGIAR (from gene banks to CGIAR breeders) and transfers to Norway which are destined to the Svalbard seed vault and took place in 2008-2009. Darker shades indicate countries that received larger quantities of germplasm from the CGIAR gene banks.

6 The legend classifies countries based on the number of samples containing material originally collected in those countries.

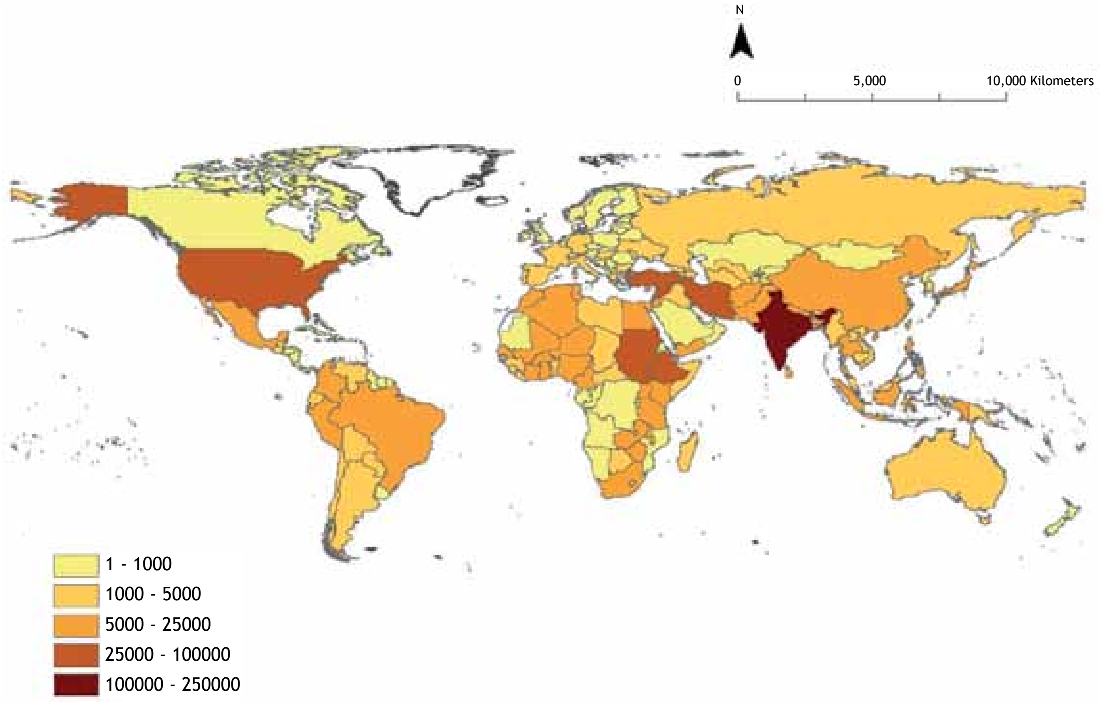

Figure 3: Global distribution of total CGIAR gene bank material (1979-2009). [7]

Source: SINGER (2012)

The rights and responsibilities of the CGIAR Centres concerning the *ex situ* collections have gradually been formalized through international legal agreements. In 1998, the centres issued a statement declaring that they considered themselves to be holding the collections on behalf of the international community. This statement did not turn out to be sufficient to calm concerns that the collections might somehow be converted to the exclusive control of countries hosting the CGIAR Centres or to the World Bank or the centres themselves (Halewood 2010). Partly in reaction to these concerns, the CGIAR Centres hosting international collections – 12 at the time – signed agreements with the FAO in 1994 to hold designated germplasm in trust for the benefit of the international community and to make samples of the designated germplasm and related information available directly to users or through FAO, for the purpose of scientific research, plant breeding or genetic resources conservation, without restriction (SGRP 2010). The centres developed their own guidelines stating that they would designate germplasm as being 'in-trust,' that they had the legal right to make it globally available and that they wanted to make a long-term conservation commitment. The centres adopted a material transfer agreement (MTA) for distributing in-trust materials, stating that in-trust materials could be made available for direct use by farmers. Under this agreement, the centres subjected themselves to the overall policy guidance of the FAO's CGRFA as far as issues related to the management of the in-trust materials were concerned. It was always understood that the in-trust agreements were a stop-gap

7 The legend classifies countries based on the number of samples sent to these countries from the CGIAR gene banks.

measure meant to clarify the legal status of the collections until the negotiations of the ITPGRFA were concluded. In 2006, 11 centres hosting collections signed agreements with the governing body of the Treaty placing their in-trust collections under the purview of the Treaty.[8] Thus, the centres subjected themselves to the overall policy guidance of the Governing Body with respect to the management of their collections and undertook to use the Standard Material Transfer Agreement (SMTA) when distributing materials they held 'in trust' or that incorporate materials from the multilateral system. [9]

2.1.2. Operational strategies

Collection, long-term conservation and distribution of germplasm

The CGIAR Centres have traditionally acquired materials either from other pre-existing *ex situ* collections or from missions to collect materials from *in situ* conditions. Collecting missions are usually organized in co-operation with national partners. Copies of the materials collected are deposited with the national partners (in the national gene bank if there is one) with the understanding that duplicates will be forwarded to the centres.

Over the years, the numbers of new, unique acquisitions have dropped considerably (a trend that began around 1992), except for a slight increase in the most recent period, which was due to a special project, which will be discussed later in this report. Figure 4 shows the trend line in total number of unique acquisitions over the time period from 1979 to 2009.

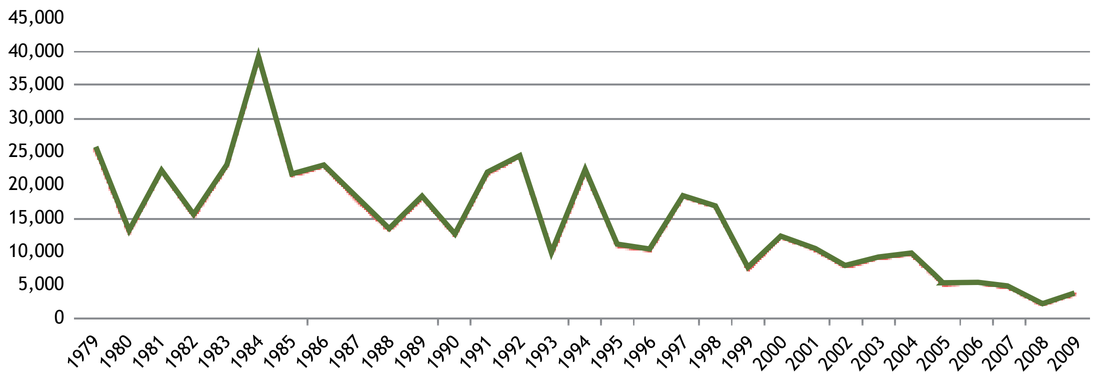

Figure 4: Trend in total acquisitions of unique accessions entering the CGIAR collections from 1979 to 2009.

Source: SINGER (2012)

8 Of the original 12 centres, the Center for International Forestry Research did not sign the revised agreement.
9 As a result of the way things have developed, the materials that the Centres actually distribute using the SMTA includes materials designated as 'in trust' under the 1994 agreements, materials the Centres received under the SMTA, and materials they received under some other instrument with permission to redistribute that material using the SMTA. Standard Material Transfer Agreement, 16 June 2006, <ftp://ftp.fao.org/ag/agp/planttreaty/agreements/smta/SMTAe.pdf>.

In terms of incoming material for long-term conservation (to the CGIAR gene banks), the last four years (2008-12) have witnessed an atypical increase in the number of samples sent to the CGIAR Centres from developing countries to be held as safety back-ups of regenerated *ex situ* materials (complete characterization data are not yet available). This increase is due to the efforts of an international 'regeneration' project supported by the Global Crop Diversity Trust (GCDT) and the Bill and Melinda Gates Foundation. Between 2008 and 2010 (inclusive), 20 developing countries sent samples of over 14 500 regenerated accessions to various CGIAR gene banks (Halewood et al. 2012). While the impact of the project has been positive, it did encounter some challenges. Some countries declined support from the GCDT on the basis that they did not want to send duplicates abroad for safety duplication and international supply. Some other countries that have received support from the project have not yet forwarded copies for back up. Some of the materials provided have been subject to diseases and could not be rescued and stored in the collections of the CGIAR Centres. In other cases, the centres had to spend considerable (and unbudgeted) resources to 'rescue' the diseased material before adding it to their collections. One country has informed three centres that it will deposit regenerated materials in their gene banks only if they agree not to redistribute those materials to countries that have not signed the ITPGRFA. The 'regeneration project' is being terminated with more copies of regenerated materials being forwarded to the CGIAR gene banks in 2012. In the absence of new funding to support countries to collect, regenerate or evaluate more germplasm, it seems likely that the rates of materials from developing countries will decrease again in the near future.

The CGIAR Centres generally make materials available to anyone – organization or individual – who requests it for the allowed purposes, for free or for a minimal fee. They may decline to provide materials if they do not have sufficient samples in stock. Most of the materials they distribute go to public sector research and breeding organizations. One of the largest users of the CGIAR gene banks is the CGIAR breeding program. Figure 5 shows the trends in the flow of germplasm out of the gene banks since 1979 for both unique accessions and the total number of samples versus the unique accessions received.

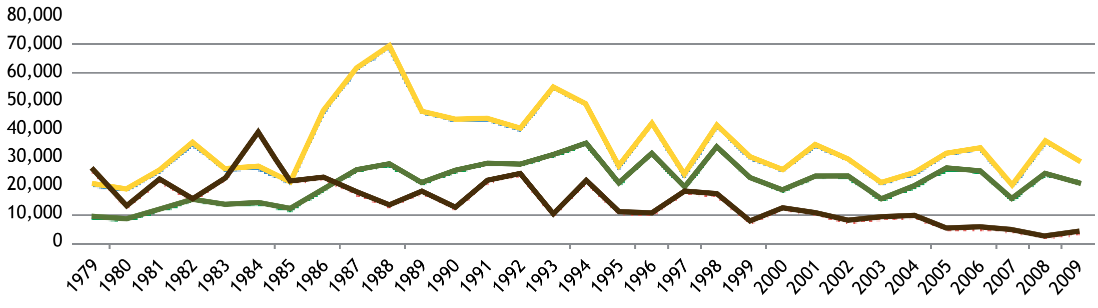

Figure 5. Number of samples (yellow line) and unique accessions (green line) distributed by CGIAR gene banks, versus number of unique accessions registered into CGIAR gene banks (brown line) from 1979 to 2009. [10]

Source: SINGER (2012)

10 The data exclude distributions within the CGIAR and transfers to Norway, which were destined for the Svalbard Global Seed Vault and took place in 2008-09 (for more information about the global seed vault, see, http://www.croptrust.org/main/arcticseedvault.php?itemid=842).

Figure 5 indicates that the levels of distribution of samples from the gene banks have experienced a slight downward trend over the last 15 years (since 1998). The gene bank managers attribute this decrease mainly to (1) the increased ability of gene banks to target responses to requests and (2) the ability of some requestors to make more targeted requests. Figure 6 superimposes the centres' genebanks' distribution of samples with their acquisition of new materials.

From 1979 to 2009 (excluding the materials sent to the Svalbard Global Seed Vault), the average yearly number of samples of PGRFA distributed by all gene CGIAR gene banks was 57 951. The average number of unique accessions of which the samples were sent was 9 404 (based on data from the SINGER website 2012). This figure indicates that a very large number of duplicates are being distributed around the world in response to demand from different countries. Figure 5 shows that this discrepancy was largest during the years up to approximately 1994. Thereafter, fewer samples of the same accessions were distributed.

The CGIAR Centres are generally by far the largest source of germplasm to public research and breeding programmes, particularly for countries in the developing world (CGRFA 2011). 2009 data collected from all of the CGIAR gene banks confirm these patterns. In 2009, the CGIAR gene banks distributed 29 441 samples, excluding intra-centre transfers and those sent to the Svalbard Global Seed Vault (SINGER wesbite 2012). Of this total, the centres report that 59 percent was sent to developing countries; 2 percent was sent to countries with economies in transition; 29 percent was sent to developed countries and 10 percent was sent to other CGIAR Centres. As far as types of recipients are concerned, 47 percent was sent to NAROs; 34 percent to universities; 5 percent to commercial companies and 10 percent to other CGIAR Centres. The remaining 4 percent was sent to a combination of germplasm networks, regional organizations and farmers (SGRP 2011). Data for 2007 and 2008 are similar to the 2009 data (SGRP 2009). Some countries, such as China, apart from receiving PGRFA from the CGIAR Centres, also obtain important amounts of germplasm through bilateral, country-to-country transfers (Wang 2012).

Tables 2 and 3 show the top countries from which gene bank material was originally collected and the countries that have received the most material from the gene banks between 1979 and 2009 (data excludes transfers within the CGIAR Centres – that is, from gene banks to CGIAR breeding programs and materials sent to the Svalbard Global Seed Vault in Norway). The tables show the high interdependence of countries around the world in terms of both volume and diversity of materials received and distributed (exchanged). India tops the recipient list with over 340 000 samples received, coming from 180 countries of source.

Table 2: Samples distributed by the CGIAR gene banks ranked by recipient country, excluding intra-centre transfers and Svalbard samples.[11]

Top 20 recipient countries	N. samples received	N. of source countries
India	341028	180
USA	47034	174
China	43382	151
Japan	22316	149
Australia	19963	142
England	18614	146
Ethiopia	17891	144
Morocco	16932	101
Pakistan	16420	138
Philippines	15611	105
Italy	14176	138
Iran, Republic of	13184	135
Tunisia	12666	68
Austria	12222	89
Colombia	12065	101
Syria	10912	90
Korea, Republic of	10000	137
Canada	9634	123
Russia	9579	90
Brazil	9198	136

Source: ***SINGER (2012)***

11 A total of over 94 000 seed samples were sent from the CGIAR gene banks to the Svalbard Global Seed Vault in Norway between 2008 and 2009. If included, Norway would jump to second place.

Table 3: Samples distributed by CGIAR gene banks ranked by country of source of germplasm, excluding intra-centre transfers and Svalbard samples.

Top 20 source countries	N. samples distributed	N. of recipient countries
India	244720	119
USA	45888	114
Iran, Republic of	40221	91
Ethiopia	39876	79
Turkey	31343	90
Sudan	29644	64
Syria	27022	82
Nigeria	21515	107
Philippines	21265	98
China	21202	104
Zimbabwe	17233	69
Indonesia	15265	87
Bangladesh	13467	84
Morocco	12679	72
Jordan	12579	66
Pakistan	12514	96
Brazil	12485	106
Mexico	12483	83
Tunisia	10853	57
Algeria	9867	73

Source: SINGER (2012)

The numbers indicate that a large number of countries have benefited from the germplasm sent from the top 20 source countries. India tops the list with close to 245 000 samples of materials originally obtained from India, and distributed by the CGIAR genebanks to 119 countries.

Figures 6 and 7 show the distribution of gene bank accessions between 1984 and 2010 in terms of their origin and destinations (developing or developed countries). Although developing countries are consistently stronger donors of material than developed countries, they are also the main recipients of CGIAR-hosted germplasm.

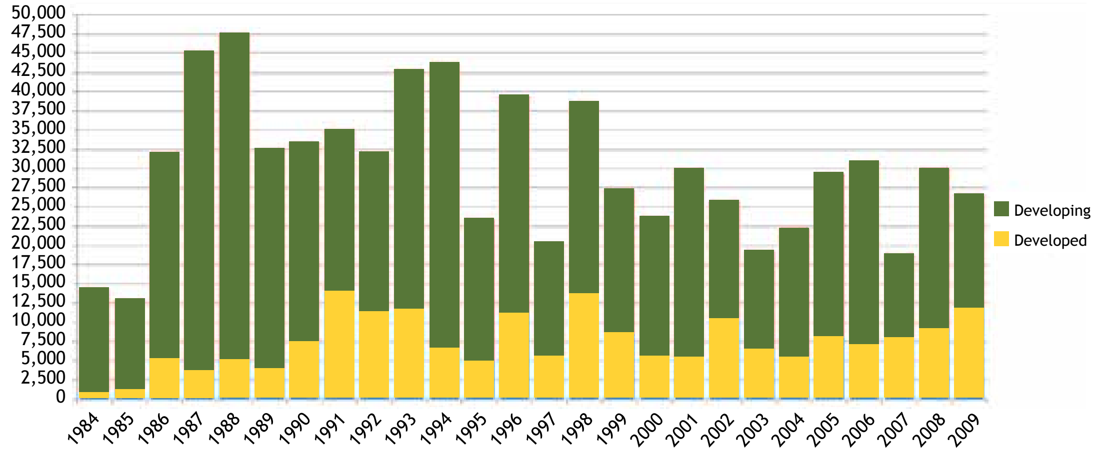

Figure 6: Total number of transfers of samples distributed from 1984 to 2009, by CGIAR gene banks, of materials originally sourced from developed or developing countries.[12]

Source: SINGER (2012)

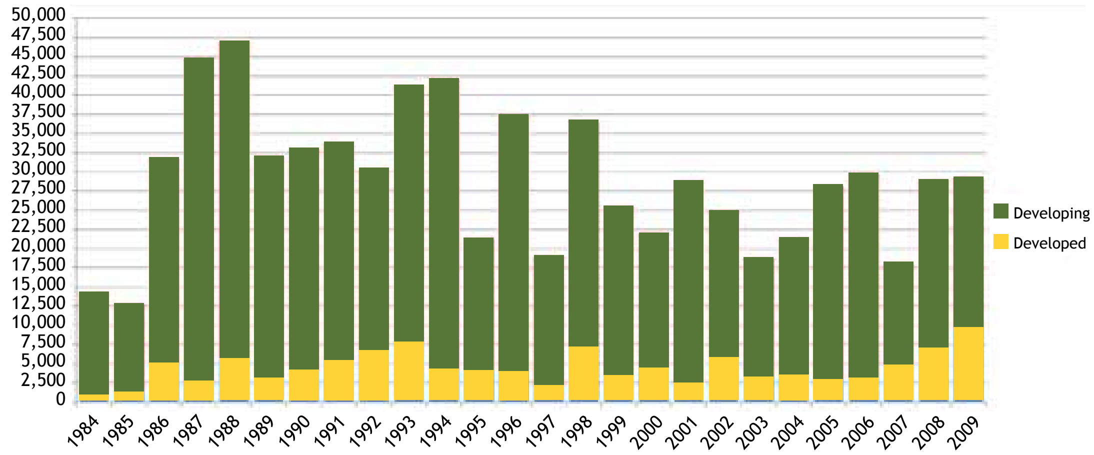

Figure 7: Number of samples distributed by CGIAR gene banks to developed and developing countries from 1984 to 2009 (excluding CGIAR transfers).[13]

Source: SINGER (2012)

12 Data exclude distributions within the CGIAR and transfers to Norway that were destined to the Svalbard Global Seed Vault and took place in 2008-09. Developed countries include countries in transition.

13 Data exclude distributions within the CGIAR and transfers to Norway that were destined to the Svalbard Global Seed Vault and took place in 2008-09. Developed countries include countries in transition.

Some CGIAR Centres are experimenting with new approaches to linking both the CGIAR and national gene banks to farmers, with the latter becoming the direct recipients and sometimes the evaluators of the germplasm.[14] This direct linking happens in the context of specific projects, such as the recently launched Sustainable Modernization of Traditional Agriculture (MasAgro) project in Mexico[15], which is led by CIMMYT (this project is discussed further later in this report), and the Seeds for Needs project, which was carried out in Ethiopia and Papua New Guinea by Bioversity International.[16] These projects represent novel and proactive ways to respond to climate change challenges. They are expected to generate important insights about creating a new kind of connection in the international agricultural research system that did not exist in the past (see Figure 1).

Until recently, most NAROs – particularly in developing countries – did not have the capacity or the mandate to share responsibilities at the international level for conserving and making germplasm available. As a result, the CGIAR gene banks tended to think they needed, on their own, to collect and conserve the diversity of their mandate crops. However, in recent years, many of the partners of the CGIAR Centres have strengthened their capacities to collect, characterize, evaluate and conserve germplasm. Some countries have initiated the building of new gene banks – for example, Mexico, Turkey, Nepal, and others, India, for example, have substantially increased the size of their collections. Furthermore, the ITPGRFA's multilateral system of access and benefit sharing provides a legal and administrative basis for countries to become much more active as international germplasm providers. The scene is set for more co-operative strategies in which the gene banks of the CGIAR Centres not only continue to play central roles but also share an increased proportion of the burden of global conservation with actors in national programs and possibly even the private sector. The CGIAR Science Council (2005) identified this possibility in 2005, observing that in the context of ex situ conservation the CGIAR should not act alone but, rather, act as one player in a rational, co-ordinated, forward-looking global system with clearly described areas of responsibility. The GCDT's proposal for the management of the CGIAR-held collections, which was approved in March 2012, reaffirms this possibility as a principle for the building of a global conservation system.[17]

Our interviews suggest that CGIAR gene banks appear to be at a crossroads right now. While the scene has been set to engage in an unprecedented level of global co-operation for the conservation and sustainable use of PGRFA, in practice the situation is largely static with many actors unwilling to assume more proactive roles. There is reluctance on the part of many potential providers to make germplasm available to the global community. While some countries have been collecting significant amounts of new germplasm, they are not reporting significant rates of providing germplasm beyond their own borders, including to the CGIAR Centres. The *Second Report on the State of the World's Plant Genetic Resources for Food and Agriculture* states that between 1996 and 2007, countries collected and stored in national *ex*

14 Traditional mechanisms used include, for example, CGIAR open houses, demonstration trials, and farmer field schools.
15 CIMMYT, MasAgro, <http://www.cimmyt.org/en/what-we-do/projects-by-region/modernizacion-sustentable-de-la-agricultura-tradicional>
16 Bioversity International, Seeds for Needs, <http://www.bioversityinternational.org/announcements/seeds_for_needs.html>
17 Consultative Group on International Agricultural Research, http://www.cgiar.org/our-research/cgiar-research-programs/long-term-support-of-cgiar-genebanks/

situ collections over 240 000 accessions of PGRFA (CGRFA 2011: 55). While some countries and organizations are willing to assume responsibility for activities such as internationally co-ordinated regeneration, characterization and multisite evaluations, they do not have the resources to take on these roles.

Characterization, evaluation and documentation of gene bank germplasm

The CGIAR gene banks do not sit passively on the diversity physically stored in their collections. In order for users to take advantage of this diversity, there is a need to further characterize and expand knowledge about it. In most CGIAR Centres, yearly field evaluation of batches of accessions for morphological and agronomic characteristics is routinely carried out, although some of the gene bank managers stressed, with concern, that there is generally a decreasing availability of funds to support these operations. This lack of funding is particularly worrisome in terms of the ability to test potentially useful germplasm and send it out expediently to areas affected by climate-related stresses or disasters.

In order to improve CGIAR gene bank knowledge management, the System-Wide Genetic Resources Programme (SGRP) of the CGIAR carried out a two-phase project called Global Public Goods (2003-10). This comprehensive program of work led to the upgrading of the CGIAR gene banks concerning the management of collections now and in the future. It also produced the Crop Gene Bank Knowledge Base, which is an open digital platform where users have access to useful information and best practices about gene bank management.[18]

Documentation and information systems have been developed to increase easy access to information on the materials available in the CGIAR gene banks and, in some cases, to their specific traits and features. SINGER is a CGIAR-wide initiative whose website allows users to search for information about the samples of crop, forage and tree germplasm and to order samples directly (figures and tables included in this report were developed by SINGER).[19] In recent years and as part of the work on information exchange conducted under the SGRP, the centres have collaborated with national and international organizations in the development of global information systems that facilitate the management and sharing of information about accessions conserved in gene banks, notably the Genetic Resources Information Network (GRIN-Global) and GENESYS.[20] The GRIN-Global project, which involved the GCDT and the US Department of Agriculture (USDA), aimed at creating a new version of the information management system used by GRIN of the USDA, which could be adapted to, and adopted by, gene banks around the world. It constitutes a keystone of an effective global network of gene banks that could make the exchange of germplasm more effective, including as it applies to the adaptation to climate change, than at present.

Supported by the GCDT and the Secretariat of the Treaty, GENESYS is a global portal with the potential to pool and provide access information about germplasm accessions from gene banks (and potentially other germplasm holders) around the world.[21] GENESYS has the

18 Crop Gene Bank Knowledge Base, <http://cropgenebank.sgrp.cgiar.org/>
19 System-Wide Information Network for Genetic Resources, <http://singer.cgiar.org/>
20 System-Wide Genetic Resources Programme, <http://www.sgrp.cgiar.org/>
21 GENESYS, <http://www.genesys-pgr.org>

capactity to facilitate the ordering of copies of accessions about which it has information, though not all data providers have opted for this functionality, preferring to 'take orders' for germplasm directly. GENESYS has data provided by the European Cooperative Programme for Plant Genetic Resources, SINGER and GRIN-USDA. According to the GENESYS website, in total, the portal stores data of 2.4 million gene bank accessions, 11 million records of characterization and evaluation, complemented by environmental data about collecting sites. Although now operational, GRIN-Global and GENESYS face technical challenges related to generating, storing and sharing germplasm data.

So-called core collections (representing 5-20 percent of the size of the original, for example, 10 percent at ICRISAT) and mini-core collections (at ICRISAT, for instance, approximately 10 percent of the core, Updhyaya et al. 2008) are developed by some CGIAR Centres to facilitate the use of diversity represented in a given collection by breeding programs.[22] As plant breeders are challenged to produce new varieties that can deal with the complex impact of climate change and other emerging constraints or desired traits (such as, for example, those traits related to improving nutritional values), there is a need to refresh core and working collections with genetic resources containing novel genes. The problem is to rationally and rapidly select a subset of germplasm from a genetic resource collection that contain millions of accessions. It is not economically or logistically feasible to screen widely for a specific suite of traits. Tools such as geographic information systems (GIS) are increasingly used to include environmental and climatic information when germplasm samples are collected in situ. This method allows individuals to assess whether selection pressures may have occurred for specific adaptive traits. Such analysis can then be used for selecting the best-bet subsets of germplasm from genetic resource collections to be screened for useful traits. This is the rationale behind what is known as a focused identification of germplasm strategy (FIGS), which is used by CIMMYT to identify bread-wheat landraces that are tolerant to abiotic stresses and that contain new genes for tolerances to both insect pests and diseases (Bari et al. 2011).

Molecular tools are being used increasingly for trait identification in germplasm collections and for the establishment of core and mini-core collections, in some cases as part of a broader strategy for climate change adaption. The Generation Challenge Programme (GCP) developed the Molecular Marker Toolkit, which is an easily accessible global public good that allows rapid access to validated marker sets for characterizing accessions of 19 food security crops.[23] In CIMMYT, the first component of the recently launched MasAgro project is called 'Seeds of Discovery,' which is aimed at characterizing all of the material stored in the gene bank, plus some wheat accessions from ICARDA and material voluntarily made available by other regional or national gene banks in Mexico. MasAgro uses an innovative approach of genotyping to improve the trait-mining exercise by allowing greater marker density and facilitating the discovery of gene-trait relations. An important focus of this exercise will be placed on traits of relevance for climate change adaptation in marginal and vulnerable areas.[24]

22 <http://www.icrisat.org/crop-pigeonpea-genebank-Mini-Core-Collection%20.htm>
23 Generation Challenge Programme, <http://www.generationcp.org/sp5/?da=09148937>
24 Grains Research and Development Corporation, <http://www.grdc.com.au/director/research/breeding?item_id=CAF4AFDFB6C2DF6C8A2167898EF8543F&pageNumber=2&filter1=&filter2=&filter3=&filter4=>

Effects of climate change on the work of the CGIAR gene banks

Some authors have pointed out that climate change has made the tasks of completing *ex situ* collections, securing their integrity and facilitating their use by making information available extremely urgent (Snook et al. 2011). Gene bank managers, however, have expressed skepticism about the sudden surge of interest in climate change. They have confirmed that many of the traits they have traditionally been interested in detecting, valuating and using are related to meeting climate-related stresses. However, they also agreed that some climate change-related changes, such as novel pest distribution patterns in some areas of the world, have pushed the demand particularly for material with tolerance to extreme environments. For example, gene bank personnel in the IRRI have noted a strong demand for cold tolerant rice (in growing areas such as Canada and Argentina) as well as for heat-tolerant (that is, early flowering) and flood-tolerant materials. They have also observed that climate change has accelerated the demand for more rapid and efficient tools for germplasm evaluation, allele mining and a focused identification of gaps in collections. These tools allow for a more efficient and effective detection of climate adaptation-related traits. They have acknowledged the importance of collecting more germplasm of crop wild relatives in order to search for both biotic and abiotic resistance genes. Along these lines, the GCDT has recently started a large project to assess the current gaps in the system and to find, collect, catalogue and store crop wild relatives of 23 crops of major importance to food security.[25]

2.2. CGIAR breeding programs

2.2.1. Origins and evolution

The origins of international crop breeding and the international agricultural research system date back to 1940 when the United States and Mexican governments requested the Rockefeller Foundation to support research on basic food crops. A special unit focusing on maize, wheat, beans and soil management was established in the Mexican Ministry of Agriculture (Byerlee and Dubin 2010). Following the Mexican example, in the 1950s, India and Pakistan established technical assistance programs funded by the Rockefeller Foundation and Ford Foundation respectively. Breeding lines were initially provided through informal exchange and contacts between scientists in different countries. Over the years, the exchange of knowledge and germplasm extended geographically and became more formalized. In 1960, the IRRI, supported by the Rockefeller Foundation, was opened in Los Baños, Philippines. The genetic improvement of rice in the IRRI followed the already formalized model of international collaborative trials and sharing of germplasm and information adopted by the wheat system in Mexico. The development of the first high-yielding semi-dwarf varieties of wheat by the Mexican program and of rice by the IRRI and the rapid expansion of both of these innovations through the international nursery networks stimulated the origin of the Green Revolution (Evenson and Gollin 2003a; Herdt and Capule 1983).

25 Global Crop Diversity Trust, <http://www.croptrust.org>

In 1966, the Mexican program was converted to CIMMYT, and, in 1967, two other centres were created, CIAT in Colombia and the IITA in Nigeria, which were largely supported by the Rockefeller and Ford Foundations. These centres not only had broad mandates for agricultural research for development but also had core international breeding programs in crops such as cassava, rice, forages, cowpeas, soya beans and maize (Byerlee and Dubin 2010; Evenson and Gollin 1997). In the course of the following decade, CIP, the International Board for Plant Genetic Resources (which is now Bioversity International), ICARDA, ICRISAT, the International Food Policy Research Institute, the International Livestock Centre for Africa, the International Laboratory for Research on Animal Diseases (which later merged to become the International Livestock Research Institute (ILRI)) and the West Africa Rice Development Association (WARDA) (which is now AfricaRice) were founded and integrated into the CGIAR. The CGIAR expanded its mandate from breeding improved cultivars of dominant staple grains to supporting small-hold farming systems in developing countries through improved management of soil, water and genetic resources.

The contribution of international agricultural research – particularly, the CGIAR Centres efforts to improve crops through yield and productivity increases – has been well documented in a number of studies (Byerlee and Dubin 2010; Evenson and Gollin 2003b).[26] The diffusion of modern varieties that farmers in developing countries are growing nowadays to cope with biotic and abiotic stresses has depended to a large degree on the germplasm coming out of the CGIAR Centres. Countries all over the world have been strongly dependent on receiving germplasm for the development of commercial varieties (Byerlee and Traxler 1995). This dependency has been demonstrated for specific crops, see, for example, a study on beans in Latin America (Johnson, Pachico and Voysest 2003), and by various country case studies, including, for example, Mexico (Bellon et al. 2005), Turkey (Mazid et al. 2009), Ethiopia (Beyene, Verkuijl and Mwangi 1998), west and central Africa (Manyong et al. 2000), Zimbabwe (Alumira and Rusike 2005), India (Janaiah, Hossain and Tsuka 2006), Nepal (Ransom 2003) and South Asia (Gauchan et al. 2011). Figure 8 shows the global distribution of all CGIAR breeding materials for 2009. Top receivers, with over 5 000 samples, are India, Argentina and Mexico.

The initial emphasis of the CGIAR Centres was on the development of improved populations and open-pollinated varieties (Bantilan et al. 2004). Three trends led CIMMYT, IRRI and ICRISAT to gradually reorient their genetic improvement programs in various crops to better align with the cultivar priority of the public and private sector seed industry: (1) hybrids of rice, maize, sorghum and pearl millet that had considerable yield advantage over open-pollinated varieties under favourable conditions; (2) increased demand by farmers for hybrids and (3) the rapid development of a hybrid seed industry in many countries, particularly in Asia (Gonzalez et al. 2011; Gowda and Reddy 2004).

IRRI was a pioneer in hybrid research starting in 1979. Since then, with partners in the public and private sectors, IRRI has led research, development and use of hybrid rice in the tropics. Today, around 90 percent of maize-breeding activities in CIMMYT are based on hybrids, which are used in parts of Latin America, Africa and Asia. In India, 100 percent of ICRISAT's breeding work on pearl millet, 70 percent on pigeon peas and approximately 50 percent on

26 See also the case studies at, <http://impact.cgiar.org/genetic-improvement>

sorghum is focused on the development of parental lines for hybrids that are mainly used by the private seed industry in India (Gowda et al. 2006). In the last decade in India, ICRISAT restricted its role to the development of parental lines to be used by members of a hybrid crop consortia that develops hybrids (Reddy et al. 2007). The development, testing and release of hybrids has been delegated to the public and private sector programs. The next challenge, according to ICRISAT's hybrid breeders, is to extend hybrids of sorghum and pearl millet to Africa where there is no program on hybrids at the moment. African NAROs and ICRISAT breeders have proposed a 'lead NAROs' approach of regionalized breeding as a strategy for increasing the efficiency of research and development activities and the sharing of regional responsibilities. The selection of a few potentially useful and representative benchmark test sites would permit regionalized variety testing and release procedures (Mgonja et al. 2005).

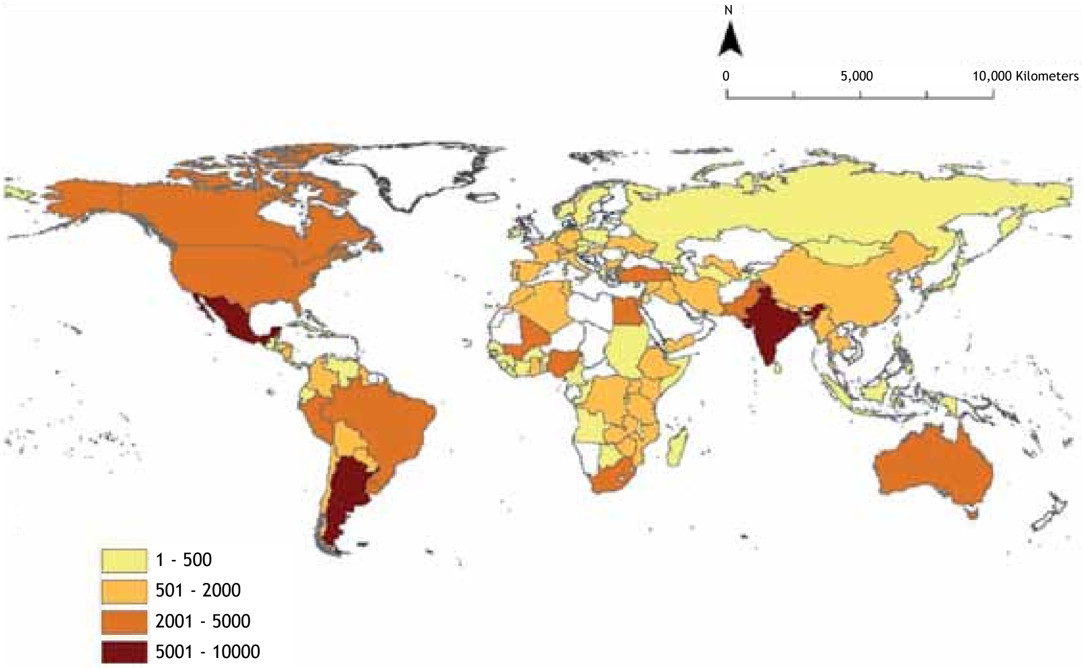

***Figure 8: Countries classified based on the number of transfers of material from CGIAR breeding programs in 2009.*[27]**

Source: CGIAR database

Over the years, breeders, at their own centres and through the CGIAR-wide programs, have increasingly made use of advanced technology, particularly new molecular biology techniques, to do their work. For example, the GCP combined genomics with molecular biology tools to develop improved crop varieties with a focus on abiotic stress tolerance, particularly drought tolerance.[28] The HarvestPlus Challenge Programme is aimed at breeding staple foods bio-fortified in micronutrients, such as Vitamin A, zinc and iron.[29] In recent

27 Data exclude exchanges among CGIAR breeding programs.
28 Generation Challenge Programme, <http://www.generationcp.org/>
29 Harvestplus, <http://www.harvestplus.org/>

years, the CGIAR Centres have become increasingly engaged in research on transgenic techniques for genetic improvement. According to a report prepared by the CGIAR's SGRP in 2008, centres are engaged in the development of transgenic varieties of banana and plantain, bean, cassava, chickpeas, cowpeas, groundnuts, maize, potato, pigeon peas, rice, sorghum, sweet potatoes and wheat (SGRP 2008). Some of the genetically modified organism-oriented projects – for example, on rice and maize in Africa – are related to climate change.

2.2.2. Operational strategies

The research programs of the CGIAR Centres currently combine classic and contemporary breeding methods. They also deploy both traditional and new types of partnerships. Depending on the crop, target region or country, the combination of breeding methods and partnerships represent different research and development approaches. There are a variety of policies that impact on the implementation processes. We present the most salient operational strategies found across these crop-focused centres.

International evaluation and improvement networks

For wheat in CIMMYT and rice in IRRI, much of the exchange and testing of germplasm and information has taken place through long-standing networks of international nurseries (the nursery model has been used since 1970). The International Wheat Improvement Network connects breeders within CIMMYT's wheat program and a global network of wheat research co-operators, who evaluate wheat, triticale and barley-breeding lines in nurseries located in different and specific agro-ecological environments. Data from the evaluation trials are returned to CIMMYT, catalogued, analyzed and made available to the global wheat improvement community.[30] The International Network for the Genetic Evaluation of Rice, which was established in 1975 and hosted by IRRI, is a system of specialized rice nurseries that provides a vehicle for exchanging as well as evaluating advanced rice germplasm.
The role of the international nurseries has remained the same over the years: '[T]o provide participants with basic information about adaptability of varieties, yield potential, disease and pest resistance; parental materials for accelerating their breeding programs; indications of which varieties might serve as immediate introductions into potentially high production areas; and a means of evaluating promising breeding materials on a worldwide basis and fostering international cooperation' (Byerlee and Dubin 2009, citing CIMMYT's annual report, 1970). However, the scope and coverage of the nurseries have grown and become more complex and sophisticated over the decades. A broad range of materials, from segregating to advanced lines, are being provided to different sites according to specific requests and the needs of the local breeding programs. According to the interviewees, sites now include areas with less potential. The role of such networks in the development of new wheat and rice varieties and the economic and social impact of such varieties have been significant (Byerlee and Traxler 1995; Reynolds and Borlaug 2006).

30 International Maize and Wheat Improvement Center, <http://apps.cimmyt.org/english/wps/obtain_seed/iwin/index.htm>

Other centres have also adopted and supported the model of a nurseries network for other crops. For example, the Bean Regional Nursery for Low Fertility Adaptation identifies and evaluates promising germplasm from a number of African countries under the CIAT-supported program Bean Improvement for Low Fertility Soils in Africa (Wortmann et al. 1986). During the 1990s and 2000s, the evaluation of cassava-improved germplasm developed by the IITA took place through international collaborative trials where advanced material was tested in a number of countries and environments and the resulting data were shared with all partners. Due to financial limitations, current cassava-breeding work in IITA is based on bilateral collaboration rather than on the multilateral model of the international nurseries, which is more costly. ICRISAT has also stopped maintaining nurseries, partly due to high costs. CIP, on the other hand, has the intention of establishing a network of evaluation sites as a strategic priority for the next few years. Preliminary test sites have already been identified.

Decentralized breeding in collaboration with NAROs

The centres send elite materials to national collaborators, often in the context of collaborative germplasm improvement projects that deal with particular production challenges. The centres' improved material is then incorporated into locally adapted materials by national partners, leading ultimately, if all goes well, to newly released varieties. Alternatively, the centres can send well-advanced materials to national programs, which select the most useful materials from the populations provided. CIP, ICARDA, IITA, CIMMYT (maize-breeding programs) and ICRISAT (cooperation with public organizations in both Asia and Africa on non-hybrid breeding) make use of this decentralized breeding approach. Usually, this kind of research is organized and undertaken through major regional hubs where the centres have offices. For example, in the case of CIMMYT, the four large regions are Meso-America, South America, Asia (India, Nepal and China) and Africa (Kenya, Zimbabwe and Ethiopia). IITA research priorities are defined concerning three sub-regions: east Africa, west Africa and southern Africa. NAROs are the main partners in these efforts, although the CGIAR Centres also work with NGOs, universities and private institutions. In recent years, many of these efforts have had an explicit climate change adaptation component, through which the development, testing and dissemination of adapted varieties and lines has been justified.

In this model, contrary to what usually happens in the international nursery model, germplasm transfer is often accompanied by a technology package as well as by capacity-building activities depending on the needs and capacities of partners. While assistance to some countries is limited to a number of precise activities, other countries require a more comprehensive package. While some partners can cross, test and select adapted germplasm from parental lines and segregating materials provided by the CGIAR Centres, others require nearly finished material.

The capacity of national partners to release finished varieties from CGIAR-improved germplasm and to distribute quality seed from such varieties varies from country to country (Grisley and Shamambo 1993). In a large number of countries, particularly in Africa, the seed sector is weak (Cromwell 1990). Public agencies do not have the capacity to provide good quality seed in a timely manner, and private seed companies, especially larger ones, will not operate in areas where there appears to be no market for improved seed, which are often those areas that are most affected by climate change-related impacts. Furthermore, the private sector sees advantages in investing in the multiplication and dissemination of hybrids (which need to be purchased every year by users in order to maintain their unique characteristics) and species with a relatively large and well-structured demand. This preference leads to the neglect of those crops planted mostly by marginal farmers with little access to cash or of those species that are not supported by national subsidy schemes. This is the case for legumes, which require large amounts of seed per hectare and are more difficult to store as well as for many other local, 'minor' species (Tripp 2011).

Hybrid research consortia

In the hybrid consortia model, companies use elite hybrid parents from the CGIAR Centres to develop hybrids, register them and multiply, certify and sell seed. The companies assume responsibility for crossing the parents and for registering and marketing the varieties. The centres take advantage of the companies' capacity to maintain and cross the parental lines and multiply and distribute hybrid seed. The CGIAR Centres draw on their strengths as upstream breeders with access and capacity to identify and introduce useful traits from the genetic diversity of the crops concerned. The role of centres in promoting and supporting the up-take of varieties developed by consortia members is limited. This distribution of responsibility between the two partners – upstream development of partental lines by CGIAR breeders and downstream crossing, maintenance and marketing by private companies – is possible as a result of the high technical capacity of the companies involved and the supportive policy environments in which they operate. For example, in India, variety registration and seed quality regulations have *sui generis* procedures (which are less bureaucratic and time consuming) for the private sector. The companies, which generally have more resources than public sector actors to test and register varieties quickly, are further supported by this exceptional treatment in the national seed registration and seed laws to get the technologies tested, approved and made available to the market more quickly and more cheaply.

At present, CIMMYT, ICRISAT and IRRI are engaged in hybrid technology development in maize, pearl millet, sorghum, pigeon peas and rice. At ICRISAT and IRRI, the delivery of improved hybrid lines takes place through the consortia, mostly to private sector companies including those from developed countries. ICRISAT shares its parental lines through the Sorghum, Pearl Millet, and Pigeonpea Hybrid Parents Research Consortia, which was established in 2000 and 2004 and is predominantly active in India. Members of the consortia pay an annual fee in order to receive information and to get access to, and the use of, ICRISAT's improved lines. ICRISAT's parental lines remain in the public domain and are available to public sector institutions for free at all stages of development (Mula et al. 2007). However, NAROs generally do not ask for ICRISAT materials because they do not have the capacity to maintain and cross the parental lines, and to multiply and supply hybrid seed to users. An advisory committee (comprising members from private seed companies and ICRISAT) provides guidance and advice for the consortium's research and development activities. The Hybrid Rice Development Consortium, which was established by IRRI in 2008, uses a similar approach but with an international scope. In 2010, CIMMYT made a proposal to create a Hybrid Maize Research Consortium, based on the same principles, for research and development of hybrid maize with private companies in Asia.

Apart from the above described major models, the CGIAR Centres transfer improved germplasm in response to individual requests, which are not necessarily part of a standing partnership or associated with a particular project. Information about materials that are available upon request is shared through annual, online catalogues and through e-mail lists. Some programs, such as those on lentils and grasspeas at ICARDA and those on chickpeas at ICRISAT, regularly organize open-door sessions where scientists from all over the region are invited to come to the CGIAR Centre and select what they prefer.

According to some interviewees, in the context of adaptation to climate change, the limited dissemination of a wider portfolio of crops and crop species, particularly those that tend to be hardier and more resilient to climate extremes, is worrying. Centres involved in breeding these crops and/or varieties are developing closer interactions with NAROs, development agencies and (organized) farmers to address this problem. In a number of cases, this strategy has translated into the development of alternative variety release, dissemination and quality assurance schemes that involve small-scale seed producer groups and the use of informal channels of multiplication and exchange. A few examples from various CGIAR Centres are provided in the following discussion.

ICRISAT has dedicated substantial efforts to develop more sustainable seed multiplication and supply systems for staple crops, including ‘minor’ dryland species of relevance for climate change adaptation (Bantilan et al. 2004). This centre contributes to strengthening farmer and community seed systems and building alternative emergency and relief seed delivery mechanisms, especially in cases where public channels have failed to deliver ICRISAT’s improved material to farmers. In India, ICRISAT and its partners have developed a method for self-sufficient reproduction of good quality and true-to-type seed by farmers (known as PDKV, the initials of the name of the researchers who developed it, Drs. Panjabrao, Deshmukh, Krishi and Vidyapeeth) (Deshmukh et al. 2001).

In Asia and Africa, ICRISAT has distributed mini-kits to farmers in areas that are not served by either formal public or private seed distribution and sale channels. These kits contain high quality seeds and an information sheet (Stevenson 2005). In Africa, farmers receive a mix of cowpeas, sorghum, beans, pigeon peas, millet and maize, which is adapted to local conditions and low-input conditions. In Rwanda, CIAT and its partners have observed that different bean seed procurement mechanisms (farm-saved, local seed purchase and/or seed or labour exchange) that are used by farmers operate reasonably well. They have therefore focused their efforts on fostering linkages between seed producers, local seed markets and local research stations, supporting community-based seed multiplication, providing training, and involving farmers in participatory plant breeding and variety selection (CIAT 2004).

CIP is involved in seed systems in the Andes. It was one of the early centres to conceptualize its own strategy in this field. Depending on the context and local needs, CIP specialists opt for strengthening formal, informal or mixed seed systems (Andrade Piedra et al. 2009). They have considerable experience in working with producer groups or NGOs in seed multiplication, and the seed is certified through alternative schemes such as quality declared seed, which was developed by the FAO. Within the recently launched Sweet Potato Action for Security and Health in Africa, known more commonly as the ‘Mama SASHA’ program, in western Kenya, CIP distributes vouchers to women’s groups that can be redeemed for two hundred cuttings of orange fleshed sweet potato vines for planting.[31] The vines are from improved varieties bred for local conditions that contain high levels of beta-carotene. The cuttings are obtained from well-trained vine multipliers, located near health clinics, in an innovative collaboration between the agriculture and health sectors.

ICARDA is unique among the CGIAR Centres in having, since 1985, an entire Seed Unit dedicated to support seed production and dissemination activities by national partners. The unit assists in the development of national seed programs in the region by providing training and technical advice, while also supporting breeding activities based at ICARDA's headquarters. One of the Seed Unit's traditional avenues of research revolves around the informal seed sector, given its importance for many of ICARDA's mandate crops and regions of work (Aw-Hassan, Mazid and Salahieh 2008). In this area, specialists help in designing alternative seed delivery systems for farmers in marginal areas in order for them to benefit from the products of plant breeding while also conserving and improving well-adapted local material (Mazid, Aw-Hassan and Salahieh 2007). This work is carried out in collaboration with the NARS and other partners such as NGOs and semi-private seed companies. The Seed Unit has been involved in direct distribution of improved germplasm to farmers on exceptional occasions, particularly in emergencies such as an outbreak of Ug99 in Ethiopia (Osborn and Bishaw 2009). ICARDA has also been engaged in the distribution of small seed packages of not yet registered lines to accelerate and facilitate diffusion to selected farmers, with the idea that they will subsequently distribute the seed resulting from the first harvest. It is assumed to be an effective way of getting material out rapidly and, depending on the strength of the existing social networks, more or less effectively and for a long period of time. In-depth assessment studies have not yet been done, however.

IITA has used direct distribution to farmers to address supply shortages in emergency situations (famines, droughts and wars). In addition to this short-term kind of intervention, IITA provides small amounts of seed to farmers interested in participating in field trials. Although this activity is not systematic (it would infringe on national variety release regulations), surveys have indicated that it has been a powerful entry point for further dissemination and adoption of IITA materials among farmers (Utoh and Ajeigbe 2009). IITA is currently involved in two projects that play a large role in the seed systems for some of IITA's mandate crops. The first project involves yam improvement for income and food security in West Africa and the second involves putting nitrogen fixation to work with small-holder farmers in Africa. One of the projects aims is to reinforce the role of farmers as seed producers. Given that most of the seed production and exchange for yam and other IITA's mandate crops is through informal means, understanding the dynamics of farmers' strategies will be key for the effectiveness of such projects.

Informal seed system research is gaining ground on IRRI's research agenda. This may be due to the evidence of the spontaneous dissemination of IRRI material through informal channels: variety TDK-Sub 1, for instance, has not (yet) been released, but it is being used widely by many projects in Lao People's Democratic Republic (PDR). In Nepal, a solution is to classify new varieties as 'truthful' to allow diffusion and adoption, albeit without formal release. In

31 Sweet Potato, Sweet Success,< http://consortium.cgiar.org/sweet-potato-sweet-succes/>

regions of India (Orissa state), discussions are underway to produce seeds of new varieties with the idea that royalties should go to poor farmers. In Myanmar and Lao PDR, IRRI is working to support private/public seed enterprises whose royalties would go to the NARO.

2.2.3. Shifts in technology generation and dissemination strategies

Different factors have influenced the way the CGIAR breeding programs have evolved in the last decade and how they have affected the access to, and use of, their germplasm by partners and farmers. In this sub-section, we present these factors and the transformations they have caused in the research and development strategies of the CGIAR Centres. We highlight that changes are still ongoing and that many of the questions they have given rise to are still unanswered. Policy issues that have arisen or have become more relevant as a consequence of these shifts will be analyzed further in Chapters 3 and 4.

Breeding for climate change adaptation

Climate change has influenced the operations of the CGIAR breeding programs only partially and mostly on a project-by-project basis. Table 4 summarizes how at present the CGIAR Centres carry out breeding activities in relation to climate change (adaptation). Note that a * indicates that a centre has made explicit mention of the importance of this particular breeding work in view of climate change in its annual reports or on its website.

The table suggests that at present breeding strategies for certain crops are targeting climate change adaptation while, for others, adaptation to climate change adaptation is not the main purpose. Early flowering and seed setting has become a priority in many breeding programs as a way of adapting to increased temperatures. Resistance to drought, salinity, flooding and extreme heat and cold are some of the priorities of current rice-breeding efforts.[32] In drought areas, heat and salinity tolerance have become more prominent in the breeding work on maize, wheat, barley, rice, chickpeas, lentils and cowpeas. The capacity of plants to resist water logging is one of the priorities of breeding in rice, forages, wheat in Asia, and certain legumes. In cassava, improving root durability has become a key characteristic, as unpredictable planting seasons require roots to last longer in storage. Changes in the geographical scope of pests and diseases due to variations in temperature and humidity have required breeders to address biotic threats outside the original crop production environments (Pautasso et al. 2012; Savary et al. 2011). To help breeders in this task, IRRI has recently hired a specialist to predict the occurrence of future pests and diseases in rice according to different climate change scenarios.

With regard to genetic improvement, the CGIAR Centres have always been engaged in breeding to meet challenges associated with difficult climates for most of the crops. However, the need to address biotic and abiotic stresses exacerbated by changes in temperatures and rainfall patterns has meant that particular traits on which CGIAR breeding work has

32 According to a survey conducted among SINGER users in 2007, the greater demand is for materials resistant to drought, heat, and submergence.

Table 4: Publicly reported CGIAR Centres' breeding priorities, 2011

	Banana	Barley	Bean		Cassava		Chickpea		Cowpea	Dry bean	Durum wheat	Faba beans	Graspea	Groundnut	Lentils	Maize	Mung bean	Pearl millet	Piegeonpea	Potato	Rice			Sorghum	Soybean		Sweet potato	Wheat	
Explicit climate change reference	No	No	Yes		Yes		Yes		No	No	Yes	No	No	No	Yes	Yes	Yes	Yes	No	No	Yes			No	No		No	Yes	Yes
Drought tolerance		ICARDA	CIAT*		CIAT*		ICARDA*	ICRISAT*	IITA	CIAT	ICARDA*			ICRISAT	ICARDA	CIMMYT*		ICRISAT		CIP*	A.Rice	CIAT	IRRI *	ICRISAT			CIP	CIMMYT	ICARDA*
Heat tolerance		ICARDA	CIAT				ICARDA	ICRISAT			ICARDA		ICARDA		ICARDA*			ICRISAT*		CIP*			IRRI *				CIP	CIMMYT	ICARDA*
Water-logging/ flooding tolerance							ICRISAT												ICRISAT				IRRI *					CIMMYT	
Cold tolerance							ICARDA*				ICARDA				ICARDA*					CIP	A.Rice	CIAT	IRRI *				CIP		
Adaptation to variable weather patterns																	ICARDA*												ICARDA*
Pest and disease resistance		ICARDA	CIAT	ICRISAT	CIAT	IITA	ICARDA*	ICRISAT*	IITA	CIAT	ICARDA*	ICARDA	ICARDA	ICRISAT	ICARDA*	CIMMYT*		ICRISAT	ICRISAT	CIP*	A.Rice	CIAT	IRRI	ICRISAT	CIAT	IITA	CIP	CIMMYT*	ICARDA*
Nutritional content/food safety of produce		ICARDA	CIAT*		CIAT	IITA	ICARDA						ICARDA		ICARDA	CIMMYT							IRRI				CIP	CIMMYT*	
Tolerance of poor soils			CIAT				ICARDA*					ICARDA			ICARDA*	CIMMYT*		ICRISAT	CIAT	CIP*	A.Rice		IRRI *	ICRISAT	CIAT		CIP	CIMMYT*	
Delayed post-harvest deterioration					CIAT*																								

Sources: CGIAR Centres websites and annual reports, 2008-10; annual reports of the Generation Challenge Programme and HarvestPlus Programme and interviews with CGIAR breeders in 2011.

traditionally focused have become more important in the last few years. The CGIAR priorities for 2005-15 state that greater investment in tolerance to abiotic stresses should be pursued as a global research issue affecting the stability of the farming systems of the poor, with a high likelihood of success from long-term investment. Such research should build upon the advances in eco-physiology, plant genomics and phenol-typing techniques and take the interrelations between traits related to abiotic stress tolerance into careful consideration (CGIAR Science Council 2005).

A recent study systematizes the genetic options for improving the productivity of different crops in face of climate change (Yadav et al. 2011). The need for genetic improvement for adaptation to climate change seems to be present in all crops, but, as experts confirm, it varies among crops and between species. Across crops, genetic improvement ranges from little adjustment for cassava, which has more plasticity given that it is a perennial crop, to major adjustment for rice, cowpeas, maize and sorghum in semi-arid subtropical regions that are heat and drought prone (Redden et al. 2011).

Greater efforts to exploit specific traits require regular access to, and use of, a broad array of germplasm. For example, the development of hybrid millet varieties that can flower at very high temperatures (42 degrees Celsius) by ICRISAT's millet breeding program has been possible thanks to the use of germplasm from India and Africa with a very broad genetic base. With these hybrids, it is now possible to harvest millet even when temperature rises above 40 degrees Celsius, which is not possible with maize and other cereals. Such advances have allowed the introduction of pearl millet into parts of southern India where it is not traditionally grown.

Unpredictable variation in climate patterns demands more rapid selection and development of material that has adaptive capacity. Molecular tools are used increasingly to be able to quickly identify useful traits in light of climate variations. Although some 'breakthroughs' have been made (for example, IRRI's SUB1A or 'scuba rice' gene) (IRRI 2010), the potential of molecular techniques remains latent to a large degree. Advanced technologies for material characterization and pre-breeding work are normally owned by large research institutes and private industry in the developed world. Getting access to such technologies under affordable conditions requires the CGIAR Centres to enter into agreements with industry owners. The GCP is seen by many as a good example of how national and international public organizations can join efforts to obtain access to pre-breeding technologies under advantageous conditions.

While economics and anthropology have long found a home in the CGIAR, the geographic sciences started in the late 1990s to be increasingly integrated at the centres (Bebbington and Carney 1990). This newer interest reflects the growing concern of the CGIAR Centres about sustainable agriculture and agro-ecological mapping as tools for better tailoring breeding efforts to local and changing environmental and climate conditions. In the 1980s, CIMMYT's wheat breeders began to reorganize their vision of the world's wheat-growing areas into a standard set of 'mega-environments.' The mega-environments were defined by crop production factors (temperature, rainfall, sunlight, latitude, elevation, soil characteristics and diseases), consumer preferences and wheat growth habit. CIMMYT wheat breeders have planned crosses between varieties focusing on key characteristics for each mega-environment. With the advent of GIS, researchers have increasingly been able to visualize these mega-environments in greater detail, delineating quantitative criteria for climatic and soil conditions, visualizing the extent of trends in climate change and ultimately helping breeders develop varieties with the precise traits that farmers and consumers want. Other projects across the CGIAR Centres have integrated GIS experts. Since the 1990s, CIAT's land-use lab (which is now converted to the Decision and Policy Analysis Programme) has been active in combining agro-ecological and characterization data for the centre's mandate crops in defining the ecology and dissemination of pests and diseases under changing climates. The CCAFS program aims to build on these efforts that integrate environmental sciences, geography and GIS modelling with the crop improvement research areas of the centres.

In regard to the availability of funds for climate change-oriented breeding, the attention of donor agencies has been focused on projects that have a strong component in climate change adaptation over the last few years. Many traditional donors of the CGIAR have identified climate change adaptation as a funding priority. Some of them, such as the International Fund for Agricultural Development and the Deutsche Gesellschaft für Internationale Zusammenarbeit, have recently developed a climate change strategy to guide their work.[33] Others, such as the International Development Research Centre, have created programs specialized in climate change (that is, the Climate Change Adaptation in Africa and Climate Change Water Programme).[34] However, it is not clear whether increased attention to climate change issues translates to more funds for the CGIAR or if both donors and the CGIAR Centres are now increasingly labelling as 'climate change' activities actions they have traditionally funded and implemented under a different banner. Some of the interviewees pointed out that some donors such as the Asian Development Bank and the World Bank are channelling more funds to national programs for climate change-related activities, while the CGIAR Centres are having more difficulty obtaining funding. A more detailed analysis of donor funding trends over the last 5 years would be required to determine if and how changes are taking place.

Changes in dissemination practices

Traditionally, the CGIAR Centres have not been called on to take care of the dissemination of improved germplasm to so-called 'end-users.' Their work was supposed to end with the delivery of improved lines to national (usually public sector) partners, who would then cross theme with locally adapted materials, or select best suited lines, and release, multiply and distribute them. In most of the research and development projects carried out by centres, the operational strategies have responded to the classic linear model of technology generation and transfer. In this model, the CGIAR Centres, in collaboration with national research institutions, are the sole source of technology. The centres, as technology originators, have historically depended on the intermediaries for the distribution of new technologies (Sechrest, Stewart and Stickle 1998). The criticism has been made that the experiences, knowledge, interests and resources of germplasm end-users (men and women farmers) are often overlooked in this classic model because they are seen as passive users of technologies (Biggs 1990).

33 International Fund for Agricultural Development, <http://www.ifad.org/climate/strategy/e.pdf>
34 International Development Research Centre, <http://www.idrc.ca/EN/Programs/Agriculture_and_the_Environment/Pages/default.aspx>

A vast number of studies on adoption and *ex post* impact assessments have been conducted. Many of them report relatively high levels of uptake of modern varieties developed with CGIAR germplasm. However, these results need to be interpreted with caution. Some of the studies are biased by the fact that they only cover areas of a country where a particular crop is most important or areas that have profited from substantial technology promotion, often through the project(s) that is sponsoring the study, which can easily lead to an over-estimation. Another shortcoming is that the nature of 'adoption' is rarely specified, making it unclear what proportions of the farmers' fields are planted with the new variety (Tripp 2011). By contrast, a number of studies report low adoption rates of CGIAR material, particularly in Africa, as compared to Asia (Gollin, Morris and Byerlee 2005; Smale et al. 1996). Some breeders have recognized that it would be difficult to find many varieties developed from CGIAR-improved germplasm in farmers' fields, especially for some crops and in certain countries. In these cases, the traditional operational strategies of the CGIAR Centres and their partners have experienced serious shortcomings in delivering improved varieties to farmers.

The top-down and linear approach described earlier has undergone some changes in the last decade due to a number of reasons. First, the general understanding in the scientific community of the processes of technology development and diffusion has evolved (Doss 2006). This understanding has led to different practices and approaches being introduced, piloted and refined by innovating scientists within the centres. Currently, technology diffusion is seen by many as a (more) complex and dynamic process that is determined by many factors and actors and that is feasible through different pathways and uptake channels. In this alternative approach, technology generation and technology dissemination cannot be completely separated – the way technology is developed will very much influence its dissemination and adoption. In addition, the institutional contexts in which research takes place will determine which actors will be involved or exposed to the new technology in the diffusion phase (Chilver 1996).

Second, the CGIAR Centres have progressively internalized the need to document and analyze the impact (planned, unplanned and undesired) of their work, partially as a result of donor pressure to demonstrate clear development outcomes of CGIAR research activities. Donors are demanding increasingly that farmers are provided with tangible, measurable development results, including an increased capacity to adapt production systems to climate change. The newly adopted CGIAR Strategic Results Framework with its commitment to 'managing for results' underscores the commitment of the centres to reform their work along these lines.

The urgency brought about by climate change has partly contributed to an increased attention to dissemination and adoption within the CGIAR. The rapid and efficient transfer of potentially adapted material to vulnerable areas is increasingly recognized as an essential element of research and development under climate change.

The rich literature on adoption and impact studies have analyzed the variety of factors that affect the adoption of crops and varieties, usually in a combination of two or more (Kormawa 2010). Authors have studied in-depth factors such as: suitability of the variety and the whole technology package (Kaguongo et al. 2012); farmers' perceptions of varietal attributes (Joshi and Pandey 2006; Sall, Norman and Featherstone 2000; Sperling and Loevinsohn 1993); socio-economic constraints (Baltazar et al. 2005; Kaguongo et al. 2012; Tambo and Abdoulaye 2012); social learning (Munshi 2004); proximity (Langyintuo and Mulugetta 2008); social networks and collective action (Song 1999; Thijssen et al. 2008) and institutional frameworks and policy and macro-economic measures (Kijima, Otsuka and Sserunkuuma 2011; Kosarek, Garcia and Morris 2001; Smale et al. 1996). Some authors have proposed measures and means that would help improve the dissemination of new varieties and their impact on agricultural productivity and poverty reduction. Interviews suggest that insights from these studies are increasingly used by the CGIAR Centres and have been translated into efforts to define and integrate, from the very beginning, a product delivery strategy as part of the research agenda (HarvestPlus 2009). Examples are CIMMYT's MasAgro project, which was discussed earlier, and the IRRI's Stress-Tolerant Rice for Africa and South Asia project (STRASA). Nevertheless, there are no systematic CGIAR-wide mechanisms for collecting and analysing feedback from partners or users about the level of adoption and satisfaction with CGIAR materials and about the technology development process itself. Interviews indicate that climate change has not brought about any systematic change.

The adoption of a much more active role at the dissemination stage has raised a number of questions and taken many CGIAR breeders out their traditional comfort zone. How far should the CGIAR Centres become involved in promoting and supporting the adoption of improved varieties? Does this responsibility rely on the centres as much as on the national partners? Many breeders are not completely comfortable with the CGIAR getting more and more engaged in development activities. Not only because this effort limits their time for pure research activities (particularly in those centres where financial resources are not sufficient to increase staff) but also because release and dissemination have traditionally been considered the responsibilities of NAROs. Thus, as the interviewees argued, the legitimacy of the CGIAR Centres to intervene in this area could be questioned. In some cases where the centres have become very much involved in these tasks, they have found themselves in competition (or perceived to be in competition) with national institutions, and, in general, it is not clear if this is the most efficient way of distributing responsibilities between international and national actors. Many breeders stress the need for the CGIAR to maintain a low profile and adopt a facilitating development role instead of an executing one.

An important issue that underlies the uncertain role of the CGIAR Centres' breeders in this regard, concerns the changes that are occurring in national agricultural research systems and related national agricultural development and research policies. In some countries, the public sector has further reduced its already weak presence in downstream activities. Reasons for such weakness include a lack of human and financial resources, low policy priority and poor infrastructure. In other countries, the public sector has concentrated its efforts on fewer crops, has shifted its priorities and resources to other activities (for example, biotechnology) or has begun to privatize certain services, for instance, seed production and marketing and agricultural extension. In some countries, however, there has been an increase in the public sector's interest and efforts in relation, for example, to the dissemination of improved varieties and seed production. As some of the interviewees mentioned, in some cases this interest has included requests and resources made available to the CGIAR Centres – for instance, ICRISAT and IRRI – to co-operate with NAROs on these efforts. In some countries where there is an increase in public investment in agriculture, some of that investment is to support the centres' direct, downstream participation in seed system. The Alliance for a Green Revolution in Africa, which is supported by the Rockefeller Foundation, the Bill and Melinda Gates Foundation, and United Kingdom's Department for International Development, has a major, multi-million dollar program on strengthening seed systems in close co-operation with NAROs in Africa.[35] More in-depth research seems warranted to document and analyze these diverse changes at the national level and if and how climate change has any influence. The next section of our study aims to contribute to such an analysis.

Integrating multiple stakeholders in technology generation and dissemination

Despite the fact that there is no systematic, co-ordinated plan for dissemination and feedback in place, greater efforts in the integration of multiple stakeholders in technology generation and dissemination have been undertaken in all of the CGIAR Centres. This effort is being achieved through ‘consortium’ projects that bring together members from both the public and private sectors. According to our interviews with scientists involved with the consortia, the consortia are expected to (1) increase the spread of improved germplasm and technologies in terms of actors and geography; (2) increase the speed of delivery to the end users and (3) create new mechanisms to improve the effectiveness and efficiency of the germplasm and technology flow systems. Some consortia pay particular attention to climate change (and adaptation to it), while others do not.

An example of a project that does focus on climate change is CIMMYT’s MasAgro project in Mexico. MasAgro supports small and medium seed company development in areas that have not yet experienced improvements in commercial maize production. These are rain-fed, marginal areas that are particularly vulnerable to climate change. The strategy is designed to develop and distribute non-transgenic variety and hybrid seeds to small farmers at a low cost. MasAgro’s ‘take it to the farmer’ component integrates uptake and feedback mechanisms in an approach that focuses on the conservation of agricultural land. MasAgro provides an illustrative example of how to simultaneously strengthen public sector research capacity and private sector dissemination capacity in ways that get needed materials into the field. Another climate change-related example is the STRASA project, which is co-ordinated by IRRI and which explicitly addresses climate change challenges. It involves NAROs, NGOs, farmer organizations and private seed companies from a number of countries. The focus of the project is on (1) the identification and characterization of promising and adapted local varieties and (2) the improvement of seed dissemination systems based on adapted local varieties. According to the IRRI interviewees, combining these two components has increased project effectiveness.

Examples that do not have a specific reference to climate change are the Latin American and Caribbean Consortium to Support Research and Development of Cassava (CLAYUCA) and the Latin-American Fund for Irrigated Rice (FLAR). These are two consortia created with the support of the CIAT to foster the development and use of cassava and irrigated rice-related technologies. Established in the 1990s as a response to shortages of public support for research, CLAYUCA and FLAR comprise alliances of cassava and rice producer countries that aim to improve the co-ordination and collaboration between public and private institutions. A non-climate change-related example from Africa is CIP’s Sweet Potato Action for Security and Health in Africa (SAHSA) project. SAHSA is based on three sub-regional platforms (east, west and southern Africa), where national programs, NGOs and farmers

35 Alliance for a Green Revolution in Africa, <http://agrasyntaxdev.forumone.com/section/work/seeds/>

group discuss and establish breeding priorities as well as join efforts for the dissemination of improved sweet potato germplasm developed by CIP in co-operation with involved countries. CIP also has experience with the Latin Papa Network promoting potato varieties (including native species) through co-operation with the private and public sectors (Haan et al. 2004). There is no evident climate change connect in this network.

In Africa, particularly for crops that have a market potential, such as soybeans, cassava, yams and bananas, breeding programs in IITA are currently integrating a value chain approach in the design and implementation of the research work. This effort translates into the increased involvement of different germplasm users (farmers, food processors and dealers) at the research and development stages and an extension of research activities into areas that are not traditionally included in breeding work, such as seed multiplication and distribution, crop marketing and so on. Participatory market chain approaches (PMCA) have also been adopted by CIP in special projects on native potatoes that do not have an established market. CIAT has used PMCA in Central America for a variety of crops including maize, while CIMMYT has used PMCA for maize in Mexico (Hellin, Keleman and Atlin 2010).

PABRA has evolved from a CIAT project to an African partnership program. It facilitates collaborative research within and between networks by providing a forum for building and strengthening linkages among multiple partners such as researchers, NGOs (including the private sector), community-based organizations and farmers (Rubyogo et al. 2010; Rubyogo et al. 2005). Within the Diffusion of Improved Varieties in Africa Cross-Centre CGIAR project, experts brought together by PABRA have played an important role in conducting a participatory mapping exercise of bean adoption areas.

Participatory crop improvement

With regard to CGIAR efforts to integrate multiple stakeholders in technology generation and dissemination processes, more decentralized crop improvement programs, which include the direct participation of farmers in more than just the final testing and adoption of technologies, deserve special attention. Participatory crop improvement started to gain wider recognition in the CGIAR in the middle of the 1990s (Ashby et al. 2000; Ceccarelli, Grando and Booth 1996). Several years later, a number of major initiatives were underway, some of which are in co-operation with NAROs and/or NGOs (Vernooy 2003).

According to a number of interviewees, in one way or another, all countries have systems to expose or farmers to engage in conventional breeding. Therefore, breeding work, they argue, is ‘participatory by nature’ because it relies on farmers’ opinions, as expressed directly by them or channelled through NAROs or private seed companies. This understanding of participation, however, represents a narrow way of interpreting participatory crop improvement in which farmers remain as end-of-the-line recipients of technology instead of co-producers of the scientific process.

Some of the CGIAR Centres have gained experience with more active and comprehensive forms of participation. These experiences include participatory plant breeding (PPB), participatory variety selection (PVS) and the organization of ‘open house’ and farmer field days. PPB involves farmers in the decision-making process about breeding priorities and strategies; PVS involves farmers in the evaluation of materials, sometimes from early on (F2 and F3) but, more regularly, in the final stages of the breeding process. PVS that is used in the early evaluation stages allows for the selection and further development of particular farmer-preferred traits. Open house and farmer field days are usually one-day events during which collections of experimental materials on station or in farmer's fields can be freely visited for on-site evaluation (sometimes including culinary tasting as well). From 1997 until recently, PPB and PVS were championed by the CGIAR's system-wide program on participatory research/gender analysis, which was convened by the CIAT and co-sponsored by CIMYYT, ICARDA and the IRRI. For a number of years, these four centres, plus ICRISAT, WARDA and CIP, piloted participatory crop improvement in a number of projects, some of them in close collaboration with NAROs and NGOs (Ashby 2009). The program ended in 2011 (Biermayr-Jenzano, Garcia and Manners 2011).

At present, participatory plant breeding only exists as a sub-program by one of the centres, ICARDA, and is housed within its participatory research program (Ceccarelli and Grando 2007). ICARDA has extended its original PPB work piloted on barley in Morocco, Syria and Tunisia to other countries and other crops in North Africa and the Middle East. In 2010, for example, ICARDA and its national partners started an innovative breeding program in four pilot zones of Eritrea. Farmers, researchers and extension staff jointly evaluated a wide range of crop varieties of barley, wheat, lentil, faba beans and chickpeas, both indigenous and introduced, to select promising ones for crop improvement. To accelerate the dissemination of new varieties, a farmer seed co-operative was established in one of the zones. A group of pilot farmers was provided with 'nucleus' seed of new varieties developed by the project, together with training on seed production, quality control and storage (ICARDA 2010 Annual report).[36] ICARDA has used this participatory approach to set up village-based seed production units in several countries, for example, in Jordan (Al-Yassin 2012).

Participatory variety selection (used in different stages) has gained ground in the CGIAR and is practised in a number of programs and projects carried out by CIAT, CIP, ICRISAT and IRRI, including some climate change-oriented ones (for example, STRASA). CIAT uses the participatory selection of rice varieties and the participatory selection and strategic use of multipurpose forage germplasm by small farmers in hillside production systems in Central America. The Bean Improvement Project initiated a project to develop drought-tolerant bean varieties for Central America, working with local NGOs organizing farmer groups who practise selection on segregating populations. CIP carries out PPB and PVS work through national partner organizations (Danial et al. 2006) and regional networks, such as INIA in Peru and the National Crops Research Institute in Uganda (Gibson, Mpembe and Mwanga 2011), investigating issues related to the marketing of roots and tubers, seed production and certification. CIP has a team of social scientists dedicating considerable efforts to participatory methodologies.

IRRI, which piloted PPB in East India in 1997, at present uses PVS to pay attention to end-user needs, including the development and strengthening of seed production systems (Paris et al. 2008). Examples are the IRRI-Japan Submergence project for Southeast Asia (Paris et al. 2011) and the Consortium for an Unfavorable Rice Environment (CURE). CURE uses

36 ICARDA, 2010 Annual report, <http://www.icarda.org/AnnReport.htm>

a partnership-building approach and combines research and extension. The development of technologies is based on farmer's needs and interests. CURE's work moves away from the traditional IRRI approach focusing on yield improvement, towards a more integrated approach that also addresses social and gender issues. STRASA uses field days to expose farmers to new varieties. CURE and STRASA have a core component on seed production, representing a still relatively new direction for IRRI. In central and west Africa, ICRISAT uses PVS in some projects – for example, on groundnuts (Ntare 2003; Ntare et al. 2008). In 2008, ICRISAT started work in Mali, Niger and Nigeria, which has allowed it to speed up the variety release process significantly and also to register and release 4 new varieties in Niger, 4 in Mali and 3 near release in Nigeria. Participatory approaches and direct distribution of germplasm to farmers have given rise to a number of policy issues that will be reviewed in Chapter 4.

Increasing co-operation with the private sector

According to a study conducted by the CGIAR's Science Council Secretariat (2006), the private sector represented only 6 percent of the 3 395 organizations working in collaboration with the CGIAR Centres in 2006. Therefore, the private sector's role in the CGIAR is still marginal compared to the role of its traditional partners in the public sector, but it has increased considerably in the last decade through a variety of co-operative links – for example, with manufacturers and processors (Reddy, Rao and Reddy 2006). Spielman, Hartwich and Grebmer (2007) distinguish five functional categories of partnerships with the private sector:

1. Resourcing partnerships: CGIAR Centres receive funding from foundations associated with private firms, or technology and scientific expertise from private firms.

2. Contracting partnerships: the facilities or expertise of CGIAR Centres are contracted to private firms, or CGIAR Centres contract private firms to conduct research.

3. Commercializing partnerships: CGIAR Centres transfer research findings and materials to private firms for commercialization, marketing and distribution.

4. Frontier research partnerships: CGIAR Centres jointly undertake research activities characterized by some unknown probability of success.

5. Sector/value chain development partnerships: CGIAR Centres collaborate with networks of public, private and civil society partners to develop a commodity subsector or its associated value chain.

The role of the private sector is particularly prominent in the stage of technology and germplasm dissemination (Spielman, Hartwich and Grebmer 2007). In many developing countries, the public sector has been inefficient in terms of seed production and marketing, particularly when addressing the needs of small and most vulnerable farmers. In countries such as Mexico and India, the price of publicly produced seed has been kept low for the major crops thanks to government subsidies. Quality is also low, however, making the adoption of seed from public programs very limited and creating distrust in the public seed certification and production systems. Combined with the growth of private seed enterprises in a number of countries (mainly in Asia and Latin America), these factors have led to strengthened collaboration between the CGIAR Centres and private seed actors.

The experiences of CIAT's CLAYUCA and FLAR and ICRISAT's Hybrid Parents Research Consortia have been documented as successful partnerships in this regard (Gowda and Reddy 2004; Patiño and Best 2002). Enhanced capacities to test materials in a diversity of environments, guaranteed seed quality control and agile seed multiplication skills have put private companies in a better position to make improved varieties available to farmers in certain countries and contexts, and these could be crucial for climate change needs.

Nevertheless, there is no clearly elaborated CGIAR system-wide vision and strategy on public-private partnerships , although the need for new partnerships of all kinds has been stated in the 2011 strategy and results framework (CGIAR 2011: 4). Existing public-private partnerships have not been thoroughly evaluated, for example, in terms of their contribution to poverty reduction (World Bank 2004). With respect to partnerships for biotechnology generation and dissemination, Ayele, Chataway and Wield (2006) criticize many of the partnerships in Africa that involve the CGIAR Centres. They argue that these collaborative efforts tend to be supply driven and not always linked to user demand. They originate with given solutions that are not clearly linked to national development goals.

In terms of the climate change relevance of these partnerships, incentives for private sector involvement are limited in those areas that are most vulnerable to climate vagaries (marginal, rain-fed, with mostly subsistence farmers) or for crops with greater potential under stressful environmental conditions (legumes and dryland crops),. The focus of private industry in these regions is on different crops or agricultural production systems (irrigated crops), which leaves the CGIAR Centres no option other than to partner with public actors. ICARDA's work in the Middle East and North Africa is an example. Some interviewees explained that the continued role of public investment and international-national public sector collaboration, particularly for the marginal areas and for 'minor' crops, remains important. It also appears as a key point in the CGIAR's new strategy and results framework.

3.0. Policy issues related to the CGIAR's access to germplasm and benefit-sharing regulations

Breeders and intellectual property managers shared their concerns about the increasing politicization of germplasm flows. They mentioned a number of cases in which national institutions have protected certain varieties that had resulted from germplasm improved by the CGIAR Centres and exploited those varieties in a restrictive manner and/or without informing the centres. Three centres are currently engaged in negotiations with national authorities to have their contributions recognized. In one case, a centre has chosen to challenge an application for plant variety protection under the national law of the country concerned. CGIAR scientists have attributed various motivations to the national scientists' desire to seek variety protection and have indicated that such actions were often backed up by national policies. They mentioned that there are incentives for national programs to inflate their own contributions and ignore those of the CGIAR Centres. Government funding for national programs depends upon demonstrating contributions to the improvement of the national crop genetic pool. Incentives to inflate national contributions seem to have increased in countries where variety registration laws and/or plant variety protection laws have recently been put in place or updated. As a result, breeders are being rewarded according to the number of varieties they register. It was also noted that in one country the recent adoption of a national policy similar to the *Patent and Trademark Law Amendments Act* (*Bayh-Dole* Act) in the United States was creating an incentive for national agencies to be more aggressive about seeking intellectual property protection over new crop varieties.[37]

In order to deal with these new, national-level institutions, some of the CGIAR Centres have adopted defensive strategies to protect their contributions. In 2005, ICRISAT signed a memorandum of agreement (MOA) with the European Patent Office (EPO) allowing ICRISAT to include its publications as part of the EPO's non-patent literature. Thanks to this agreement, information and knowledge generated by ICRISAT is being provided to European patent examiners for consultation in prior art searches. CIAT has intended to follow ICRISAT's example, but the MOA was never implemented. CIAT has not abandoned this approach, however, and is considering signing an agreement with the Colombian patent office in 2012. IRRI, in co-operation with Philippine authorities, is developing a public register of germplasm collected before the entry into force of the ITPGRFA. The aim is to defeat novelty claims in possible plant variety protection or patent applications over such germplasm in all other countries. Some centres are considering proactively protecting some of the varieties that they have improved by claiming plant breeders' rights to limit germplasm users' ability to apply exclusive rights over the use of such varieties at a future point in time.[38]

37 The Patent and Trademark Law Amendments Act (1980) [Bayh-Dole Act] deals with intellectual property arising from US federal government-funded research. Among other things, it gives US universities, small businesses and non-profit organizations intellectual property control of their inventions and other intellectual property that resulted from such funding. The Bayh-Dole Act reverses the presumption of title permitting a university, small business or non-profit institution to elect to pursue ownership of an invention in preference to the government. For more details, see <http://www.ucop.edu/ott/faculty/bayh.html>

38 Some cases of misuse of publicly made available varieties have occurred already in the past, such as a yellow bean of Mexican origin (which became known as the 'Enola' bean and was released by the Mexican government), for which twenty years later a patent was claimed by a US company (in 1999). The claim was successfully contested by CIAT, the FAO and the ETC group and overturned by the US Patent and Trademark Office in 2008. See International Center for Tropical Agriculture, <http://webapp.ciat.cgiar.org/newsroom/release_31.htm>

These research findings point to the increased politicization of access and distribution of germplasm in the international agricultural research system at large and the institutionalization of property rights at the national level. It is hard to pinpoint a precise starting date for this trend, but its evidence emerged clearly from interviews with the breeders and property right specialists in the CGIAR Centres.

3.1. The impact of international agreements

The rules governing the access to, and use of, genetic resources have changed dramatically, as demonstrated by the Agreement on Trade-Related Aspects of Intellectual Property rights (TRIPS Agreement) in 1992, the CBD in 1993 and the ITPGRFA with its multilateral system of access and benefit sharing in 2004.[39] While twenty years ago, germplasm was collected, conserved and exchanged in a relatively open system of flows between different users of plant genetic resources, these activities are now subject to international and national regulations. The development of these regulations occurred when the internationalization of *ex situ* conservation and crop breeding and the expansion of intellectual property rights raised tensions among nations about who would bear the cost of conservation and who would benefit most (commercially) from its use.

The transformation of international agreements that affect germplasm exchange and use into national-level measures has proven challenging (Lopez-Noriega, Wambugu and Mejías 2012; Mwila 2012), particularly with regard to access and benefit-sharing questions (Chiarolla and Jungcurt 2011; Ruiz and Vernooy 2012). This situation has obviously affected the operations of the CGIAR Centres with respect to activities that lie at the core of their mandates, such as collecting germplasm for conservation and research purposes and transferring gene bank and breeding material to other users.

Our interviews with scientists confirmed that it is becoming increasingly difficult for the CGIAR Centres to obtain access to germplasm for inclusion in their gene banks or breeding programs. In general, respondents noted that it is particularly difficult to obtain materials from developing countries, although one developed country was also mentioned in a number of interviews. Gene bank managers and breeders most often mentioned the largest developing countries in this regard, which have (1) a large diversity of the mandate crops of the CGIAR Centres; (2) strong agricultural research programs and (3) long histories of accessing and using different kinds of materials from the centres' gene banks and breeding programs. In this context, it is important also to recall that these countries are also among the largest providers of materials in the CGIAR Centre-hosted collections (see Table 1). However, most of these materials were collected and transferred to the centres in the 1970s and 1980s. Overall, the interviewees highlighted a shift away from willingness to make materials available over the last 10 to 15 years, and all of them expressed strong concern about this trend.

Most gene bank managers and breeders interviewed attributed their difficulties obtaining access to new genetic diversity to three factors: (1) a combination of high levels of

39 Agreement on Trade Related Aspects of Intellectual Property Rights, Annex 1C of the Marrakech Agreement Establishing the World Trade Organization, 15 April 1994, 33 ILM 15 (1994).

politicization of genetic resource issues and 'inappropriate' policy initiatives, including what they called 'strong' (restrictive) access and benefit-sharing regulations (as a result of the CBD); (2) pressures to globalize intellectual property rights through international trade agreements and (3) insecurity on the part of officials about actually agreeing to provide materials to the CGIAR Centres. Similar findings have been documented based on interviews with CGIAR gene bank managers in 2005 and 2006 (Halewood et al. 2012). Although a restrictive approach has become common, it is important to point out that the interviewees noted considerable differences between countries. For example, scientists from a few centres indicated that access to germplasm from a number of African countries is not particularly difficult but that it is actually limited by a lack of funds and human resources necessary to set up strong collaborative research initiatives and formal and informal networks under which germplasm can be exchanged.

Some positive impacts of the ITPGRFA's multilateral system have been documented, including its contribution to the willingness of countries to deposit in the CGIAR genebanks samples of up to 90,000 regenerated accessions and allowing them to be redistributed using the SMTA (Halewood et al, 2012). Nonetheless, many of the respondents observed that the ITPGRFA and its multilateral system of access and benefit sharing does not appear to be having a wider, more significant impact on the willingness of previously reluctant providers to make germplasm available. Some respondents thought that the Treaty might have contributed additional challenges that need to be addressed. Among the factors they cited in this regard were: the perceived complexity at the national level of putting mechanisms in place to implement the multilateral system; the fact that germplasm providers have not (or not yet) actually received any benefits through the Treaty's benefit-sharing mechanism, and the fact that some crops not being included in the Annex 1 list of crops in the multilateral system has encouraged countries to take a restrictive approach to access considerations. Others opined that while acceptance of the SMTA and the Treaty's multilateral system of access and benefit sharing has been slow initially, providers will eventually be more willing to make materials available through that system. It was acknowledged that increased willingness would not happen automatically but that it would require action on the side of provider countries and the respective authorities in charge of implementing the Treaty.

Interviewees mentioned that strength and longevity of relationships between individual CGIAR Centres and countries were factors that helped to overcome some of these challenges. They also said that larger research projects, in which transfers of genetic materials are supportive of broader research objectives, can be instrumental. Scientists involved in networks noted that long-term co-operative links (for example, through the SINGER network led by IRRI) are less affected by the reduced willingness of countries to share germplasm. However, the existence of long-term relationships and networks does not automatically imply the smooth exchange of germplasm. A few scientists pointed out that national policies and regulations, particularly those related to access and benefit sharing and intellectual property rights, have begun disrupting even those networks that used to be very functional. They observed that the behaviour of some countries is affecting the overall effectiveness of these international networks.

For some crops, the relative importance of the lack of access to germplasm appears to be tempered by the fact that (1) there is considerable unexplored germplasm in the CGIAR gene banks or (2) that breeders have a fair amount of improved materials at their disposal. On the other hand, in all cases, gene bank managers and breeders confirm that there is material in different countries that they would like to obtain access to, particularly wild crop relatives. All of the interviewees stated that while the ongoing drop in germplasm flows may be acceptable for some crops in the shorter term, in the longer term, particularly as a result of climate changes, access to plant genetic diversity from beyond the international collections and extant breeding lines will become increasingly important. Shifts in pest and disease patterns, which are among the most significant effects of environmental changes, would necessitate exploration and transfer of traits that may not be represented in the CGIAR collections. Prior work has shown that lack of access to new material, for crops such as soybeans, yams, banana, groundnuts and forages, is already limiting breeding possibilities because neither international gene banks nor open national collections such as the one held by the USDA hold a sufficient diverse collection of germplasm, particularly in terms of wild relatives (Khoury, Laliberté and Guarino 2010).

In the 1970s and early 1990s, the CGIAR Centres routinely arranged collecting missions, often with the active participation of the International Board for Plant Genetic Resources (which eventually became Bioversity International). With a few notable exceptions, the centres report that it is now extremely rare for them to be able co-ordinate joint missions with NAROs to collect genetic resources from *in situ* conditions. Both gene bank managers and breeders expressed concerns about this trend. New diversity that is evolving in natural or agricultural ecosystems that are exposed to climate change is not making its way into globally shared *ex situ* collections.

When we embarked on this research, we expected to find that the CGIAR breeders would be less concerned about restricted access to genetic resources, due to the fact that they are involved in networks which would help overcome some of the reluctance of would-be providers. However, the breeders we interviewed expressed the same concerns as the gene banks, in very similar terms, and with the same sense of urgency.

A number of the centres reported receiving increasing amounts of material under restrictive material transfer agreements and having to reject germplasm whose use is subject to too many limitations. They have had to refuse germplasm because they were not allowed to pass it on to other users. Examples mentioned by interviewees include parental lines of legumes and wild species of maize. Problems derived from the inability to transfer accessions received from national partners have arisen also when assembling reference sets from gene bank core collections for gene discovery under the GCP. As one of the scientists involved in the GCP explained, reference sets serve to provide a representative sample of the diversity of the crop concerned for upstream research by organizations all around the world. The non-inclusion of diversity from any collections in the development of these sets potentially compromises their completeness and, thus, their utility. Some breeders reported other restrictive conditions concerning some materials – for example, the requirement to grant first access to research results to the germplasm or technology provider. Another example mentioned is to acknowledge the source of germplasm in academic publications.

3.2. Increasing intellectual property protection

Debates concerning access to plant germplasm and technologies subject to intellectual property rights have been chronicled extensively in the literature since the 1980s (Aoki 2004; Lamola 1992; Maskus and Reichman 2004; Mooney 1979; Primo Braga and Fink 1997).

They became particularly inflamed following the adoption in 1994 of the TRIPS Agreement, which requires all member countries of the World Trade Organization to adopt minimum standards of intellectual property protection. More recently, growing attention has been paid to understanding the implications of using intellectual property rights to protect technologies (including plant germplasm) that hold promise for mitigating and/or adapting to climate change.

Prior work has shown the simultaneous growth of applications for patents and plant breeders' rights seeking control of the exploitation of plants, plant varieties and their seeds. This has been particularly evident in developed countries and emerging economies (Koo, Nottenburg and Pardey 2004; Lopez-Noriega 2012). Applications by public research agencies account for a considerable degree of this increase, which is in some cases enabled by public policy modelled on, or similar to, the US *Bayh-Dole Act* (1980).

Heller (1998) uses the term 'tragedy of the anti-commons' to refer to the constraints that research organizations may face when trying to use patented knowledge for further scientific The concept and term have been further developed by other scholars (Bentwich 2010). With reference to climate tolerant plant varieties, reports by the ETC Group (2010) and the Third World Network (Shashikant and Kohr 2010) reflect a long-standing critique on the concentration of technology in the hands of a limited number of private companies in developed countries and the potential negative impacts of this trend for access to promising germplasm by public research institutions. The literature criticizes, in particular, the monopolistic US patent system, which, unlike most European and other countries' patent and plant variety protection laws, does not provide for a form of exemption in case of research (Ghijsen 2009; Tripp, Hu and Pal 2010).

Empirical evidence of the precise impact of intellectual property protection on crop improvement efforts in developing countries is scarce, however. Jaffé and van Wijk (1995) researched experiences of breeders and farmers in Argentina, Chile, Colombia, Mexico and Uruguay. Their study concluded that the introduction of plant variety protection systems in these countries has had a positive effect on access to elite materials generated by seed companies in developed countries, in particular, hybrid lines of major grains and improved propagating material of ornamental plants and fruit trees (Jaffé and Van Wijk 1995). A study conducted by the Union for the Protection of Plant Varieties (UPOV) in Argentina, China, Kenya, Poland and South Korea arrives at a similar conclusion for the same species (UPOV 2005). An in-depth review of the impact of intellectual property rights on the plant breeding industry in China, Colombia, India, Kenya and Uganda did not lead to any 'strong' conclusions one way or another (Louwaars et al. 2005). Focusing on the research and commercialization of protected plant germplasm of staple crops in developing countries, Koo, Nottenberg and Pardey (2004) emphasize that concerns around intellectual property rights are overstated. Although both the scope and the geographical extension of protection is expanding, the preponderance of protection pertains to high and medium-high income countries, leaving poor countries free to tap these technologies. Moreover, a large share of the protected varieties are ornamentals not food crops. Most plant varieties are afforded protection that enables rights holders to limit or exclude others from marketing, but not breeding, the protected material. This ability offers researchers in both developed and developing countries the freedom to use such varieties in their breeding activities.

The CGIAR scientists and intellectual property specialists who were interviewed generally confirm that intellectual property rights are not posing a significant hurdle for the CGIAR Centres to obtain access to technologies they need as inputs for their crop improvement efforts. They did not mention any particular intellectual property rights issue related to a climate change technology of interest to a centre or to the CGIAR as a whole. Several factors may account for this silence. Most of the centres do not report actually needing to obtain, or trying to obtain, access to proprietary technologies for their crop improvement work. For some of the mandate crops used by the centres, the private sector's investments in crop improvement is relatively low, with the result that companies are not generating the elite material that might be protected. Indeed, it seemed that the opposite situation is often the case – it is the centres that are producing the improved germplasm that the private sector wants access to – for example, parental lines for commercial hybrids. Some of the scientists and intellectual property specialists who were interviewed concurred that the existence of patents or intellectual property rights over a needed technology increases the transaction costs. They pointed out that these costs could delay access to, and use of, such technology in comparison to those technologies that are not subject to intellectual property protection.

The interviewees explained that when the CGIAR Centres consider using advanced germplasm and technologies from public and private entities in developed countries (for example, molecular markers and other pre-breeding tools or transgenes), the technology is often old and out of date and the patent has expired or is not subject to intellectual property protection in the countries where the CGIAR wants to deploy them. Another reason that was given is that there are no relevant intellectual property laws in many of the countries where the CGIAR deploys its technologies. An example cited in the literature illustrates this particular scenario. Many thought that the main obstacle for making the Vitamin A-fortified cultivar 'Golden Rice' available would be the large number of patents involved in the development of the product – 70 patents belonging to 32 different patent holders around the world with Syngenta being the most prominent (Kryder, Kowalski and Krattiger 2000). The negotiation process of the licensing agreements between the fortified rice producers and the patent holders lasted less than six months, allowing Golden Rice to be exploited for the public good (with certain limitations). The unexpected low transaction costs and the successful partnership between public and private actors were not the only interesting aspects of the case. Most of the patents identified are not applicable in the top 10 rice-producing countries (Kryder, Kowalski and Krattiger 2000) nor in many of the countries that suffer the most serious levels of Vitamin A deficiency and are also high consumers of rice (RAFI 2000).

4.0. Policy issues related to the distribution of CGIAR germplasm

The CGIAR Centres fulfil a very important role as pumps in the global movement of germplasm, both from their own crop improvement programmes, and from the international collections of germplasm that they conserve and curate. In light of continued, and in some cases increasing, restrictions on the access to and use of germplasm worldwide, the centres' role in this regard becomes more important (and anomalous) as time progresses. The following two examples – of the CG genebanks' worldwide distribution of materials from Brazil and India, and the centres' facilitation of germplasm from around the world going to those countries – illustrate the scope and effectiveness of the activities of the gene banks.

The CGIAR gene banks currently hold 15606 accessions originally collected from Brazil. Between 1979 and 2009, the CGIAR gene banks distributed 12 485 samples of those materials around the world (7 057 unique accessions) to 120 countries, as shown in Figure 9. Over the same period of time, Brazil received 9 198 samples (7 971 accessions) from the CGIAR gene banks, which were originally collected in 137 different countries. In addition, in 2009 alone, the Centres sent Brazil 4 583 samples of material from CGIAR breeding programs.[40]

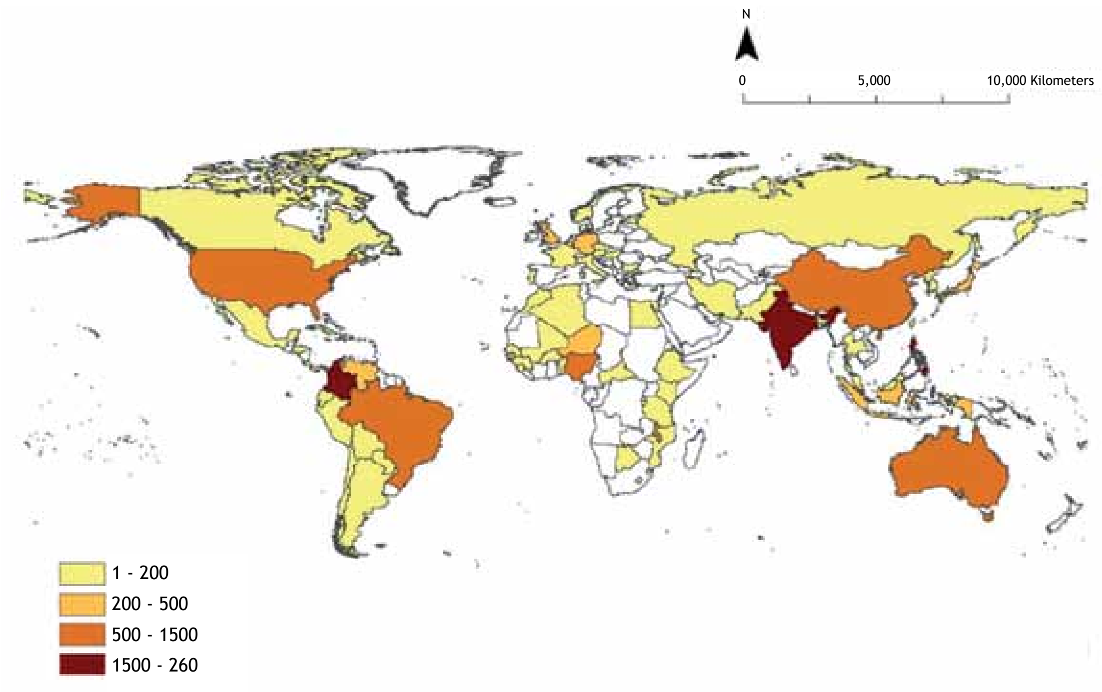

Figure 9: Global distribution of germplasm of Brazilian origin (1979-2009).[41]

Source: SINGER (2012)

40 Some of the samples could include duplicates. The data are not consistent.
41 Recipient countries are classified according to the number of distributions they received that contained material originally collected in Brazil.

The numbers associated with India are even more impressive. The centres currently hold 66 864 accessions originally collected from India, (approximately 10% of the total held in all CGIAR collections). Between 1979 and 2009, the CGIAR gene banks distributed 248 783 samples of (101 568 unique accessions) of material that was originally sourced from India, to 122 different countries. Over approximately the same period of time, the centres sent recipients in India 341 028 samples (119 207 unique accessions) of materials originally collected from 137 countries. In 2009 alone, the Centres sent India 7 049 samples from CGIAR breeding programs.[42]

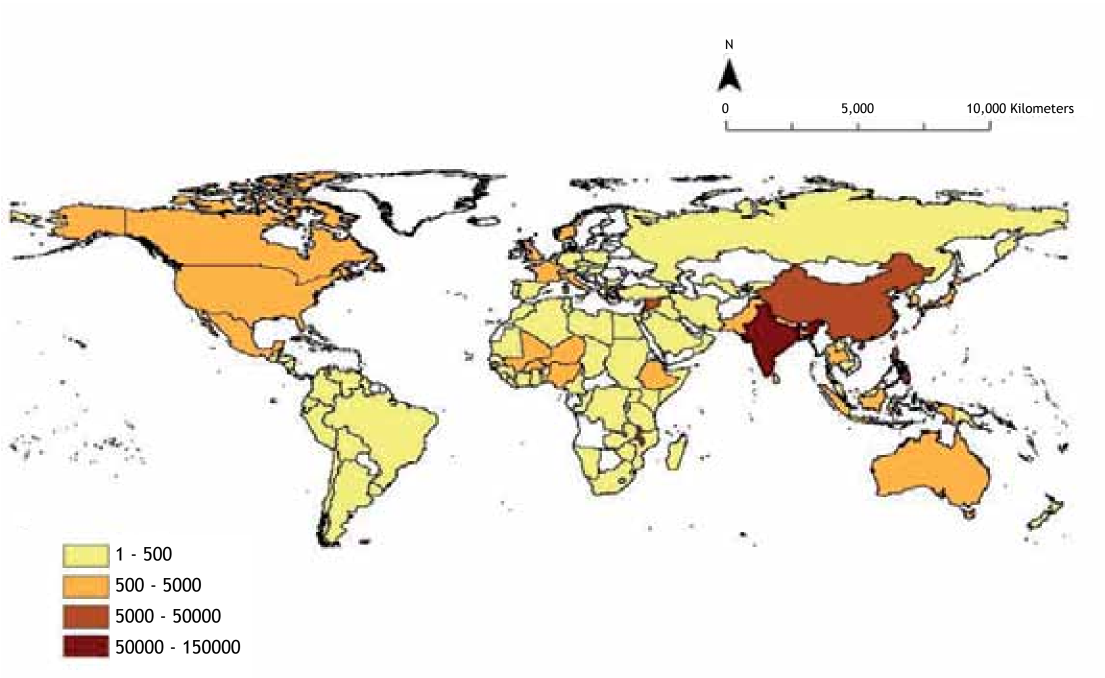

Figure 10: Global distribution of germplasm of Indian origin (1979-2009).[43]

Source: SINGER (2012)

The collections hosted by the CGIAR Centres' gene banks include materials originally collected from 195 countries. By physically pooling those resources, investing in their conservation and making them available, the centres allow countries to avoid the enormous (often prohibitive) transaction costs they would face if they had to independently search for and negotiate a supply of the same genetic resources from each supplier country. This is particularly important given that so many countries are currently opting not to share much or any PGRFA beyond their own borders. If those countries had not previously agreed to allow the centres to conserve and distribute those materials, they would not be available now. These materials are only currently available due to the less restrictive approaches of the countries of

42 Some of the samples could include duplicates. The data are not consistent.
43 Recipient countries are classified according to the number of distributions they received that contained material originally collected in India.

source in the past, and because the centres continue to invest in conservation and distribution. Given the increased climate-driven interdependence and urgency for the exchange of adapted germplasm, this mechanism for facilitated access is particularly important.

In the following subsections we analyze the extent to which policies – at organizational, national and international levels – are supporting or creating challenges for the centres breeding programmes and gene banks to continue to act as international pumps of centre-improved materials and materials conserved in the gene banks. We will also examine how policies affect the subsequent diffusion and uptake of germplasm distributed by the centres.

4.1. Challenges related to the distribution of germplasm under the multilateral system of the ITPGRFA

As stated above, the legal status of the *ex situ* collections hosted by the CGIAR gene banks was confirmed by the 1994 FAO-CGIAR in-trust agreements and, more recently, in 2006, through agreements between the CGIAR Centres hosting collection and the Governing Body of the ITPGRFA. Those agreements confirm, for the first time, within the context of an international, legally binding treaty, the centres' ability to continue their role facilitating international access to the 'in trust' materials held in the gene banks for the purposes of research, breeding and training for food and agriculture. Pursuant to those agreements, the centres also agreed to use the SMTA when distributing germplasm that they have improved when it incorporates 'in trust' germplasm, or any other materials in the multilateral system of access and benefit sharing. In such cases, if the materials are still under development, while the CGIAR Centres are obliged to use the SMTA, they may add terms and conditions that can apply until the development process is finished and the final product is commercialized on the open market.[44] As such, the Treaty, combined with the Centres agreements with the Governing Body provide a solid legal basis for most of the distributions of materials from the CGIAR gene banks and breeding programs.

As reported to the Fourth Session of the Governing Body in 2011, during the first three years of operating under the Treaty's framework, from January 2007 to December 2009, inclusive, the centres' gene banks and breeding programmes combined distributed a total of 1.15 million samples of PGRFA. "Approximately 84 % of the samples were sent to developing countries or countries with economies in transition, 9.5% to developed countries and 6.5% to CGIAR Centres. 18% were sent by the Centres'gene banks, and 82% from the breeding programmes." (SGRP 2011: 9-10)

In general, CGIAR scientists seem to have a good understanding of the SMTA and feel comfortable using it. Respondents in one centre thought that familiarity with the SMTA and

44 In their reports to the Governing Body of the Treaty covering the period 2007-2009 inclusive, only one centre, Bioversity, reported adding any additional terms and conditions to the SMTA when transferring PGRFA under Development (and that was to pass on conditions that had been imposed by the depositor of that materials to the international musa collection). Numerous interviewees confirmed that since that time, a number of centres have developed terms and conditions which the routinely add to the smta when distributing PGRFA under Development.

its use was considerable at the headquarters but was lower in regional and country offices. According to the experience of gene bank managers and breeders in most of the centres, the use of the SMTA for the transfer of material is not causing major difficulties with traditional public recipients, although there have been complaints about the length of the review and signature process. The CGIAR Centres have made considerable effort to help recipients become familiar with the ITPGRFA's multilateral system and the SMTA. Explanations about the multilateral system can be found on the website of some centres. CIMMYT and IRRI have posted frequently asked questions related to the multilateral system and the SMTA, and IRRI has developed tutorials. In addition to frequently asked questions, the SGRP has developed a guide for the CGIAR Centres to use in relation to the SMTA, which provides guidance on how to deal with different issues related to the transfer of CGIAR germplasm.[45] In the context of the expanding public-private partnerships and their relevance for climate change research and development, CGIAR scientists have provided formal and informal guidance on the SMTA to private companies involved in ICRISAT and IRRI hybrid consortia. CIMMYT staff have made similar efforts for public and private members of large projects such as CIMMYT's MasAgro with the aim of reassuring them that the SMTA is acceptable.

However, there are still a number of distribution-related uncertainties and challenges associated with the Treaty's multilateral system and the centres' agreements with the Governing Body. These issues can be divided into two groups: issues related to how the centres operate *within the scope* of their agreements with the Governing Body, and issues related to how they operate *beyond the scope* of those agreements.

Perhaps the most pressing question within the scope of the agreements concerns 'what additional terms and conditions can a centre add when it is distributing 'PGRFA under development'? Can they restrict access to materials or seek IPRs over them, or allow other to seek IPRs over the germplasm they have improved? Strictly legally speaking, the centres discretion with respect to the first question is fairly broad. However, for years, there have been questions raised by centre scientists, donors, and other about the conditions under which the centres should enter into agreements whereby they limit access to their research products. The recently adopted CGIAR Principles on the Management of Intellectual Assets[46] have the practical effect, as a matter of CGIAR system-wide policy, of narrowing the centres' discretion under the Treaty, by establishing minimum threshold justifications for centres entering into exclusive arrangements, and obliging them to various forms of disclosure. The IA guidelines are new, and it will likely take some time before their relevance to centres distributing PGRFA under Development are fully understood and operationalized.

Another frequently raised question concerns 'how much money can a centre request when supplying PGRFA from its gene bank? The SMTA says 'when a fee is charged, it shall not exceed the minimal cost involved. As the centres move into full cost recovery, it become very important to ascertain how much of the cost of conservation can be considered 'minimal' under the Treaty? (This issue is discussed in more detail below.)

45 System-wide Genetic Resources Programme, <http://www.sgrp.cgiar.org/sites/default/files/Guide_SMTA.pdf>
46 Consultative Group on International Agricultural Research, <http://consortium.cgiar.org/principles-on-management-of-intellectual-assets-approved/>

A third issue has to do with the impracticality of using the SMTA when the centres distribute materials to farmers on farmer field days, or in the context of PVS or PPB projects. Often the farmers are illiterate and likely to be disconcerted when presented with the 12 page SMTA to approve. So far, the best that can be suggested is that the centres follow processes that are commonly accepted in the countries concerned for explaining contracts to illiterate farmers as a precursor to their being able to express consent. Even more impractical is the expectation that farmers will pass on seeds, through their informal contacts with other farmers, using the SMTA.

Two closely related outstanding issues that arise at the fringes of, or beyond, the centres' agreements with the Governing Body, are:

- Does a CGIAR Centre gene bank have the right to distribute materials for non-food/non-feed purposes (purposes other than those listed in the Treaty) for example, for biofuels-related research? If so, under what access and benefit-sharing conditions can these materials be distributed?

- Can a centre gene bank distribute materials to farmers for direct use? (Direct use in cultivation is also not included in the purposes for which materials are made available under the Treaty or the SMTA.) If so, under what terms and conditions?

These are issues that have been raised repeatedly by CGIAR scientists since signing agreements with the Governing Body (SGRP CGIAR 2007). The CGIAR Genetic Resources Policy Committee (which was suspended as of January 2011) considered these issues during its last sessions. It forwarded draft policies and draft legal instruments to the CGIAR Consortium Board for consideration (including a draft policy for distributing materials for non-food/non-feed purposes and a material transfer agreement to use for those transfers). The Consortium Board and Consortium Office are still considering possible system-wide mechanisms for addressing issues of this nature, so these questions continue to be addressed on a centre-by-centre, case-by-case basis. Two years ago, the Centres also submitted a request for feedback on these issues to the Ad Hoc Technical Advisory Committee on the SMTA and MLS (TAC-SMTA) which was created by the Governing Body of the Treaty. At its third meeting, in July 2012, the TAC-SMTA confirmed its opinion that the centres can distribute materials they developed, and materials they held in trust under the 1994 in trust agreements, for non-food/non-feed purposes and for direct use to farmers, and that the centres should not use the SMTA for these purposes[47]. The opinions of the TAC-SMTA are not however, legally binding. The opinions can be considered and adopted by the Treaty's Governing Body. Even then however, the substance of those adopted opinions could be challenged in national courts. While they don't provide legal certainty for the centres, they nonetheless provide some 'cover' for the centres if their practices were ever challenged, in as much as the centres could argue that they exercised due diligence by obtaining an opinion from the TAC-SMTA. It is also a good practice for the centres, as a means of demonstrating their commitment to transparency, to refer such issues to the attention of the TAC-SMTA.

Finally, it is important to note that some private companies and universities that work closely

47 The report of the TAC-SMTA meeting has not yet been released by the Treaty Secretariat.

with companies have expressed reservations about receiving materials under the SMTA, and some have adopted policies to avoid accepting such materials if possible. In general, companies and universities that anticipate patenting PGRFA products are most vocal in this regard, though the ISF published a critique of the SMTA (presumably on behalf of all its members) as early as 2007 (International Seed Federation 2007). However, respondents from various centres also reported that some US universities do not accept the SMTA because the arbitration clause conflicts with federal laws to which the US universities adhere. The most frequent complaints from private sector partners with respect to the SMTA concern a number of points summarized in the following list.

- The SMTA imposes an obligation to pay back to a 'benefit-sharing fund' in the case that a product derived from the use of the received germplasm is subject to protection and already commercialized. Companies have often not heard of such an obligation, and it is uncommon, legally speaking.

- The SMTA does not specify a time limit, which, in terms of time, makes this obligation more restrictive than a patent. Companies are not clear whether and when the obligation expires. Is it in perpetuity?

- Usually, breeders calculate royalties to be paid according to how much of the original material is incorporated in the final product. It is understood thought that if the final product incorporates less than 12.5 percent of the original germplasm there are no royalties to be paid. Breeders are not comfortable with other 'rules.'

4.2. Intellectual property right-related challenges

Increased involvement of the private sector in the dissemination of new CGIAR germplasm – which is clearly a trend that emerges from this study – has raised issues related to intellectual property rights over what were traditionally considered global public goods. Some of the recent agreements with private firms have a clear commercial nature. The establishment of hybrid consortia includes payments to the CGIAR Centres (in the form of fees) in exchange for access to improved materials. Some of the centres have received royalties from industry's use of advanced germplasm – for example, in the case of cassava. IRRI is currently developing a centre-wide policy that includes the payment of royalties if the IRRI-improved material is used for commercial purposes.

The approach to partnerships, particularly regarding issues related to intellectual property rights, is not consistent across the CGIAR (CGIAR ADE-PSC 2009). Some of the CGIAR Centres address contractual obligations, and particularly intellectual property rights, in a more formalized, systematic manner. Others do not have a specific procedure or policy but act on a case-by-case basis. All of the interviewees stressed that ensuring the wide dissemination of technologies is the inspiring principle behind all dissemination strategies. However, they pointed out that in order to ensure such a goal and to keep it at an affordable price, the centres sometimes need to accept restrictions on their ability to distribute materials they have developed. The recently approved CGIAR Intellectual Assets Strategy sets the rules for all centres concerning the conditions under which centres may restrict the availability of their assets (including germplasm), the kinds of restrictions they may use and how much information about such arrangements they must disclose, and to whom. The strategy is expected to bring order in the range of practices that currently exist. An inter-centre working group has been set up to assist centres with the actual implementation of the strategy.

4.3. Phytosanitary requirements

Phytosanitary requirements are central to proper germplasm acquisition and distribution. All germplasm samples for both import and export pass through the germplasm health unit of the CGIAR Centres to make sure that the germplasm meets the host country import and export requirements. Cleaning processes become more time and resource consuming as national regulations become stricter and better enforced and as plant safety standards increase thanks to the improvement of technologies used to detect pests and diseases in plant samples. Some gene bank managers and breeders noted that some countries have adopted phytosanitary policies that were contributing to lower acceptance rates of materials. There are countries that do not have the capacity to carry out the analyses that their phytosanitary policies require. The result is that the countries concerned cannot accept these particular materials or they have to request assistance from specialized agencies in other countries. This requirement, in turn, leads national scientists to stop making requests because they know the materials will not reach them in a timely manner or at all.

The authorities of some countries hosting the CGIAR Centres have prevented the import of samples on several occasions for safety reasons. For example, the national phytosanitary authorities of the country hosting one CGIAR centre did not allow the centre-concerned to import germplasm coming from East Africa. In these cases, the centre's health unit had to negotiate with, and convince, the authorities on a case-by-case basis. Sometimes, the process takes so long that it seriously affects the breeding cycle. This delay can have serious consequences, for example, if adapted material is needed in the shortest time possible to address emergency situations – for example, severe drought or massive floods. In general, a lack of the necessary technical and human resources for plant health inspection is a major gap in many developing countries, particularly in Africa, which makes the safe movement of germplasm difficult.

4.4. Negative effects of the CGIAR's full-cost recovery policy

A few interviewees expressed concerns that the CGIAR's recently adopted policy of full-cost recovery could have a significant impact on germplasm distribution by the centres. These concerns were expressed by scientists in centres where full-cost recovery strategies had already resulted in significantly higher charges being given to germplasm recipients. It is expected that the impact of this policy will have different consequences for different crops. In one centre, breeders asserted that requests for vegetatively propagated crops and legumes have decreased since recipients started to be charged costs involved in germplasm transfers, such as regeneration, plant quarantine and shipment. One scientist, making reference to a particular legume crop, estimated that the full-cost recovery had accounted for an approximately 20 percent drop in materials distributed from this particular centre. This number represents a considerable decrease. A more systematic review of the current experiences and envisioned practices of the centres in this regard, including the potential impact on more effective strategies for climate change adaptation, has not yet been carried out.

4.5. Long and limiting variety release procedures

The regulation of the release of new plant varieties was originally developed in Europe as a result of the development of specialized plant breeding products in the mid-nineteenth century. The objective was to create transparency in a seed market where variety names were rapidly proliferating and farmers could not be certain what they were purchasing (Bishaw and Gastel 2009; Louwaars and Burgaud 2012). Most of these regulations require that a variety registered for commercial purposes needs to be distinct from all varieties of common knowledge, uniform in its essential characteristics and highly stable after repeated multiplication (the so-called DUS requirements). These criteria are meant to ensure that when a farmer buys seeds of a registered variety, they will be indeed of that variety and will perform as such over time. Testing for value in cultivation and use (VCU) was introduced to provide an independent assessment of the yield, quality and value of the grain.

Many developing countries have established seed production systems greatly inspired by these European countries and their rules (GRAIN 2005). The adoption of the 'European model,' however, has not always responded to particular country conditions. Formal release systems suit only a very small portion of the seed market in many developing countries. The situation varies by crop and region – for example, for rice in Bangladesh the estimate is 10 percent (Hosssain, Bose and Mustafi 2006), but studies show that the formal system of seed supply provides, on average, 15 percent of the total seed used by farmers in developing countries (Cooper 1993; FAO 1998). Limited capacities and resources of both breeders and national agencies in charge of variety release have resulted in long and sometimes uncertain procedures to test candidate varieties. In some countries, seed regulations are rarely enforced at the local level, and both traditional and modern varieties are exchanged freely among farmers and sold in local markets (Louwaars 2002). Farmers in many countries continue to produce and exchange seeds 'outside' the national formal regulatory framework, but in many places this practice has become stressd (Ruiz and Vernooy 2012).

The breeders that were interviewed stated that variety testing and some kind of formal release are necessary steps for guaranteeing the identity and quality of new varieties and for making them available for public and private agencies to multiply and distribute. The same breeders, however, complained about the length of time the current procedures take in many countries. In some cases, it can take more than five years and up to ten years. They observed that often the testing procedures at the national level repeat what the CGIAR Centres have already accomplished. This repetition not only appears to be a waste of scarce resources but also holds up the process unnecessarily. Some breeders also questioned the capacity of certain states to make the current procedures function efficiently and to serve as a quality control that actually benefits farmers.

Another bottleneck identified by the interviewees is the rigidity of the DUS and VCU criteria and the costs involved in variety registration and seed certification. These two factors make variety release systems unfriendly for traditional cultivars and new varieties developed through PPB. PPB varieties, including those specifically developed to be able to adapt to climate change, remain outside the formal mechanisms of seed production and dissemination as well as benefit-sharing arrangements (Farm Seed Opportunities 2009; Ruiz and Vernooy 2012). The diffusion of products from PPB is also hampered by phytosanitary laws that are aimed at controlling varietal identity and purity as well as seed quality control mechanisms that check viability, purity and health (Halewood et al. 2007). Seed from such varieties does circulate among farmers through informal means, but the fact that they have not gone through the formal registration and quality control procedures puts them in a disadvantageous market situation. Such seed is neglected when the use of certified seed of registered varieties is either recommended by extension services, linked to credit facilities and subsidies or is obliged by the processing industry (Moseley, Carney and Becker 2010; Pascual and Perrings 2007; Tripp 1997).

The existence of a single officially recognized seed supply system that includes only these traditional approaches to variety recognition discourages the development of alternative mechanisms for seed supply for many of these varieties (Lipper et al. 2010). The end result is that seed preferred by farmers may not be available in sufficient quantities (Kastler 2005; Leskien and Flitner 1997; Louwaars 2002). The potential benefit of decentralized, participatory approaches for germplasm evaluation, selection and dissemination in communities and areas particularly exposed to climate vagaries can be significant. Any obstacle in the subsequent diffusion and upscaling of these efforts, starting with the complex procedures for seed certification, could reduce the advantages of these efforts. Some of the social scientists who were interviewed from IRRI, for example, mentioned that they have been facing this obstacle in some of their work (Manzanilla et al. 2011).

As noted earlier in this report, some projects are currently underway that will put into place variety and seed quality control mechanisms that also serve germplasm users in the informal sector of seed multiplication and dissemination. Different models have been proposed and tested to create a space for differing methods of seed production and supply. Keeping the formal system's original objectives of providing transparency and ensuring seed quality, these models are trying to address the information gaps commonly found in informal seed systems by regulating the commercialization of traditional and modern varieties in a way that better adapts to the needs of small farmers. The Quality Declared Seed System proposed by the FAO (1993) has been widely used in areas where seed markets are not functional and government resources are too limited to effectively manage comprehensive certification systems. Under this system, seed producers are responsible for quality control, while government agents check only a very limited portion of seed lots and seed multiplication fields. The system has been recently revised with the aim of recognizing the role of national policies and providing a clearer explanation on how quality-declared seeds can accommodate local varieties (FAO 2006).

The CGIAR Centres have been actively involved in policy processes aimed at adapting seed laws to national circumstances and experimenting and promoting alternative schemes of seed production, variety registration and seed certification. Centres started doing so before climate change appeared on the agenda. CIAT initiated such efforts in the second half of the 1990s in eastern Africa (David 2004; David, Kasozi and Wortmann 1997; David and Sperling 1999) and, more recently, in Ethiopia (Sperling and McGuire 2010). CIMMYT has made efforts in developing community-based seed production strategies in eastern and southern Africa (Setimela, Monyo and Bänziger 2004). At the regional level, the CGIAR Centres located in

Africa have played a facilitating and advisory role in the negotiations leading to seed law harmonization. The diffusion of varieties across regions may be limited by the country-specific seed certification rules. Efforts for regional harmonization are underway in several parts of the world. Through a participatory process involving the key stakeholders in various countries, a legal framework for the harmonization of seed legislation is being developed and subsequently adopted by the regional bodies. Once implemented at the country level, such regional agreements can ensure that an improved variety registered in one country is automatically considered to be registered in other countries within the same region. Thus, seed can be multiplied and sold in these other countries, potentially contributing to the more rapid dissemination of 'climate smart' material and practices across regions (Louwaars, Le Coent and Osborn 2010).

At the national level in Africa, Asia and Latin America, there are a number of examples of how the CGIAR Centres have engaged in policy dialogue in order to encourage institutional recognition of alternative varietal release and dissemination systems for given crops and contexts. In several countries, CIP has advocated for the use of 'true potato seed' and 'quality declared seed' (QDS) for ensuring quality in decentralized, efficient community-based tuber productions while avoiding the more complex and bureaucratic official procedures that would be impossible for small-scale seed producers to follow (Jayasinghe 1995; Kadian and Upadhya 1994). This work promotes the strengthening of informal seed systems (Thiele 1999), which is a recurring area of work shared by several CGIAR Centres (Thijssen et al. 2008; Tindimubona, Kakuhenzire and Hazika 2000; Tiwari et al. 2009). Within the collaborative RedLatinPapa project, CIP scientists have used policy dialogue with national authorities to obtain the acceptance of varieties obtained through participatory varietal selection and certified through the QDS system in the national varietal registry. An example is the Serranita potato. CIAT has experimented with the sale of small seed packs on a commercial basis in collaboration with, and under the auspices of, the Malawi's Bean Improvement Programme (Phiri et al. 2000).

Nepalese partners, in collaboration with Bioversity International, have managed to convince national authorities to apply the uniformity requirements of the *Nepalese Seed Act* in a 'soft' manner in order to accommodate the application of farmers for the registration of certain varieties developed through PPB together with traders and hoteliers in 2006 (Gyawali et al. 2010).[48] In Malawi, ICRISAT and its partners have convinced the government to buy and distribute improved groundnut and pigeon pea seeds produced by local, informal seed multipliers (Jones, Freeman and Lo Monaco 2002). It is a national seed-aid approach that creates local jobs, introduces better varieties and provides a positive incentive to grow the seeds (Rohrbach, Bishaw and van Gastel 1997). ICRISAT has undertaken lobbying efforts to improve the variety certification and release system in India. A case is the groundnut variety ICGV91114, which has encountered difficulties in being made available to publicly managed seed stores because of the subsidized regime that favours lower quality materials (Birthal et al. 2011). Specialists of ICARDA's Seed Unit have worked actively with its public partners to study the ways in which variety release procedures can be accelerated so that the private sector can have access to them quickly and can produce seed in a timely manner.

48 Nepalese Seed Act, <http://www.sqcc.gov.np/publications/the_seed_act_1988.pdf>. In order to enforce the Seed Act, 2045 the Government of Nepal formulated the "Seed Regulation, 2054" (1997).

4.6. Subsidies and their effects on germplasm availability

Subsidies are a form of incentive provided by a government or other institution to encourage individuals or organizations to engage in activities they may not otherwise undertake. Subsidies are a commonly used instrument to promote the adoption and diffusion of new agricultural technologies by lowering the initial risks and the cost of learning to use a new technology (Ellis 1992; Feder and Slade 1985). The effectiveness of subsidies to promote the adoption of a given crop or variety depends upon, among other things, the crop to which they are applied, the environmental context and socio-economic characteristics of the potential adopters and the policy and institutional context of the country or region (Dorward 2009). By overcoming temporary market failures, which offsets the fixed costs of infrastructure and reduces risk, subsidies can enhance the use of inputs (seeds of improved varieties, fertilizer, pesticides and credits) for increased agricultural production, which, according to some studies, may eventually contribute to poverty reduction (World Bank 2008). To date, it seems that no subsidy programs have yet been put into place to respond directly to climate change-related challenges in crop production and crop improvement.

Although there is no well-tested empirical evidence of the isolated effect of subsidies on germplasm diffusion and uptake, there is broad evidence of the cumulative effect of subsidies and other support measures on the dissemination of improved germplasm and its associated technology. Many examples can be found in the literature. Without public support in the form of incentives, information and infrastructure, the Green Revolution in Asia would not have been successful. The development and dissemination of hybrid rice technology in China has only been possible due to the strong policy support that was translated into public subsidies for seeds and related technologies. The diffusion of high-yielding varieties of wheat and rice, particularly in India and China, was made possible through strong policy support and investment in agricultural research and development (Lin 1990; Singh and Kohli 1997). Similarly, economic incentives, including subsidized seed and maize-based food prices, have been key in the adoption and dissemination of maize in Africa (Byerlee and Eicher 1997). More recently, the subsidized mini-kit program implemented by local governments in West Bengal, India, has helped the diffusion of enhanced germplasm of rice and other crops (Bardhan and Mookherjee 2011). Some breeders that were interviewed had positive impressions about the use of subsidies to support agricultural development. They mentioned, for example, a project initially launched by ICRISAT on the use of a technology package (machinery for drainage, seed and fertilizer) for the production of cereals in the Ethiopian Vertisols. This project reached its objectives only when the Ethiopian government started to subsidize the adoption of the technological package by farmers.

Subsidies can have perverse effects as well. Several studies in Africa have shown that the subsidized distribution of seed of major crops such as maize discourages seed enterprise development in the long term (Byerlee and Eicher 1997; Tripp and Rohrbach 2001). Subsidies are increasingly recognized to potentially hinder the demand for, and the use of, crop diversity in agricultural production. Such efforts could hamper adaptation to local climate change. Subsidies are generally provided for improved varieties of major cereals (rice, wheat and maize) through public distribution systems. This action often results in disincentives for farmers to cultivate other crops including those that their livelihoods depend on, such as small grains, legumes and tubers. Subsidies can also have a negative impact on the use of traditional varieties of such crops or of varieties developed through alternative breeding approaches.

Some studies show how in the Philippines widespread government subsidies in hybrid rice have distorted the ability of farmers to make an informed choice between growing hybrid and inbred rice varieties. The result has been the limited adoption of hybrid varieties, contrary to the original objective. The program has not only been ineffective but also costly in terms of wasting scarce budgetary resources. It has also compromised the government's regulatory functions and promoted corruption (Cororaton and Corong 2009; David 2007).

Interviewees confirmed that in several Asian and Latin American countries seed delivery and adoption patterns have been affected by complex public subsidy schemes, which are not exclusively aimed at the development of agriculture. For example, in Mexico, the poverty reduction program 'Opportunities' has influenced the way in which small farmers adopt and use both hybrid and traditional maize varieties in a variety of ways (Bellon and Hellin 2010). In India, traditional crops such as millet, sorghum and pulses, which are key for farmers' food security and climate change adaptation (for their hardiness and rusticity), are not covered by agricultural subsidies, while other crops are – for example, rice, wheat and maize. Seeds made available through national and state seed corporations are often subsidized by up to 50-60 percent of the market price and sometimes handed out for free. If seed of a variety developed or promoted by a CGIAR Centre and/or its partners is not picked up and disseminated through the state seed corporations, its higher, full-market cost will act as a significant disincentive to would-be consumers. Subsidies are also available for fertilizers, machinery, irrigation and other agricultural inputs. The national Indian program of subsidized food systems for the poor promote the consumption of foods based on wheat, rice, maize and sugar. According to the interviewees, it is having an indirect, negative impact on the demand for food based on improved varieties of pearl millet, sorghum, pigeon peas and so on. In this case, ICRISAT (and other CGIAR Centres) have joined in a national campaign to have foods from a wider range of regionally appropriate crops included in the nationally subsidized food program.

5.0. Synthesis of the main findings

This chapter summarizes the most relevant findings in relation to germplasm flows to and from the CGIAR gene banks and breeding programs in the context of climate and policy change.

5.1. CGIAR gene banks

Gene bank managers and breeders expressed skepticism about the sudden interest of donors and development agencies in climate change. They confirmed that many of the traits they have traditionally been interested in are related to abiotic stresses due to climate (change) factors. When pressed, however, many of them identified some priorities that are linked to recent climate changes in particular areas of the world. Most notably, interest in collecting and characterizing wild relatives of some crops is increasing in the hope of finding useful, so far undiscovered, traits of particular interest – for example, tolerance to extreme heat or cold.

The total number of new acquisitions by the CGIAR gene banks has experienced a downward trend. It is becoming increasingly difficult for most of the CGIAR gene banks to access new germplasm to include in their collections with the exception of materials from well-established gene banks in Europe and North America. Managers of the CGIAR gene banks report that joint missions with NAROs to collect genetic resources *in situ* for the CGIAR gene banks to conserve and distribute internationally have become a rarity. Some gene banks have on occasion received materials that they requested under legal conditions that are too restrictive to be accepted. Some countries will deposit new materials in selected CGIAR gene banks only if they agree not to redistribute them or to do so only to germplasm users in countries that are parties to the ITPGRFA. A number of national institutions are co-ordinating their own fairly extensive collecting missions, but so far very little (perhaps none) of the collected material appears to be available to recipients outside the countries concerned, including the CGIAR gene banks.

The gene bank managers attribute some of the difficulties they face to the political volatility of genetic resources issues, to inappropriate policy initiatives including national legislation on access and benefit sharing inspired by the CBD and to pressures to globalize intellectual property rights protection through international trade agreements. Some of the respondents thought that the ITPGRFA and its multilateral system of access and benefit sharing had gradually become more effective, following a slow start in 2007. Some thought that the Treaty might might be contributing additional challenges because of the perceived complexity of implementing the multilateral system at the national level or because the crops they wanted to access were not included in the multilateral system thereby increasing the felt need to subject access to those non-annex 1 materials to extra scrutiny and restrictiveness.

The relative importance of the lack of access to new germplasm appears to be tempered for some crops by the fact that (1) there is already considerable unexplored germplasm in the CGIAR Centres' gene banks or (2) the centres' breeders already have a fair amount of improved materials at their disposal. On the other hand, most of the gene bank managers confirmed that over time this diversity will not be sufficient to deal with new stresses that will occur, including those induced by climate change, particularly for some crops. Some of them expressed concern about this reality.

The level of sample distribution from the gene banks has experienced a gradual downward trend over the last 15 years in response to more targeted requests from recipients and the ability of the CGIAR Centres to better identify specific sample sets. Some CGIAR Centres are experimenting with new approaches to directly linking both the CGIAR and the national gene banks with farmers, with the latter becoming direct recipients and sometimes evaluators of germplasm. Examples include the MasAgro project in Mexico led by CIMMYT and the Seeds for Needs project carried out in Ethiopia and Papua New Guinea and led by Bioversity International. These projects represent novel and proactive ways to respond to climate change challenges. Respondents from a few of the centres expressed concerns about a possible recent trend (too early to be tested system wide) of decreasing distribution rates due to an unwillingness from would-be recipients to pay higher fees associated with the CGIAR's new policy for real-cost accounting to donors.

Gene banks appear to be at a crossroads right now. While the scene has been set to engage in an unprecedented level of global co-operation for the conservation and sustainable use of PGRFA, in practice the situation is largely static with many actors unwilling to assume more proactive roles. One of the challenges has to do with a continued reluctance on the part of many potential providers to make germplasm available. While some countries have been collecting significant amounts of new germplasm, they are not transferring significant rates of germplasm beyond their own borders, including to the CGIAR Centres. Another challenge has to do with a scarcity of resources. While some organizations and countries are willing to assume responsibility for activities such as internationally co-ordinated regeneration, characterization and multi-site evaluations, they do not have the resources to take on these roles. In the absence of globally co-ordinated (and supported) programs to contribute support for such activities, new actors are not emerging to volunteer for such responsibilities in co-operation with the CGIAR gene banks.

5.2. CGIAR breeding programs

The CGIAR Centres have been breeding improved materials in response to climate change-related stresses for a long time. Several breeders expressed skepticism about the felt need for donors and research and development organizations to suddenly put so much emphasis on climate change. Nonetheless, most of the breeders were able to identify some new breeding activities and the use of new technologies that were directly linked to climate change-related factors, such as increased drought, more extreme temperatures, more widespread flooding, higher levels of salinity and shifting patterns of pest and disease occurrence. The rationale driving these CGIAR breeding practices has not changed – the aim remains to develop targeted elite materials.

The CGIAR Centres' original and still very prominent crop genetic improvement operational strategy has been to do crossing/introgressions at their headquarters or regional breeding stations and then to send the improved materials to NAROs. NAROs with enhanced capacity are capable of using less developed materials and crossing them with locally adapted materials. NAROs without such capacities depend on the receipt of highly advanced materials from which they can make selections to be released as varieties.

In recent years, many of the centres have adopted new collaborative forms of germplasm development and diffusion involving various kinds of partners. Participatory approaches to crop improvement have made some inroads, particularly through PVS, in collaboration with NAROs and NGOs. Some of this work has a climate change adaptation focus.

Other centres are developing parental lines to be used by private companies for the development of hybrid varieties. Still other centres, in collaboration with NAROs, are working directly with farmers' organizations and NGOs to select the most useful material and have the quality seed of open-pollinated varieties (OPVs) multiplied and distributed to farmers. This work responds to the fact that both public and private sector actors in the countries concerned seem incapable of ensuring that quality seed reaches the targeted farmers. Several breeders reported that their recent partnerships with the private sector in the context of hybrid consortia are leading to uptake and diffusion of improved technologies that were not otherwise possible. Between these two strategies, a number of variations exist – for example, large research consortia in which the CGIAR Centres partner with public and private organizations, wherein public organizations are involved in developing and promoting OPVs and companies are involved in the development and diffusion of hybrids. These consortia with their wide range of partners and shared roles and responsibilities are occurring with increasing frequency.

Climate change adaptation strategies alone are not driving these changes, however. Instead, the changes are mostly brought about by the recent shift in international development culture towards achieving impact – the need to provide farmers with tangible, measurable ways to improve their production systems. The newly adopted CGIAR Strategic Results Framework with its commitment to 'managing for results' underscores the commitment of the CGIAR Centres to reforming their work along these lines.

The new (or increasingly relied upon) operational strategies bring the centres into contact (or increase their contacts) with a range of policy-related challenges. The new upstream research focus on development of technologies to be used and released by private companies requires them to strike delicate policy balances between providing incentives for private sector engagement and maintaining maximum public availability for the goods that the centres develop. In some cases, the centres and their partners appear to have struck a relatively easy balance. In other cases, there has been public controversy. Generally, the centres have not identified significant challenges associated with getting access to proprietary technology from companies and research institutions. Instead, most of the difficult intellectual property-related issues have arisen in those situations where the centres are providers of technologies to private sector companies.

The long and relatively difficult process to develop a CGIAR system-wide policy addressing these issues is testimony to their complexity and contentiousness. Now that the CGIAR Principles on the Management of Intellectual Assets (CGIAR IA Principles) have been accepted by the CGIAR Fund Council and the Consortium of CGIAR Centres, the outer parameters or limits on the kinds of arrangements the centres can make with private sector partners concerning the assignment of exclusive rights for centre-improved materials are at least clearer.[49]

49 The principles were approved by the Consortium Board on 1 March 2012 and by the Fund Council on 7 March 2012. They were made part of the Common Operational Framework as of 7 March 2012. Common Operational Framework, <http://www.cgiarfund.org/cgiarfund/common_operational_framework>

The increased downstream involvement of many of the CGIAR Centres in enhancing seed systems for the production and availability of quality seed brings increased exposure to national level policies (or lack thereof), which influences the success of these activities. Most of the relevant policies in this context concern variety registration, seed production, quality control and marketing and subsidies. Concerns exist about the limited dissemination of a wider portfolio of crop species, particularly those that tend to be hardier and more resilient to climate extremes. The centres involved in breeding these crops are developing closer interactions with (organized) farmers. In some cases, it has also led to the development of alternative variety release, dissemination and quality assurance schemes that involve small-scale seed producer groups and use informal channels of multiplication and exchange. A few examples from the various centres follow.

Many breeders expressed concerns about their inability to access (new) plant genetic resources. They stressed the difficulties related to getting access to, and using, materials from public research organizations or private companies, although the situation is different depending on the centre, the potential provider organization and the crop. Some breeders and officers in charge of intellectual property issues reported being sent materials subject to legal conditions that were so restrictive that the centre could not accept them. Breeders in some centres described the movement of germplasm as having become one way – always going out with nothing coming in.

The breeding programs have traditionally made their improved germplasm available to anyone who asks for it. Since 2007, they have used the SMTA, which was adopted for the exchange of germplasm included in the ITPGRFA's multilateral system of access and benefit sharing. Recently, some of the CGIAR Centres have started distributing materials that they have improved with terms and conditions additional to those of the SMTA, most often to private sector recipients through mechanisms such as the hybrid consortia.[50] These conditions include prohibitions on the ability of recipients to pass material on to third parties. Some companies and US universities have indicated their discomfort receiving materials from the centres under the SMTA, but, in general, there appears to be a fairly widespread acceptance of the use of the SMTA by recipients around the world. Flows of germplasm coming into and going out of both the CGIAR Centres' gene banks and breeding programs have been affected by phytosanitary requirements, which appear to have become stricter.

50 The SMTA explicitly states that providers can add complementary terms and conditions to those included in the SMTA when transferring 'PGRFA under development.'

6.0. Reflections and next steps

The findings indicate that the operations of the CGIAR Centres in the last decade have come under various forms of pressure, which, taken together, have led to the exploration of a number of new operational strategies. Climate change is one of the factors contributing to this pressure, but at least so far it has not (yet) radically changed gene bank and breeding priorities and approaches. In the context of adaptation to climate change, some concerns exist about how to assure the continued access to new diversity – in particular, of crop wild relatives – and allow the discovery and use of climate relevant traits.

Survey findings point to an increasing influence of international and national policies and legal frameworks on all of the operations of the CGIAR Centres from upstream to downstream levels. It appears that, broadly considered, recent changes in the policy environment are not having significant positive impacts on the efforts that the centres and their partners are making to continuously access and use plant genetic resources. This situation may, in the longer term, have a serious impact on efforts to adapt to climate change. However, degrees of concern expressed about this tendency vary considerably within the centres, within the breeding programs of individual centres and across the centres themselves. A very strong and common voice of concern did not need emerge from our study.

The CGIAR Centres have broadened their connections through new forms of co-operation with civil society organizations as well as with the private sector. In the case of the latter, this co-operation is taking place in the area of hybrid breeding in particular. Collaboration with the private sector seems to be one of the means by which the centres are achieving greater impact in terms of the diffusion of research results and products. Important new challenges have arisen, however, as a result of closer co-operation with the private sector, particularly concerning intellectual property rights.

A start has been made with a more systematic integration between social sciences, geographical and environmental sciences and crop research, as called for in the new CGIAR strategy. Climate change adaptation has yet to make it to the core of CGIAR programming. Some of the new tools under development could be instrumental in achieving this goal, but it would require, for example, the development of crop and environmental modelling to include complex regional and local climatic factors and disturbances. Another task ahead is the improvement of downstream efforts to increase the efficiency and effectiveness of delivery mechanisms in response to the very diverse needs of vulnerable farmers. The establishment of more rigorous mechanisms to provide feedback by farmers and other users also seems warranted in order to strengthen climate change adaptability. A spectrum of technology dissemination approaches can already be found across the CGIAR and within each of the centres, ranging from conventional (top-down and linear) to participatory (multi-stakeholder, decentralized), but a coherent strategy across centres is absent.

In order to complement this first phase of the study, we aim to research in the second phase the ways in which key actors, in particular breeders and national gene bank managers, are involved in national agricultural research and development, how they perceive new climate change-related germplasm challenges and how they draw on existing and/or new resources to respond and adapt to the evolving context. The national level study will be done in about 20 countries from around the world. The selection of countries will be based on a combination of a number of criteria, comprising, among others, the poverty level, the degree of exposure to climate change, the level of use of CGIAR gene bank materials and the level of use of materials from CGIAR breeding programs. Ultimately, by combining the results of the two phases, the goal will be to shed light on the roles of the CGIAR Centres as key nodal agencies embedded in internationally co-ordinated agricultural research and development *vis-à-vis* national-level efforts to respond to climate change.

Appendix 1: Survey instrument

General background and objectives of the study. The study we are undertaking as part of CCAFS aims to understand how germplasm is accessed, used and distributed by CGIAR centres and their partners, and how diffusion to final users is taken care of. We want to identify factors that facilitate or hinder access to, use and diffusion of germplasm by the centres and their partners, and, most specifically, policy-related barriers or, on the contrary, policy-related success factors. We are particularly interested in these issues in light of climate change, and the need to ensure that the centres and their partners have policy support for assisting farmers in adapting to climate change.

1. Breeding objectives and priorities (status and trends) – TO BREEDERS

Introduction. I'd like to ask you about the main breeding priorities and objectives in your area of work. This is useful for us to frame your work within the CG system and assess its climate change relevance (which will be further explored in subsequent phases of this interview).

MQ 1.1. Could you briefly explain the primary objectives of the current breeding work you do?

Optional probes (P):

- Are you selecting for specific traits? Which traits? OPT: How do you establish breeding priorities?
- OPT: What information do you have and from what sources, on farmers priorities, in order to orient breeding?

MQ 1.2. Would you say that your breeding objectives have changed over the past five years?

Probes (P):

- What has changed?
- What would you say are the primary reasons for these changes?

2. Partners (role, status and trends) – BREEDERS AND (partially, see *) UPTAKE SPECIALISTS

Introduction. I would now like to understand the typology of partners, any possible change in partners over the years (and reasons for that change) and their specific role in collaborative projects, with special respect to the contribution/exchange/release and distribution of germplasm.

** MQ 2.1. Could you give me an idea of which partners are usually involved in breeding projects and in the diffusion of the breeding results?*

Some breeding projects include partners from the private sector while others are from the public sector; they also vary in size. Please refer to key or illustrative projects, if useful.
P: Which are the largest partners?
P: Which factors affect the choice of partners and the establishment and continuation of partnerships?
P: What roles do your partners play? How do you work together to get the requisite work done?

** MQ 2.2. Would you say that the mix of partners has changed over the last five years?*

P: Have some new partners emerged?
P: Have some partners become more prominent, while others less prominent? Which ones? Why? Is this linked to the fact that the partners' roles are also changing?
P. [to be asked if respondent emphasizes new partnerships with private sector …] Did you initially have any concerns about increasing partnership with the private sector? What kinds of issues were you worried about? How did you address them? Is there a published document which sets out the policy or practices you have worked-out to address those issues?

** MQ 2.3. Has this affected:*

- Breeding priorities?
- The diffusion channels for the distribution of improved germplasm?
- The (level of) adoption of improved germplasm by farmers?

MQ 2.4. Each region of the world is different in terms of the typology of institutions involved in germplasm conservation, improvement, diffusion and use. How do differences between regions affect your modus operandi (i.e., breeding priorities, partners, research and development approaches and dissemination of improved material)?

3. Material exchange (among CG breeders and partners) – TO BREEDERS

Introduction. I would like to understand where the germplasm for breeding comes from and how germplasm exchange between breeders within and outside CIMMYT takes place.

MQ 3.1. For the breeding projects that you are involved in, which are the main sources of germplasm?

That is, does the germplasm mainly come from your working collection, that of other breeders (i.e., partners) involved in the project or international/national gene banks?
P: Has there been a change in the type of germplasm needed for breeding in the recent years?

MQ 3.2. Would you say that access to the germplasm you need has become easier, more difficult or about the same over the past 5 years? Why?

To better understand how formal agreements affect the exchange of germplasm and the work you do on breeding projects, we wanted to ask you about your experience with the SMTA.

MQ 3.3. How consistently would you say that the SMTA is used for materials received into the breeding programmes?

Does the use of an SMTA affect the availability of germplasm **into the breeding programme** (ease, quantity, quality)?

MQ 3.4. Has the frequency of SMTA for the use of these ***incoming materials*** *increased, decreased, or remained about the same over the past five years?*

- Does this affect partners and are some partners affected more than others?
- Are some types of projects affected more than others?
- What types of materials are (if any) more affected?

M.Q. 3.5. How do you deal with incoming material from non-Treaty member States or which have not been put – automatically or voluntarily - under the multilateral system?

MQ 3.6. Does your centre always send outgoing material under SMTAs? If not, when does it use some other instrument (hint: repatriation)? For what kinds of materials, in what kinds of relationships?

MQ 3.7. Has the centre's agreement with the Governing Body of the Treaty, and its use of the SMTA affected its ability to distribute materials?

- Does this affect partners/recipients and are some partners/recipients affected more than others?
- Are some types of projects affected more than others?
- What types of materials are (if any) more affected?
- Has the research partnership somehow limited the difficulties by partners in receiving materials under the SMTA?

MQ 3.8. In what ways, if any, should the SMTA be changed to better accommodate partners' needs or the needs of the projects?

4. IPR issues – TO BREEDERS AND IPR SPECIALISTS

Introduction. We would like to understand how intellectual property rights (IPR) issues on any of the product or inputs to your breeding projects may affect the release of materials and the adoption by final users. By IPRs, we are not only referring to intellectual property rights but also to contracts that may affect the terms and conditions under which you receive materials (including licenses and material transfer agreements (MTAs)) other than the SMTA under the Treaty.

If intellectual property or contractual (including MTAs and licenses) issues ever come up on the breeding projects you are involved in:

MQ 4.1. Please describe these issues and how they affect your ability to obtain needed germplasm or information inputs for your breeding projects?

P: Overall, would you say that IPR or contractual issues have an adverse, beneficial, or neutral effect in this regard?
P: How have you approached dealing with these problems?
P. Have there been any cases where you could not get what you wanted? Or where you did not even ask because you knew the 'owner' would not provide you access and the material was protected by a patent?

MQ 4.2. Please describe these issues and how they affect the breeding projects and the distribution and adoption of improved germplasm?

P: Overall, would you say that IPR or contractual issues have an adverse, beneficial, or neutral effect on the projects you do?
P: How have you approached dealing with these problems?

MQ 4.3. What criteria does your institution use to take decisions upon acquisition and/or distribution of material under any of these IPR or contractual issues? And what are the processes (if any) the institution undertakes in order to make these decisions?

MQ 4.4. Do you have any available experience of, example of, how partnerships and networks have helped breeders to overcome intellectual property and or contractually created barriers to get access to proprietary technology they need for their work?

P. Does it facilitate getting access to materials if you have an established relationship with the person or organization you are requesting materials from?
P. In particular, are your new partnerships with private partners in research and breeding projects helping you to gain access to technologies you could not have accessed before? If yes, can you provide an example?

MQ 4.5. Is there any way in which climate change is affecting the pattern of IP protection, patents and contracts (including MTAs and licenses) in your work experience?

P. If needed: for example has it incremented protection over technologies that are potentially useful for climate change mitigation or adaptation or by putting more pressure over patent holders to license users of such technology? Or suddenly are proprietary owners more proactive in making such materials available since they can be part of higher profile climate change related programs?

5. Diffusion strategies – TO BREEDERS AND UPTAKE SPECIALISTS

Introduction. We would like to understand how your improved germplasm, or material it has developed in partnership with others, is eventually distributed to final users and which factors you perceive or know to be most likely affecting success or failure of germplasm diffusion efforts (downstream surveys will follow involving intermediate organizations).

MQ 5.1. How is the improved material generated by the centre on its own, or in partnership with partners, eventually made available to farmers? What are the regular dissemination channels? If useful, please describe illustrative projects, strategies, regional patterns.

> P. It is my understanding that in most cases, centres transfer improved material (still under development) to national agricultural research organizations (NAROs) on the understanding that the NARO will ultimately finish the development of whatever cultivars are eventually released. Or alternatively, the centre transfers finished materials for multi-location testing by the NARO. In both such cases, is it generally agreed that it is the NARO that will take responsibility for diffusing those cultivars (through whatever mechanisms they choose)? Would you say that most of the material improved by your centre is distributed in this fashion – that is, from you, to the NARO, to farmers through mechanisms co-ordinated by the NARO? What proportion, either in terms of centres' resources dedicated, or germplasm actually distributed, is distributed by the centre by this means (roughly, could you say it's very little, around half, more than half, basically all)?
>
> P. In other cases, I understand breeders engage in initiatives that facilitate participation of farmers in the development of improved germplasm, and the centre supplies farmers directly with improved material? (e.g., farmers' field days, participatory breeding, participatory variety selection, seed fairs and other). What proportion, either in terms of centres' resources dedicated, or germplasm actually distributed, is distributed by the centre by this means?P. Same line of question with respect to partnerships with private sector. Does the centre leave it to the private sector partner to diffuse? What proportion overall?
>
> P. Are there other mechanisms for diffusion that we have not discussed so far?

MQ. 5.2. To what extent does the centre take into consideration the dynamics of informal seed systems and attempt to make use of them to disseminate new germplasm among farmers? Is there any example you could share?

> P. This would clearly be part of your strategy when you have farmer field days, for example. You expect them to share material and knowledge informally with other farmers, and so on. What about in other situations? Do you know what your NARO partners are doing *vis-à-vis* exploiting informal seed systems to get materials diffused?
>
> P. Do you have information concerning varieties that were picked up by farmers in testing activities and subsequently widely used by farmers, but which were not formally released in national system (due to perceived poor performance or other reasons)?

MQ 5.3. Do you have any sort of feedback system – that is, any way of receiving information on whether the materials generated have been adapted to the environmental conditions in farmers' fields and socio-economic context?

MQ 5.4. What factors affect the distribution of your improved material and its adoption by final users? In your experience, are there key factors influencing the success or failure of diffusion efforts?

> P. Do existing policies affect the distribution and adoption of your improved germplasm by farmers? How (e.g., variety registration and seed certification systems, agricultural subsidy schemes, phytosanitary regulations, IPRs and so on)?
> P. With respect to the different diffusion models we discussed above, do you have information about factors (including policies) that affect NAROs' ability to diffuse CGIAR materials or materials they developed that incorporates with CGIAR material? How about for materials disseminated by private sector partners? How about by farmers when the centre gives it to them directly?

MQ 5.5. Has the centre developed a promising line that didn't get distributed? If you have had such an experience, can you tell me what happened?

MQ 5.6. In your knowledge, how much lobbying and advocacy efforts does the centre enter into to promote the adoption of its germplasm and technologies? How much is the centre involved in lobbying efforts at the highest levels (i.e., with Ministries of Agriculture, big donor agencies and so on)? Has this changed with respect to the past? Does the change in type of donors require more or less of this kind of work?

MQ 5.7. Have the diffusion strategies and channels changed in the last decade? What are the reasons?

> Have changes in the institutional arrangements, implemented policies or other policy aspects in the partner countries influenced your choice of diffusion strategies and/or the effectiveness of the diffusion strategies?

MQ 5.8. In your opinion, what needs to be done to improve the dissemination and adoption of your improved germplasm?

MQ 5.9. (TO BE ADDED TO THIS SECTION ONLY DURING THE INTERVIEW WITH UPTAKE SPECIALISTS*, to include climate change issues since not all climate change questions that follow are relevant to this interview). In your opinion, do the effects of climate change influence your diffusion strategies?*

6. Climate Change – TO BREEDERS

Introduction. Now I would like to direct the discussion to the effect that climate change is having on your work. While the term climate change is often used broadly, I would like to address the specific ways in which climate change may be affecting your work.

MQ 6.1. In your opinion, do the effects of climate change influence your breeding priorities?

Is it a substantive effect, on:

1. types of projects
2. research objectives
3. types of partners
4. sources of germplasm
5. sources of funding (donor strategies oriented to CC research)

More 'symbolic' or bureaucratic – that is, on:

- project labels or categories

MQ 6.2. Has climate change increased the demand for certain types of germplasm such as wild relatives or landraces from areas with extreme weather conditions? Has it changed the sources of germplasm as well?

P: If so, are you encountering difficulties in getting access to such germplasm? What kind of difficulties?
P: Which measures can you suggest to facilitate the access to, and exchange of, germplasm necessary for climate change-oriented breeding?

7. Role of the gene bank in accessing/providing material for breeding – TO GENE BANK MANAGER

Climate change issues are included as from the beginning, given the shorter length and complexity of this interview.

MQ 7.1. What kind of materials are you most interested in acquiring to conserve in the gene bank? Why (e.g., greater demand for a certain type of material (cwr/landraces/...) and/or material with specific traits from breeders)? Does this represent a change from the kinds of materials you have been interested in in the past? Is your shift in priority linked to climate change?

MQ 7.2. What kinds of materials are most requested by users from the gene bank (e.g., greater demand for a certain type of material (CWRs/landraces/...) and/or material with specific traits? Does that represent a change from the kinds of materials you have been interested in the past? Is your shift in priority linked to climate change?

MQ 7.3. Are there political reasons or regional patterns causing variation in your capacity to access new germplasm (closure of some countries to collection/material exchange)? Do partnerships and relations of trust help?

MQ 7.4. Do you feel that recent developments in international and national laws and policies are making any difference in your capacity to access new material for the gene bank and for your breeding needs?

MQ 7.5. Do you feel that recent developments in international and national laws and policies are making any difference in your distribution of material? Please refer, among others, to the use of the SMTA.

MQ 7.5. Do you feel that recent developments in international and national laws and policies are making any difference in your distribution of material? Please refer, among others, to the use of the SMTA.

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