Assessing the potential for monetary payments from the exchange of plant genetic resources under the Multilateral System of the International Treaty on Plant Genetic Resources for Food and Agriculture

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Identifying Benefit Flows

Studies on the Potential Monetary and Non-Monetary Benefits Arising from the International Treaty on Plant Genetic Resources for Food and Agriculture

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Studies on the Potential Monetary and Non-Monetary Benefits Arising from the International Treaty on Plant Genetic Resources for Food and Agriculture

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Note to the reader

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Study 1 – Drucker, A. and Caracciolo, F. (2012). *The economic value of plant genetic resources for food and agriculture.*

Study 2 – Stannard, C., Caracciolo, F. and Hillery, P. (2012). *Modelling payments to the Benefit-sharing Fund, resulting from the Standard Material Transfer Agreement.*

Study 3 – Srinivasan, C.S. (2012). *Assessing the potential for monetary payments from the exchange of plant genetic resources under the Multilateral System of the International Treaty on Plant Genetic Resources for Food and Agriculture.*

Study 4 – Oldham, P. and Hall, S. (2012) *Intellectual property, informatics and plant genetic resources.*

Study 5 – Guiramand, M., Moeller, N. and Marino, M. (2012). *Plant breeding and the use of the Standard Material Transfer Agreement: consultation with plant breeding experts.*

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Abbreviations and acronyms

Annex 1 crops	List of crops covered under the Multilateral System of the International Treaty on Plant Genetic Resources for Food and Agriculture
CGIAR	Consultative Group on International Agricultural Research
CIMMYT	International Wheat and Maize Improvement Centre
EPO	European Patent Office
EPC	European Patent Convention
EU	European Union
FAO	Food and Agriculture Organization of the United Nations
GM	Genetically modified
HYV	High-yielding variety
IARC	International Agricultural Research Centre
IITA	International Institute of Tropical Agriculture
IPR	Intellectual Property Rights
IRRI	International Rice Research Institute
ISF	International Seed Federation
ITPGRFA	International Treaty on Plant Genetic Resources for Food and Agriculture
MLS	Multilateral System of the International Treaty on Plant Genetic Resources for Food and Agriculture
MLS-PGR	Plant genetic resources included under the Multilateral System
MV	Modern variety
NARS	National Agricultural Research System
OPV	Open-pollinated variety
PBR	Plant breeders' rights
PGR	Plant genetic resources
PVP	Plant variety protection

SMTA	Standard Material Transfer Agreement
SMTA-PGR	Plant genetic resources exchanged under Standard Material Transfer Agreements
SoWPGR	Report on the State of the World's Plant Genetic Resources for Food and Agriculture (FAO)
SRR	Seed replacement rate
TRIPS Agreement	Agreement on Trade-Related Aspects of Intellectual Property Rights
UPOV	International Convention for the Protection of New Varieties of Plants
WTO	World Trade Organization

Preface

Plant genetic resources (PGR) for food and agriculture are the basis of world food security. Access by farmers and plant breeders everywhere to the widest possible range of plant germplasm is of crucial importance for crop improvement, for confronting environmental and agricultural challenges such as climate change, and for ensuring economic and social development as well as food security for a world population expected to reach 9 billion people by 2050. In this context, the Conference of the Food and Agriculture Organization of the United Nations (FAO) adopted the International Treaty on Plant Genetic Resources for Food and Agriculture ('the Treaty') on 3 November 2001, following seven years of negotiations. The Treaty, which came into force on 29 June 2004, establishes a binding international framework for the conservation and sustainable use of PGR for food and agriculture, and the fair and equitable sharing of benefits arising from their use. As of 1 April 2013, the Treaty had been ratified by 127 states.

As coherent international policy architecture for the conservation, sustainable use and exchange of resources fundamental to food security, the Treaty makes a sizeable, direct contribution to world economic growth and social welfare. However, accurate quantification of the Treaty's economic benefits and an assessment of its full economic potential have not so far been attempted because of the complexity of this task. The full economic potential of the Treaty, including its many non-monetary benefits and its overall impact on social welfare, needs to be better understood.

In particular, no methodology has been developed to date to provide a preliminary projection of funds likely to result from the exchange of PGR for food and agriculture under the Standard Material Transfer Agreement (SMTA), the centrepiece of the Treaty's Multilateral System of Access and Benefit-Sharing ('Multilateral System'). Because of the uncertainty regarding the Treaty's overall economic impact and especially the resources that are likely to become available to the Treaty's Benefit-sharing Fund in the short and medium term, the Government of Australia decided to support an innovative research project entitled "Identifying the potential monetary and non-monetary benefits arising from the utilization of plant genetic resources under the Multilateral System of the International Treaty on Plant Genetic Resources for Food and Agriculture".

The research undertaken in the project focuses on laying methodological foundations, assessing the adequacy of current data sources, and identifying potential new data sources that could be utilized or modified for quantifying benefits flowing from the Treaty. Five interlinked technical studies were prepared between July 2011 and March 2012 by a team of experts from various disciplines. This is the first systematic step towards delineating in economic terms the potential magnitude of monetary benefit-sharing and assessing the importance of non-monetary benefits arising from the use of PGR for food and agriculture. Moreover, they provide a first hypothetical projection of possible income over time to the Treaty's Benefit-Sharing Fund.

Together, the five studies initiate the capacity for an ongoing analysis of volume and trends relating to the exchange and use of PGR for food and agriculture under the SMTA. The mathematical algorithm that was developed to project possible income to the Benefit-sharing Fund is a flexible methodology, where the various elements of the model can be manipulated to create a variety of scenarios and to test factors such as the relative value of the PGR currently listed in Annex 1 of the Treaty and other PGR for food and agriculture, resources held by Contracting Parties and by countries that are not Contracting Parties, and resources held by the Consultative Group on International Agricultural Research. It can also evaluate the relative importance of mandatory and voluntary payments, in accordance with the SMTA, and the effects of breeders choosing to use or avoid the use of SMTA materials. While it is crucial to note that the model's predictions are strictly hypothetical and based on data of unequal quality, the articulation of the various factors that need to be evaluated and the relative values that the model generates are a major contribution to understanding the Treaty's potential. A further important outcome of the project is that it provides an estimate of the value of the current international seed market. Here, a number of methodologically innovative analytical tools have also been developed. Access to a high-end computing facility at Lancaster University, United Kingdom has enabled large-scale querying of multiple databases and associated text mining, which has resulted in the refinement of digital methods available for the generation of statistics regarding PGR for food and agriculture cited in patent applications, with the specific aim of generating data for monetary and non-monetary benefit quantification.

The studies brought together in this book aim to provide quantified information to Treaty stakeholders and the wider interested audience to help understand the economic dimensions of the Treaty as a whole and the Multilateral System and its benefits in particular. While the results are indicative due to the data limitations, the research has clearly demonstrated the utility of economic and quantified approaches to understanding the Treaty; they offer a foundation on which, it is hoped, other scholars will be tempted to build.

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Executive summary

The International Treaty on Plant Genetic Resources for Food and Agriculture (the 'Treaty') makes a sizeable, direct contribution to world economic growth through the establishment of a coherent international policy architecture for the conservation, sustainable use and exchange of resources fundamental to food security. The Treaty's Multilateral System of Access and Benefit-Sharing and its Standard Material Transfer Agreement (SMTA) make it the first international instrument to provide a practical method of access and benefit-sharing, facilitating the exchange of genetic resources of 64 crucial food crops and forages (Annex 1 crops) without the need for complex bilateral negotiations.

In June 2006, the Treaty's Governing Body adopted the SMTA, and since then, a large number of SMTAs have been entered into. However, at the time of writing, no payments have been made to the Benefit-sharing Fund in accordance with the provisions contained in the SMTA, and the picture of possible income for the Benefit-sharing Fund under the SMTA remains unclear. Moreover, no methodology has been proposed to provide the Governing Body with a preliminary projection of funds likely to result from the exchange of plant genetic resources (PGR) for food and agriculture under the SMTA. Furthermore, the full economic potential of the Treaty, including its wide non-monetary benefits and overall impact on social welfare, needs to be better understood.

This book presents the findings of five interlinked technical studies carried out with the financial support of the Government of Australia to address the present uncertainty about the overall economic impact of the Treaty and, in particular, regarding the resources likely to become available to its Benefit-sharing Fund in the short and medium term. Due to data constraints and resource limitations, the studies were forced in many instances to work with proxies and estimates, and as such are best understood as paving the way for further work in this highly underdeveloped field of inquiry.

Chapter 1 provides an overview of both the conceptual bases for assigning economic values (monetary and non-monetary) to PGR for food and agriculture, and the existing methodologies for establishing such values. ***Chapter 2*** comprises an economic analysis of the values of global seed production and their distribution across crops, regions and countries in order to provide estimates for potential monetary flows as well as the overall value levels used in the mathematical model of ***Chapter 3***, which constitutes the core of this book, modelling potential flows of income into the Benefit-sharing Fund. ***Chapter 4*** develops and tests informatics methodologies that make possible large-scale computational analyses of patent and other databases. Its aim is to assess the commercial use of material brought under the terms and conditions of the SMTA, and to value and quantify non-monetary benefits. The ***Annex***

presents the results of a preliminary expert consultation of the plant-breeding community that was carried out through interviews and questionnaire surveys.

Quantification of the Treaty's non-monetary benefits is complex. Methods to assess the non-monetary benefits in question are under development, but need refining. Assessing potential monetary benefit flows arising from the use of the SMTA is equally difficult, especially given the lack of relevant experience and adequate data. The SMTA was only adopted in 2006, and the build-up of a steady stream of monetary benefits will take many years, not only due to the slow nature of plant breeding, but also because a large number of Contracting Parties have not yet made all or part of their PGR available under SMTAs. Moreover, the unpredictability of technological development in plant breeding further complicates projections over the long period of time that is involved for the Treaty's full potential to be reached.

For best possible results given the constraints, a pragmatic approach to the estimation of the flow of income to the Benefit-sharing Fund has been chosen. This approach is based largely on past data drawn from use of Consultative Group on International Agricultural Research (CGIAR) materials (see Chapter 2), and a mathematical modelling approach (see Chapter 3) employing estimates provided by the other studies. Time and resource constrictions forced the authors to limit their focus to a few important crops for which information was available and easily accessible. The crops chosen were wheat, maize and rice, but other Annex 1 crops and non-Annex 1 crops were also investigated as groups.

Key findings

The Treaty's overall economic benefits are extensive and reach far beyond the commercial value of PGR for food and agriculture. Through the promotion of the conservation and sustainable use of PGR for food and agriculture, the Treaty has a direct impact on social welfare and contributes to non-monetary benefits such as climate change adaptation and food security, which underpin the very continuation of human civilization. Moreover, mobilization by the Treaty of international-level *monetary* benefits translates into *non-monetary* goods and services at the national or local level through projects supported by the Benefit-sharing Fund.

With a view to establishing broad orders of magnitude of potential benefit flows, Chapter 2 established an upper bound level of US$97 million as a reasonable estimate for annual payments into the Benefit-sharing Fund arising from SMTAs. These levels will not be reached for many decades. Even under the most favourable conditions (e.g. fully effective participation by Contracting Parties, participation of more countries in the Treaty, full compliance with voluntary payment stipulations, and no deliberate avoidance of use of material from the Multilateral System in institutional breeding programmes), payment flows will not surpass this bound within a foreseeable timeframe.

Chapter 3 uses a different methodology for estimating monetary benefits and estimates the likely speed with which they will build up. It suggests that maximum levels will not be reached until the 2080s. The model shows that even without expansion of Annex 1, the estimated annual return by 2030 could reach $24 million, at a relatively high level of effective voluntary payment, if current members make all their resources available immediately. The projection based on material currently known to be available, however, is only $10 million. If all potential members had already joined the Treaty, $39 million annually might theoretically be available in 2030.

Benefit flows are contingent on a range of factors, including some of the following important ones:

Treaty membership: The participation of more countries in the Treaty (especially countries with major gene bank holdings, such as China, Japan and the United States of America) would substantially enhance the potential level of benefit-sharing flows.

Effective performance: Although the Multilateral System covers nearly two-thirds of global *ex situ* holdings of Annex 1 crops, its utilization in crop improvement programmes is constrained by a lack of effective access to resources held by Contracting Parties and by inadequate characterization and evaluation information on the accessible resources. To date, a large number of Contracting Parties have failed to make all or part of their PGR available as stipulated by the Treaty. More effective participation by Contracting Parties, including making the necessary legal and administrative arrangements for access to PGR for food and agriculture, need to be made to optimize benefit flows. In addition, improving germplasm collection, conservation and characterization efforts would increase possible income levels of the Benefit-sharing Fund, and the rate at which they build up.

Intellectual property choice and effective payment rates: Benefit-sharing provisions apply in cases in which material accessed under an SMTA has been incorporated into a commercial plant variety. In such cases, mandatory payment of 1.1 percent (minus 30 percent) of the income from seed sales of the variety in question is required (under Article 6.7 of the SMTA) when the new variety is restricted with regard to further research and development, such as when a patent protects the product. In the event that the product is not subject to intellectual property protection and may be freely used without restrictions in the development of follow-on products, payment is voluntary (under Article 6.8 of the SMTA). No level of payment is stipulated in such cases. Evidence from the initial survey of plant-breeding experts (see Annex) suggests that voluntary payments are in practice likely to be minimal at best. In strategic terms, voluntary payments by one company, which competitors avoid, would create uneven competition and a market disadvantage. Lack of certainty regarding the intentions of competitors creates a situation in which companies hesitate to be the first to make payments. The magnitude of potential income to the Benefit-sharing Fund is acutely contingent on institutional arrangements that incentivize a high level of voluntary payments.

SMTA use and avoidance: Different institutional players may have different propensities for requesting and using materials from the Multilateral System for their breeding programmes. Private sector institutions that seek to appropriate returns from their innovations may be inclined to avoid the use of materials subject to SMTA conditions that would force them to make payments to the Treaty's Benefit-sharing Fund. This is particularly the case when products are brought under patents, due to the mandatory nature of the payments required. The avoidance of materials under SMTA conditions is, however, not necessarily related to financial decisions, but must also be viewed in the light of technical process: the difficulties of documenting all ancestral materials throughout the many crosses in breeding populations may affect overall willingness to use material under SMTA conditions. Moreover, plant genetic materials are of little use to breeding programmes unless passport data and characteristic information on agronomic traits, agro-climatic adaptability, and susceptibility to diseases and pathogens is available and accessible. The use of materials under the Multilateral System will depend on the extent to which such critical information is accessible to potential users. This may vary by crop, country and institution hosting the collection. Even large, diverse and accessible collections may not be utilized unless supported by available, relevant information. Making the use of materials under SMTA conditions more attractive would enhance benefit-sharing flows.

Research intensity: In using grants of PVP certificates for different crops as a measure of research intensity in developed countries, it has been revealed that non-Annex 1 crops account for two-thirds of all PVP certificates. The coverage of crops in Annex 1 of the Treaty, therefore, omits nearly two-thirds of research efforts in plant breeding from its purview. Research effort into non-Annex 1 crops and resulting innovations will not translate into benefit-sharing payments. The share of Annex 1 crops in research effort has also been declining; their share in PVP certificates declined from 75 percent in the 1960s to less than a third in 2010. Over time, the share of plant breeding research effort has increased for non-Annex 1 crops due to increased research over the last two decades on crops that are not included in Annex 1, such as soybean, cotton and sugarcane. The share of these crops in the value of the global commercial seed market is also increasing. The limited coverage of crops currently included in Annex 1, not including certain major crops that have attracted considerable research effort in recent years, severely constrains the potential for generation of benefit-sharing payments through the exchange of PGR under SMTAs.

Based on the preliminary results of the mathematical model, which projects benefit flows according to alternative future scenarios, a key conclusion of this work is that the potential income to the Benefit-sharing Fund is high, but that projections based on current arrangements are low. Obstacles to substantial success, in particular avoidance of SMTA materials and low level of voluntary payments, are very real.

Maize plays a key role in potential income to the Treaty, as it is currently the main crop to attract mandatory payments. Avoidance practised by breeders of transgenic maize varieties would proportionally reduce the only significant mandatory source of income. Coupled with a failure to make substantial voluntary payments, the projected income to the Treaty would vanish.

Finally, the results of the mathematical model suggest that, even under favourable assumptions, the initial build-up of income will be slow. With present membership and availability it will take a minimum of 38 years to reach the current fund-raising target. Even under two very favourable sets of assumptions – that all members immediately make available all their material and that voluntary payments reach the same predictability as mandatory payments; or that all potential members immediately join the Treaty and make available all their materials, and voluntary payments reach a 50 percent level – it would take approximately 15 years to reach the current annual fund-raising target of US$23 million set by the Governing Body for the Benefit-sharing Fund.

Introduction

Background

Access to a rich diversity of PGR for food and agriculture may be more important today than it has ever been. Conservation and development of these genetic resources play a crucial role in confronting serious environmental and agricultural challenges such as climate change, and in ensuring current and future food security for a growing world population. Whereas broadening the genetic resource base allows farmers to successfully address changing climatic conditions, and protects and improves the livelihoods of the economically marginalized,[1] genetic erosion increases household vulnerability to pedoclimatic stresses and world crop price fluctuations, undermining the stability of rural household livelihood, especially in developing countries.[2] And yet, genetic erosion of these resources continues worldwide.

By promoting the conservation and sustainable use of PGR for food and agriculture, the International Treaty on Plant Genetic Resources for Food and Agriculture (hereinafter 'the Treaty'), adopted by the Conference of the Food and Agriculture Organization (FAO) of the United Nations in 2001 and in force since 2004, contributes to food security and agricultural resilience, both of which underpin the very continuation of human life and society. By aiming to establish a global system to provide access to plant genetic materials, the Treaty supports farmers, plant breeders and scientists in their crop improvement work for an optimal adaptation to unpredictable environmental changes and future human needs.

Although the scope of the Treaty covers *all* PGR for food and agriculture,[3] it has established a special regime of *facilitated access* for, at present, 64 food crops and forages listed in its Annex 1 (hereinafter referred to as 'Annex 1 crops').[4] This regime, known as the Multilateral System of Access and Benefit-

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1 See, for example, Asfaw and Lipper, 2011.

2 This has been clearly shown through studies such as Gore, 2002 and Thrupp, 2000.

3 Treaty Article 3.

4 These crops have been chosen based on criteria of food security and interdependence (Treaty Article 11). The list also reflects a number of other factors, important among which are: (i) the historical legacy of crop genetic resource exchange between regions and countries dating back to Neolithic times; (ii) the international exchange regime for plant genetic resources for food and agriculture, and paradigms prevalent prior to the International Treaty and the Convention on Biological Diversity (particularly, the International Undertaking on Plant Genetic Resources); (iii) international collaboration on agricultural research facilitated by the IARCs of the CGIAR; and (iv) the progressive application of intellectual property rights with regard to plant variety innovations over the last four decades in developed countries, and the extension of intellectual property regimes in developing countries following the Trade-Related Aspects of Intellectual Property Rights (TRIPS) Agreement under the WTO. Finally, the provisions of the Treaty defined the boundaries of the Multilateral System, representing the outcome of an extended and

Sharing (hereinafter referred to as the 'Multilateral System'),[5] considers the materials listed in Annex 1 to form part of a common pool shared by Contracting Parties and the entities under their jurisdiction.

The world's *ex situ* collections of PGR for food and agriculture are distributed among national and international gene banks, and other institutional repositories. The provisions of the Multilateral System apply to all Annex 1 crops held either by Contracting Parties or in trust by international institutions that have signed Treaty Article 15 Agreements. International institutions are obliged to make certain non-Annex 1 holdings available, in accordance with Article 15.1b. Both these sets of materials are available free of charge and without any other condition for access with the exception of the acceptance of a Standard Material Transfer Agreement (SMTA).

The SMTA is a private law contract between the provider and the recipient of the material in question, and sets the terms and conditions for benefit-sharing, which take both monetary and non-monetary forms. Benefit-sharing is not only a way to achieve the Treaty's objectives through the funding of sustainability and conservation projects, but is also understood as a matter of equity.

The Multilateral System and its SMTA make the Treaty the first international instrument to provide a practical method of access and benefit-sharing, facilitating the exchange of genetic resources of Annex 1 crops without the need for complex bilateral negotiations.

The material distributed to individuals or institutions under the terms and conditions of the SMTA can be used in plant-breeding programmes (public or private), some of which may be incorporated into a new plant variety as part of its parentage. A number of new plant varieties thus developed will enter the market as commercial products, very often protected by intellectual property rights. In certain cases, utility patents are used for new plant varieties, in particular if these are also transgenic. More often, however, plant variety protection (PVP) is sought, although it is possible that a commercial variety may be released without being subject to any form of intellectual property protection.

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complex political negotiating process (Frison *et al*., 2011).

5 Part IV of the Treaty, Articles 10–13. The Treaty has now been recognized as a constituent instrument of the Nagoya Protocol on Access to Genetic Resources and the Fair and Equitable Sharing of Benefits Arising from their Utilization (ABS) to the CBD: *"The international regime is constituted of the Convention on Biological Diversity, the Protocol on Access to Genetic Resources and* the Fair and Equitable Sharing of the Benefits Arising from their Utilization, as well as complementary instruments, *including the International Treaty on Plant Genetic Resources for Food and Agriculture* and the Bonn Guidelines on Access to Genetic Resources and Fair and Equitable Sharing of the Benefits Arising out of their Utilization" (emphasis added) (UNEP/CBD/COP/10/Decision VII/19 D, 4th recital). Annex 1 to the Decision (the Protocol itself), in this regard, Recital 15 recognizes the "interdependence of all countries with regard to genetic resources for food and agriculture as well as their special nature and importance for achieving food security worldwide and for sustainable development of agriculture in the context of poverty alleviation and climate change and acknowledging the fundamental role of the International Treaty on Plant Genetic Resources for Food and Agriculture."

The SMTA provides for monetary benefit-sharing when material accessed under an SMTA has been incorporated into a commercial plant variety. The payment provisions are stipulated in the SMTA itself: Article 6.7 provides for a mandatory annual payment of 1.1 percent, less 30 percent, of the total sales of any product or products that are not "available without restriction to others for further research and breeding". Article 6.8 provides for a voluntary payment in the case of any product or products that are "available without restriction to others for further research and breeding", and the Treaty does not state what the expected level of such payments is. Under its Article 6.11, a recipient may opt for an alternative payment scheme, at the time of receiving an SMTA, for a specific crop or crops, whereby an annual payment is due for any product or products of this crop, independent of whether or not these are available without restriction. The rate of payment is 0.5 percent of sales. The SMTA is an unusual contract in that it creates a beneficial interest for the Treaty (rather than for the provider), which provides for payments to the Treaty's Benefit-sharing Fund on commercialization of "a product that is a plant genetic resource for food and agriculture and that incorporates material accessed from the Multilateral System" (Article 13.2d(ii)). The Benefit-sharing Fund forms part of the Treaty's Funding Strategy, whose overarching aim is to mobilize funds "for priority activities, plans and programmes, in particular in developing countries and countries with economies in transition" (Article 18) in order to assist farmers in conserving and sustainably using plant genetic resource for food and agriculture, with a particular focus on adaptation to climate change. Furthermore, the SMTA enjoins the recipients of material to share *non-monetary* benefits resulting from research and development carried out on the material through "the exchange of information, access to and transfer of technology, [and] capacity-building" (Article 13.2).

The wider economic benefits of the Treaty, however, reach far beyond the monetary and non-monetary sharing of benefits stipulated by the SMTA. In particular, it is important to note that access – the very basis of crop improvement, and crucial for sustainable economic and social development and food security – "constitutes in itself a major benefit of the Multilateral System" (Article 13.1). By defining access as a major benefit in itself, the Treaty makes clear that its economic impact is wider than the commercial benefits that access generates. Access under the Treaty expressly encourages the greatest possible use of PGR in plant breeding, which impacts positively on food security, sustainable agricultural development and wider economic growth. Moreover, the Treaty provides for the development of PGR networks (Article 16) and a global information system on PGR for food and agriculture (Article 17).

As the first international instrument to provide a functional mechanism for multilateral benefit-sharing, the Treaty promotes an institutional policy harmony with direct economic benefits. As a multilateral instrument, it expands the range of beneficiaries to whom benefits flow and thereby differs fundamentally from bilateral institutional arrangements such as the Convention on Biological Diversity, or CBD. "Access and Benefit-Sharing" under the CBD invariably amounts to an exclusive bilateral use licence, with monetary payment to the provider of materials, who constitutes the ultimate beneficiary. Under the Treaty, both access and monetary benefit-sharing are multilateral. Materials from the Multilateral System may be accessed as a non-rival good, and monetary benefits paid to the Benefit-sharing Fund are transformed through the projects it funds as a cascade of non-monetary benefits that reach a wider set of beneficiaries.

While the commercial value of PGR for food and agriculture has been shown to constitute only a relatively small component of its total economic value,[6] a certain part of this commercial value can be expected to flow into the Benefit-sharing Fund of the Treaty, and thereby directly contribute to furthering its objectives through projects aimed at the conservation of PGR for food and agriculture and sustainable practices for their use. A reliable prediction of the magnitude of these flows would help with the strategic planning and agenda setting of the Governing Body with regard to implementation of the Treaty and its Funding Strategy. The studies brought together in this book constitute the first steps toward such a prediction.

A large number of SMTAs have been entered into since the Governing Body adopted the SMTA in June 2006. It is estimated that, on average, around 800 materials are transferred every day via SMTAs.[7] The Consultative Group on International Agricultural Research (CGIAR) collections are important in this context, given that they hold at least 50 percent of all materials in the Multilateral System. For example, between 1 August 2008 and 31 November 2009, the IARCs released 608 664 samples of accessions under SMTAs, and received 41 902 accessions of Annex 1 crops under SMTAs.[8] Moreover, 21 countries of the European Region reported to the Fourth Session of the Governing Body that they had issued 2 687 SMTAs, covering 318 001 samples.[9] Several Contracting Parties have also issued a large number of non-Annex 1 accessions under SMTAs, as an independent policy decision, thereby creating a beneficial interest for the Treaty in products resulting from those accessions. For example, the Nordic Council of Ministers (grouping Denmark, Finland, Iceland, Norway and Sweden) decided by the Nordic Ministerial Declaration, Access and Rights to Genetic Resources (2003) that "the Nordic Gene Bank should provide access to all its accessions on equal terms, regardless of whether they are covered by the scope of the multilateral system of the IT-PGRFA or not". Canada, Germany and the Netherlands have also decided to make all their PGR for food and agriculture available under the terms and conditions of the SMTA.

However, at the time of writing, no payments have been made to the Benefit-sharing Fund in accordance with the provisions contained in the SMTA. One reason is that a large number of Contracting Parties have failed

6 See Smale, 2005, in particular, but also Chapter 1 of this volume.

7 *Experience of the IARC of the CGIAR with the implementation of the agreements with the Governing Body, with particular reference to the use of the standard material transfer agreement for* Annex 1 *and non-*Annex 1 *crops* (IT/GB-4/11/Inf. 05).

8 *Report on the Implementation of the Multilateral System of Access and Benefit-Sharing*, para. 39 (IT/GB-4/11/12).

9 *Compilation of Submissions by Contracting Parties on the Implementation of the Multilateral System*, Appendix 9 (IT/GB-4/11/Inf. 9).

to make all or part of their PGR available as actually stipulated by the Treaty.[10] The performance of each Contracting Party in giving effect to the Treaty (e.g. notifying the Governing Body of materials available under the Multilateral System and making the necessary legal and administrative arrangements for access) plays a major role in determining the quantity of materials actually available through the Multilateral System for use in the innovation process, and hence affects benefit flows.

Another reason for the lack of payments to the Benefit-sharing Fund is that plant breeding is, by its nature, a slow process. Additionally, parental germplasm originating from a gene bank will in most cases require pre-breeding efforts for developing a commercial variety. This period of time can vary greatly depending on the trait complexity and the 'wildness' of the original germplasm. Pre-breeding (also called 'parent-building') within applied breeding programmes takes years if not decades and may account for 10 to 20 percent of the total of crosses made. Furthermore, a large majority of breeding crosses do not result in a commercial variety. In the private sector, breeders will typically start tens if not hundreds of new breeding populations every year, with the development of a single new commercial variety per year considered as a success. Since no payments have so far been made to the Benefit-sharing Fund in accordance with the provisions contained in the SMTA, it has to be assumed that no products deriving from materials accessed under an SMTA have yet been commercialized.

Aware that the build-up of a steady stream of monetary benefits from the use of the SMTA is likely to take many years, the Governing Body established a target for fund-raising for the Benefit-sharing Fund of $116 million by 2014,[11] to be mobilized through contributions from donors, not directly deriving from the workings of the Multilateral System and the SMTA. Contributions are actively encouraged from Contracting Parties and international institutions as well as from foundations and private donors. In 2009, Norway made the important decision to donate a sum equal to 0.1 percent of all annual seed sales in the country to the Fund. Voluntary contributions from several other countries allowed the Benefit-sharing Fund to exceed the target for 2010, and have already enabled the Treaty to fund a number of projects in developing countries.

The broader picture of possible income for the Benefit-sharing Fund under the SMTA remains, however, unclear. Moreover, there is a lack of recognition regarding the Treaty's wider economic benefits, which are extensive and reach far beyond the commercial value of PGR for food and agriculture exchanged under SMTAs. Policy makers generally fail to recognize this full range of

[10] "Considering that there are 127 Contracting Parties to the Treaty, a significant number of them is yet to provide information or notify the Secretariat of plant genetic resources for food and agriculture within their jurisdictions that are in the Multilateral System", *Report on the implementation of the Multilateral System of Access and Benefit-Sharing*, para. 28 (IT/GB-4/11/12).

[11] Resolution 3/2009.

economic dimensions of PGR for food and agriculture, engendering policies that risk sub-optimal levels of genetic resources conservation and sustainable use.[12]

This book brings together a set of studies that, for the first time, address the question of how to identify the panoply of benefits to which the Treaty gives rise, and in particular, how to achieve a robust estimation of income to the Benefit-sharing Fund.

Structure of the book

In Chapter 1, Adam Drucker and Francesco Caracciolo provide an overview of both the conceptual bases for assigning economic value to PGR for food and agriculture, and of the existing methodologies for establishing such values. While determining the Treaty's overall economic value is an important task, quantification is beset by complexity and would moreover require comparison against other possible institutional arrangements, including those in which bilateral exchange of PGR or open access predominate – rather than multilateral exchange. Some promising approaches to such quantification are suggested in Chapter 1.

In Chapter 2, C.S. Srinivasan approaches the determination of the potential income that may flow from the use of SMTAs into the Benefit-sharing Fund through an innovative empirical investigation, which bases its estimations on the proportion of value of the global seed market attributable to plant varieties incorporating material accessed under SMTA conditions. In the absence of reliable information on the use in product development of materials accessed under SMTA conditions, Srinivasan uses the proxy measure of the value share in the commercial seed market of varieties incorporating germplasm traceable to CGIAR collections, which has always been freely available to and substantially used by private and public sector institutions in developed and developing countries. It can therefore serve as a historical indicator of the likely use of crop genetic resources now in the Multilateral System.

Another pioneering approach to determine the potential income to the Benefit-sharing Fund from the use of the SMTA is presented in Chapter 3. Clive Stannard, Francesco Caracciolo and Peter Hillery have developed an algorithm that models the process of developing commercial products from materials accessed under an SMTA. The factors of this algorithm can be varied so as to simulate the magnitude of flows into the Benefit-sharing Fund under a number of possible scenarios. The approach applied by the model, similar to Srinivasan's economic analysis, begins with valuing the international seed and planting material market, and within this overall value, the seed market for Annex 1 crops. It then estimates the proportion of products likely, at a given date, to

[12] See also Wale, 2011.

be derived from materials accessed under an SMTA. A number of functions are then applied to these values in order to estimate the part of the market to which the terms and conditions of the SMTA apply at a particular time.[13] This is the first attempt to develop a methodology to project monetary benefits likely to flow into the Benefit-sharing Fund, in order to estimate the time needed for these benefits to build up to a significant annual level. By varying its parameters, the model can test the relative importance of a number of factors for the likely flow of income to the to the Benefit-sharing Fund over time, as well as evaluate the sensitivity and importance of the individual factors within the algorithm. It is clearly a theoretical construct that produces hypothetical estimates, with a wide range of uncertainty: given current data constraints, it is not a calculation of real values, with a strong degree of certainty. The results of implementing the model must be seen as indicative, to be adjusted in future work and when robust data become available. For now, the relationship of the estimates under different sets of assumptions is more significant than the actual numbers.

With a view to developing methods to assess the use of material under SMTA conditions in plant variety development, Paul Oldham and Stephen Hall test an informatics-based approach in Chapter 4 through the coordinated use and mining of multiple databases. This approach assesses the commercial use of material brought under the terms and conditions of the SMTA by linking protected plant varieties that *potentially* involve the use of materials under SMTA conditions – i.e. Annex 1 species, through detailed breeding histories and genealogy information – to materials *actually* accessed under SMTA. Their work brings together plant variety innovation databases,[14] genealogy databases and breeding histories, as well as information on SMTA-use, and uses high-end computing capacity and purpose-designed algorithms to analyse these resources. Oldham and Hall also take steps to estimate the value and quantify the Treaty's non-monetary benefits by large-scale computational analyses involving, in particular, patent and plant variety-protection databases, text-mining tools and digital collections of scientific publications.

Some of the parameters of the mathematical model (Chapter 3) are set using values yielded by Srinivasan's investigation (Chapter 2) and the informatics-based approach (Chapter 4) yield. Moreover, the results of a survey of plant-breeding

13 The absolute margin of error therefore lies within the bounds of these empirical values, and is likely to be less subject to the errors of other approaches. An alternative approach might, for example, identify the number and kind of materials accessed under SMTAs since the adoption of the SMTA, project forward the likely releases of further materials under the SMTA, and then attempt to estimate the products derived from them over time and their likely value. Such an alternative, however, would be subject to increased cumulative error.

14 In developed countries, some form of intellectual property protection is almost universally applied to plant varieties. Intellectual property databases can serve as good sources of information on new plant varieties intended for commercialization. Of particular use in this context are patent databases and PVP databases. In developing countries, intellectual property is still mostly rarely applied to plant varieties, in spite of the extension of PVP regimes to these countries, in accordance with the TRIPs Agreement. The identification of relevant products in developing countries may require reliance on other types of data sources, such as variety registration systems or recommended variety lists. See also Chapter 2 below.

experts led by Maryline Guiramand (see Annex) have been key in supplementing and bolstering the data used in the modelling process. This survey has used direct inquiry and expert consultation of the plant breeding community, through interviews and questionnaires, to obtain figures for the mathematical model based on best estimates, where harder data have been impossible to find elsewhere. Its results are based on too small a sample size to be representative, and further work in this area is envisaged.

Monetary benefit flows

Monetary benefit flows to the Treaty's Benefit-sharing Fund are directly contingent on the use of materials governed by the Multilateral System and distributed by means of a SMTA. The use of materials under SMTA conditions is in turn influenced by a range of factors, some of which can be significantly affected through policy choice.

The Multilateral System currently covers nearly two-thirds of global *ex situ* holdings of Annex 1 crops. The duplication of crop germplasm across multiple collections implies that some material may be available both in collections that are part of the Multilateral System and collections that are not. While the availability of materials outside of the Multilateral System will vary by crop, little information is available on the size and coverage of these collections. During the consultations undertaken with plant breeding experts (see Annex), diverse opinions were expressed regarding private collections and the holdings of natural and legal persons. Some indicated that few commercial breeders maintained collections of material, but rather immediately introduced new material samples into their breeding programmes, relying on the national and international public sector for conservation. Others suggested that some of the larger breeding companies had built up *ex situ* collections in order to be able to work independently of the Treaty. With a view to achieving the fullest possible coverage of the Multilateral System, all holders of PGR for food and agriculture listed in Annex 1 have been invited to notify the Treaty's Governing Body of materials that they are effectively making available through the Multilateral System, under the terms and conditions of the SMTA. The Governing Body has also stressed the importance of adequate information on these resources being made publicly available. As more of such holdings are covered by the Multilateral System, product development incorporating these materials, and therefore benefit flows, are likely to increase. The participation of more countries in the Treaty would also significantly enhance the potential level of benefit-sharing flows, especially given that countries with major gene bank holdings, such as China, Japan and the United States, have not yet joined the Treaty.

In practice, the demand for materials from the Multilateral System is also likely to be influenced by ease of access and related transaction costs.

Although one of the main objectives of the Treaty is to facilitate access to materials included in the Multilateral System through standardized terms and conditions, ease and speed of access and associated transaction costs can vary across Contracting Parties and institutions, depending on how effectively the Treaty has been implemented. At the time of writing, a large number of Contracting Parties have failed to make all or part of their PGR available as stipulated by the Treaty. More effective performance of Contracting Parties, including making the required legal and administrative arrangements for access, would increase possible income levels into the Benefit-sharing Fund, and the rate at which these build up. Relatedly, *ex situ* collections are generally maintained with relevant information for the identification of individual accessions ('passport data') and their potential use, albeit the level of detail and comprehensiveness of information may vary considerably both within and across gene banks and repositories. Plant genetic materials are of little use to breeding programmes unless passport data and characteristic information on agronomic traits, agro-climatic adaptability and susceptibility to diseases and pathogens are available and accessible. The use of materials under the Multilateral System will depend on the extent to which critical characterization information is accessible to potential users. This may vary by crop, country and institution hosting the collection. Even large, diverse and accessible collections might not be utilized unless supported by availability of relevant information. The utilization of germplasm under SMTA conditions in crop improvement programmes may hence be constrained by lack of effective access to resources held by Contracting Parties and by inadequate characterization and evaluation information on those resources that are accessible.

Another factor influencing use of materials under the Multilateral System is the composition of crop germplasm. For any crop, the materials in collections included in the Multilateral System may consist of: (i) wild relatives; (ii) traditional cultivars or landraces; (iii) pre-bred lines (i.e. current research material) and (iv) advanced improved cultivars or elite lines. As new pathogens emerge or agro-climatic adaptation needs shift, breeding programmes may be forced to go back to wild relatives or traditional cultivars, but the demand for these decreases rapidly as their useful traits are incorporated into breeding lines and advanced cultivars. Breeding lines are usually incorporated quickly into commercial varieties, whereas wild relatives take much more work and longer periods of time. Improved materials are therefore likely to be in greater demand by breeders than unimproved materials and will be included in a greater number of commercial products over a shorter period of time. A considerable proportion of the material released under SMTAs by the CGIAR Centres is a result of their research and development breeding programmes. The Centres reported to the Governing Body in 2011 that, for Annex 1, 71 percent of their distributions were of improved materials, and for non-Annex 1, 31 percent. The CGIAR Centres are, therefore, likely to have a relatively very high weight in generating payments to the Benefit-sharing Fund, not least because of the high proportion of improved material in their collections.

The demand for materials from the Multilateral System in breeding programmes is likely to vary with the amount of innovation activity that a particular crop attracts. This, in turn, is likely to be influenced by the size of the commercial market for that crop, research capacity available for that crop, and the research priorities and mandates of institutional breeding programmes. Using the grants of PVP certificates for different crops as a measure of research intensity in developed countries, Srinivasan presents the striking data in Chapter 2 that non-Annex 1 crops account for two-thirds of all PVP certificates. The coverage of crops in Annex 1 of the Treaty, therefore, omits nearly two-thirds of the research effort in plant breeding from its purview. Research effort in non-Annex 1 crops and resulting innovations will not translate into benefit-sharing payments. The share of Annex 1 crops in research effort has been declining over time, with their share in PVP certificates decreasing from 75 percent in the 1960s to less than one-third in 2010. An increasing share of plant breeding research effort has been applied to non-Annex 1, the result of increasing research efforts attracted over the last two decades by crops not included in Annex 1, such as soybean, cotton and sugarcane. The share of these crops in the value of the global commercial seed market is also increasing. The limited coverage of crops currently included in Annex 1 severely constrains the potential for generating benefit-sharing payments through the exchange of PGR under SMTAs. Based on survey data from the FAO's Global Partnership Initiative for Plant Breeding Capacity Building (GIPB), Chapter 2 further reveals that the potential for generation of innovations in Annex 1 crops, based on materials exchanged under SMTAs, is greater in developing countries. Yet, this potential may not translate into a larger flow of benefit-sharing payments, because these innovations are produced predominantly in the public sector, whose mandate to encourage the widespread adoption of improved varieties is likely to prevent the forms of intellectual property protection that lead to mandatory payments.

The relative importance of institutional players in the innovation process differs by country and crop, and has changed significantly over the last three decades (Anderson *et al.*, 1994; Pardey *et al.*, 1991). In most developing countries, the public sector has been and remains the dominant player in plant breeding research, although the private sector has started to play an increasing role with respect to several crops (Morris, 1998). In developed countries, the role of the public sector in 'near-market' plant breeding research has declined over the last two decades with the private sector now playing a dominant role in the breeding of new varieties of key crops (e.g. maize in the United States), particularly those involving the application of biotechnology.[15] These different institutional players may have different propensities for demanding and using materials from the Multilateral System for their breeding programmes. Private sector institutions that seek to appropriate returns from their innovations may be inclined to avoid the use of materials subject to SMTA conditions that would

[15] See, for example, Alston *et al.*, 1998.

oblige them to make payments to the Treaty's Benefit-sharing Fund. This is particularly the case with products brought under patents due to the legally enforceable mandatory nature of the payments required. The emergence of the CBD, the extended negotiation process leading to the Treaty, and the uncertainties surrounding the nature of the plant genetic resource exchange regime that would eventually emerge may have created additional incentives for private sector breeding programmes to stockpile materials before the Treaty came into force. Moreover, technical difficulties and transaction costs are imposed on a breeder by the need to document all ancestral materials throughout the many crosses in breeding populations, which might also impact willingness to use material under SMTA conditions. Some programmes may hence have adopted breeding strategies that avoid the use of materials brought under SMTA conditions and, if necessary, seek to access material from collections that do not form part of the Multilateral System. The preliminary survey of plant breeding experts (see Annex) found evidence for such explicit avoidance in the private sector. Making the use of materials under SMTA conditions more attractive, particularly to the private sector, would enhance benefit-sharing flows.

Monetary benefit-sharing provisions apply in cases in which material accessed under an SMTA has been incorporated into a commercial plant variety. In the event that the new variety is not subject to intellectual property protection and/or may be freely used without restrictions in the development of follow-on products, payment is voluntary (under Article 6.8 of the SMTA). Evidence from the plant breeder survey suggests that voluntary payments are in practice likely to be minimal at best. In strategic terms, voluntary payments by one company, which competitors avoid, would create uneven competition and a market disadvantage. Lack of certainty regarding the intentions of competitors creates a situation in which companies hesitate to be the first to make payments (see also Chapter 3). The magnitude of potential income to the Benefit-sharing Fund is acutely contingent on institutional arrangements that incentivize a high level of voluntary payments.

Furthermore, at the time of writing, the Treaty's Benefit-sharing Fund has not received any payments in accordance with provisions contained in the SMTA; therefore, the studies in this book all proceed on the assumption that no products incorporating materials accessed under SMTA conditions have to date been developed. In order to empirically assess the potential development of such products and the concomitant payment obligations in the future, however, access to detailed breeding histories of new plant varieties is necessary. Since mandatory or voluntary payments arise from the SMTA when material received under an SMTA is used in the development of new varieties of plants, genealogical information of new plant varieties is necessary to project payment obligations. Yet, the availability of such genealogical information varies considerably across countries, crops and sectors. While the CGIAR has set up fairly extensive genealogy databases for four to five major crops through the International Crop Information System (ICIS), no pedigree information is available on proprietary varieties developed by the private sector. This makes it extremely difficult to assess the use of material under SMTA conditions in product innovation. The empirical assessment of such use requires the collation of information from product innovation databases, genealogy databases and crop databases; such a methodology is tested by Oldham and Hall in Chapter 4.

Initial caveats

Information currently available to evaluate and quantify the benefits presently and potentially flowing from the use and exchange of PGR for food and agriculture, under the Multilateral System, is extremely deficient. In many instances, the studies in this book had to make us of proxies and estimates, and their results need to be understood as preliminary.

Due to time and resource constrictions, the studies presented here had to limit their focus to a few important crops for which information was available and easily accessible. Wheat, maize and rice were chosen as objects of study.[16] Moreover, these large crops are expected to contribute a substantial part of the overall flow of income to the Benefit-sharing Fund, and are the mandate crops of the CIMMYT, IRRI and the Africa Rice Centre. These three international institutions have concluded Treaty Article 15 Agreements and their collected germplasm is available by means of the SMTA. For completeness, Annex 1 crops and non-Annex 1 crops were also studied, as groups.

The magnitude of income flows into the Treaty's Benefit-sharing Fund is directly related to the commercial value of new plant varieties incorporating material accessed by means of an SMTA; however, severe data constraints make the determination of this value very difficult. Particularly problematic for the purposes of the studies brought together in this book has been the state of information on the value of the global commercial seed market. Given the timeframe of the project, aggregate data published by the International Seed Federation (ISF), itself based largely on estimates, have had to be used in conjunction with a commercial report prepared by Global Industry Analysts (GIA, 2010). The problems arise in particular from lack of adequate statistical sources on the seed market. There are only three main sources of seed statistics: (i) seed companies in the public and private sector; (ii) the seed regulatory system (i.e. seed certification); and (iii) trade statistics on seed exports and imports. None of these statistics provide reliable information at the crop or variety level, which is critical for assessment of likely payments in accordance with the SMTA.

[16] It is important to note that during the consultations undertaken with plant-breeding experts (see Annex to this volume), the commercial importance of vegetables as a potential source of income to the Treaty was stressed. However, vegetables as a category are very heterogeneous in agronomic terms, with some included in, and some excluded from, the Multilateral System. For this reason, and given the time constraints of the research project that produced the present studies, it was decided not to include vegetable crops as a distinct category in the first iteration of the mathematical model in Chapter 3. This, however, should be a priority in any further development of the model.

An initial report summarizing the findings was submitted to a number of peer reviewers from all regions and sectors, whose valuable suggestions are reflected in the chapters of this book. Some peer reviewers from the plant breeding industry highlighted the need for realism regarding the assumptions in the scenarios modelled in Chapter 3. They expect extensive avoidance of materials under SMTAs and believe that voluntary payments will be minimal. These two factors are simulated in the model and are tested at different rates of performance, from high to low. The results confirm that they are indeed crucial. A consistent, relatively high acceptance of SMTA materials as well as consistent voluntary payment were assumed when testing other factors. This was to ensure comparability between scenarios and should not be misunderstood as a statement of likelihood.

Moreover, the computational model is restricted to *ex situ* collections of countries and international institutions due to lack of information on the size and the nature of the holdings of PGR by natural and legal persons. For this reason, no attempt was made to model the latter, despite the importance given to them in Articles 11.2 to 11.4 of the Treaty. Nor does the model adequately reflect the very high value of materials issued by the breeding programmes of the CGIAR, rather than by their *ex situ* collections.

All findings indicate that there may be long timescale for the build-up of income to the Treaty. Moreover, the longer the timescale, the more likely that plant breeding methodologies and market conditions will change. With respect to the mathematical model, the probability of accuracy declines with distance in time; no methodology can remedy this intrinsic uncertainty.

None of the authors seek to propose changes to the provisions of the Treaty and the SMTA, or suggest alternative benefit-sharing systems. This is not the purpose of this book and the studies on which it is based. Changes to the Treaty or the SMTA are the prerogative of Contracting Parties, and there are no indications from the Governing Body on which such speculation could be based. The research presented here therefore strictly reflects the actual provisions of the Treaty and the SMTA.

Chapter 1

THE ECONOMIC VALUE OF PLANT GENETIC RESOURCES FOR FOOD AND AGRICULTURE

Adam Drucker and Francesco Caracciolo

1.1 Introductory note: scope of this chapter

The potential benefits that may be associated with access, exchange and use of PGR for food and agriculture under the Treaty arise from:

- the establishment of an agreed international framework for the conservation, sustainable utilization, exchange and use of PGR for food and agriculture generally; and
- at the level of the Multilateral System of Access and Benefit-sharing, the economic value of the collections of the crops that it covers ("Annex 1 crops"), made available under facilitated access.

An understanding of the wide range of monetary, indirect monetary and non-monetary (broadly and narrowly defined) benefits arising from access, exchange and use of SMTA materials provides a basis for the estimation of the magnitude of monetary contributions to the Benefit-sharing Fund as performed in Chapter 2 and for the modelling of these contributions in Chapter 3. The present chapter contributes to this understanding by undertaking a review of existing literature, leading to the documentation and synthesis of the underlying conceptual basis for assigning economic values to PGR for food and agriculture, the methodologies for valuing it, as well as the attributed values. In particular, this chapter:

- provides a general framework for improved understanding of the potential monetary and non-monetary values that may be associated with the access, exchange and use of PGR for food and agriculture in general, and more specifically under the Treaty, as the relevant international policy framework;
- reviews the existing conceptual and quantitative literature regarding the total economic value (including use and option values) of PGR for food and agriculture, and the methodologies for establishing such values.

Our review indicates that the indirect monetary and (broadly defined) non-monetary benefits generated by the existence of the Treaty and its Multilateral System are indeed likely to be significant. The commercial value of the use of PGR for food and agriculture has in general been shown to be only a relatively small component of its total economic value to society compared to the overall social welfare impact of productivity benefits accruing to society as a whole and especially to consumers in terms of lower food prices.

Although methods that could be used for attributing the benefits of specific plant breeding programmes are extensive and continue to be refined, in determining the impact on overall social welfare of the benefits arising from the institutional existence of the Treaty and the Multilateral System, it would first be necessary to compare them against some alternative bilateral and/or open access exchange scenarios, for example, through a simulation model approach. Such approaches should account for the associated transaction costs, which include implementation, monitoring and enforcement, which are implicit in each scenario.

For the narrowly defined non-monetary benefits, a potentially innovative and promising way in which to identify such benefits (as a first step to assessing their impact on overall social welfare) could involve drawing on scientometrics or bibliometrics (the analysis of scientific literature). Through the mapping of research networks, it appears to be increasingly possible to identify such non-monetary benefits in terms of actual collaborations between researchers, and the training and exchange of students and postdoctoral researchers and staff between institutions. Through such an approach, such collaborations embodying knowledge exchange and transfers within networks may also be revealed to be a major component of non-monetary benefit-sharing. In Chapter 4, the practical execution of such an approach is tested.

1.2 The nature of the monetary and non-monetary values that may be associated with access to, and use and exchange of plant genetic resources for food and agriculture

Overviews and surveys discussing the sources of economic value of PGR for food and agriculture have been numerous, including Pearce and Moran (1994), Swanson (1996), Evenson and Santaniello (1998), and Gollin and Smale (1998).

In general, all sources of economic value associated with crop biodiversity, as with other goods and services, are considered to emanate from human preferences, given economics' utilitarian and anthropocentric underpinnings (Randall, 1988). Pearce and Moran (1994) argue that the maintenance of biodiversity generates economic values (use and non-use), which may not be captured in the market place. The result of this 'failure' is a distortion where the incentives are against biodiversity conservation and sustainable use and in favour of the economic activities that erode such resources.[1] Such outcomes are, from an economic viewpoint, associated with market, intervention and/or global

1 Institutional arrangements can contribute to such distortions. For example, genetic resources conservation and sustainable use concerns arise from the way property rights have been assigned within the plant breeding "industry". Swanson and Göschl (2000) argue that in a vertical industry, the location of a property rights assignment is a crucial factor determining the incentives for efficient levels of investment at various levels of that industry. In the context of plant genetic resources, the current assignment of property rights has been at the retail end of the pharmaceutical and plant breeding industries. The assignment of plant breeders' rights (PBRs) has consequently led to an increase in: the number of research and development (R&D) programmes; the total number of plant breeders; and in the aggregate amount of R&D expenditure and private R&D (see Swanson and Göschl, 2000. p. 84). At the same time, however, there is no evidence that investments increased in the essential input activities that would maintain a flow of genetic resources into the future (e.g. habitat and biodiversity conservation). Hence, PBRs have tended to create incentives to invest at the end of the industry (i.e. the plant breeding sector), but not in the earlier parts of the industry (i.e. the genetic resource providers sector). This has had an impact on both efficiency and equity within the industry. *Farmers' rights have been proposed as a form of counterbalance to PBRs, leading to the protection of traditional knowledge and equitable participation in benefit sharing. The Treaty Benefit-sharing Fund may be viewed as a different type of institutional arrangement that also contributes to such outcomes.*

appropriation failures. As a result, genetic resources are unlikely to have an exchange value that reflects their economic scarcity. Furthermore, when such goods (i.e. biodiversity) have both private and public attributes, a social dilemma results. Although such goods generate benefits for society, their public good nature will result in a tendency for them to be under-maintained relative to national, regional, or global needs. Policy interventions to support their production would therefore be considered justifiable if society's goals are to be met, provided that it can be demonstrated that such interventions can generate net benefits.[2] An example of a social goal is the sustainable management of crop and livestock biodiversity (Drucker *et al*., 2005).

Concerns about genetic erosion in crops have led to a genuine effort to "insure" against losses by sampling and storing large numbers of landraces and wild relatives of cultivated plants *ex situ* (out of place or origin, or source) in collections, or gene banks. Some experts consider that a large proportion of genetic variation in a number of major crop plants is conserved *ex situ*, in gene banks or plant breeders' collections (Evenson *et al*., 1998, p. 2; Fowler *et al*., 2001). However, *ex situ* efforts have focused mainly on major staple crops and their wild relatives[3] and do not cater to safeguarding the larger spectrum of agrobiodiversity and its associated knowledge, culture and traditions.

Effective policies to stem agrobiodiversity loss also require improved tools and the capacity to both properly account for the values associated with the services and benefits derived from agrobiodiversity, as well as to design appropriate instruments to capture such values, given that many of them are not reflected in the marketplace. Without such tools, cost-effective interventions and associated policies can neither be designed nor implemented.

In a review of methodologies for the economic analysis of genetic resource conservation and sustainable use, Drucker *et al.* (2005) and Smale and Drucker (2007) note that such methods, when used in conjunction with rural appraisal methodologies, can reveal useful estimates of the values that are placed on market and non-market attributes. Such data are generally considered crucial*, inter alia,* for:

- identifying trait values in breeding programmes;
- demonstrating the benefits, as well as the costs of conservation;
- identifying cost-efficient, diversity maximizing, or optimal conservation strategies;
- orienting policies aimed at genetic resources conservation/sustainable use, including through incentive and benefit-sharing mechanism design.

The potential utility and contribution of economics to crop genetic resources conservation and sustainable use is further highlighted by the CBD Conference of the Parties (COP) 8 Decision VIII/25, which, for biodiversity in general, encourages the strengthening of "research activities including research cooperation and exchange at national, regional

2 In the case of the Treaty and the Multilateral System, its implementation, monitoring and enforcement costs should be considered in the process of determining the existence of net benefits.

3 See Gepts (2006) for a review on conservation of plant genetic resources.

and international levels [...] in order to promote a common understanding of valuation techniques among governments and stakeholders" (para. 7) and "to explore options for the design and application of flexible and reliable innovative tools for assessment and valuation of biodiversity resources and functions and associated ecosystem services" (para. 10c). The development of positive incentives is further called for under the CBD's Strategic Plan for 2011–2020.[4]

1.2.1 Total Economic Value Framework

In order to determine the degree of the importance of the market and non-market values associated with access to, use and exchange of crop genetic resources and how they can be taken into account to support conservation and sustainable use, it is useful to consider the different types of value that can be associated with these resources.

In this context, a total economic value (TEV) framework approach (Turner *et al.,* 2003; Pearce and Moran, 1994) is generally used in order to allow an effective categorization or taxonomy of the different types of value that one may attribute to PGR for food and agriculture (see Figure 1.1).

Although the exact terminology changes among studies, such values can broadly be categorized into use and non-use values (Smale and Koo, 2003). Use values may be direct or indirect. **Direct use values** derive from the utility gained from the food, fibre and medicinal products contributed by the PGR, including the amenity and socio-cultural values associated with their attributes. Such values may consequently be associated with a mixture of private and public goods; the latter are more difficult for individuals to appropriate.

There are also many current and future uses for these resources other than their direct use in breeding new crop varieties. **Indirect use values** reflect the contribution of crop genetic resources to surrounding habitats or ecosystems. In addition, a use value, **option value**, which is a type of insurance against unknown future change, provides flexibility to deal with unexpected future demand (such as that resulting from climate change). Subtly different but related to option values are **quasi-option values**. The latter relates to the extra value attached to future information made available through the preservation of a resource. Quasi-option values arise from the irreversible nature of species or variety loss (after which no further learning can take place) and can occur even in the absence of uncertainty (FAO, 2007).

Non-use values, such as **existence or bequest values**, reflect the satisfaction individuals or societies may derive simply from knowing that something exists or will be passed on to future generations, independently of whether or not it is used.

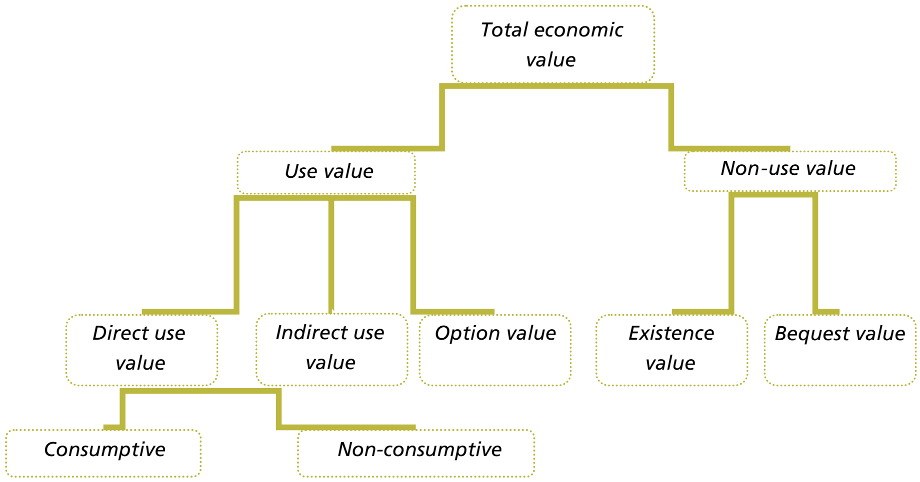
Policy makers generally fail to recognize this full range of the economic dimensions of PGR for food and agriculture (Wale, 2011), engendering policies that risk sub-optimal levels

[4] COP 10 Decision X/2, available at: www.cbd.int/decision/cop/?id=12268

of genetic resources conservation and sustainable use. Although it is generally assumed for crop genetic resources that most of the value associated with their diversity is related to use, rather than non-use, or existence values (Smale and Koo, 2003),[5] the full range of public/private goods associated with the use values still needs to be accounted for.

The significance of these values has led crop genetic resource gene banks to be widely established, with the aim of enhancing direct use values of these resources, while at the same time safeguarding option values. Determining such values is not straightforward, however, even conceptually, because it should be appreciated that, under the TEV framework, values may not be mutually exclusive and overlap. Accurate quantification of the benefits of PGR for food and agriculture remains a difficult task. This assignment is further exacerbated given the multidimensional and inter-temporal nature of germplasm stocks. The peculiarity of the natural reproducibility of the good and the impossibility to clearly establish property rights and to distinctly identify beneficiaries intensify its public good characteristics, which together with the existence of a significant number of non-monetary benefits (see section 1.4.3 below for further details) makes the valuation task even more complex (Smale and Koo, 2003).

Figure 1.1 Total economic value (TEV) framework: a taxonomy of biodiversity



TEV = UV + NUV = (DUV + IUV + OV) + (XV + BV)

Source: Pearce and Moran, 1994.

[5] It is interesting to note that this is a feature that tends to distinguish agrobiodiversity from other types of diversity.

In practical terms, the evaluation of a marginal accession value often requires "significant expense in time, talent and money" (Pardey *et al.*, 1999) and generally ends up underestimating the total value of the resource stock as the material is often used more than once, in subsequent breeding efforts, at different times and in different places (Rubenstein *et al.*, 2006). Furthermore, strong uncertainty characteristics associated with the option and non-use values aggravate this tendency.

In addition to such challenges, some have argued that using economics to assign any value to a species is inherently unethical (Ehrenfeld, 1988). By ignoring 'intrinsic values' (i.e. values nominally unrelated to human use, such as the 'right' of a species to exist) and by putting economic conditions on the conservation decision, it is argued that these rights are contravened (Pearce and Moran, 1994). Others have viewed valuation as self-serving, seeking to justify, rather than explain or predict. At other times, the emphasis on the valuation is perceived as "distancing economists from natural scientists" (Dyer Leal, 2002). However, Pearce and Moran argue that: the economic view can also be regarded as a moral view given that it takes an effectively utilitarian approach to conservation; due to the current situation of crisis, a utilitarian approach is likely to be superior from the point of view of saving biodiversity in real world contexts; current human population growth makes further loss of biodiversity inevitable and therefore is essential to establish priorities, which is inconsistent with arguing that everything has an equal right to exist; given that 'economic' causes are important, whatever one's moral standpoint, a practical agenda for conservation should begin with economic factors; and finally, that since people are often utilitarian, it is the only approach that truly explains why biodiversity is being lost, and hence the process of policy correction. Nevertheless, even proponents recognize that valuation should not be viewed as an end in and of itself, but rather as a tool that can assist in designing policies to support the sustainable management of biodiversity.

Despite such challenges to the effective valuation of PGR for food and agriculture, an increase in the scientific literature (reviewed by scholars such as Drucker *et al.*, 2005,[6] among others) has eased major methodological/analytical constraints, and over approximately the past 20 years, a wide range of tools and analytical approaches have been successfully applied to a number of crops/species and domestic animal breeds, production systems and locations. These methods and their associated findings are considered in the following section.

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6 This review was undertaken as a result of a specific recommendation of the "Managing Agricultural Biodiversity for Sustainable Development" workshop organized by the International Plant Genetic Resources Institute (IPGRI) for the System-wide Genetic Resources Programme (SGRP) of the CGIAR (Nairobi, October, 2003). Subsequently, SGRP agreed to support an expert workshop entitled "Valuation tools for managing agricultural biodiversity: state of the art and future directions" (Washington, DC, October 2005) and contributed to the discussions at SBSTAA 11 (Montreal, Nov/Dec. 2005).

1.3 Economics of plant genetic resources for food and agriculture – state of the art

There is a large literature regarding the economic benefits of improved crop varieties in commercial agriculture, and an extensive amount of conceptual and theoretical literature concerning the sources of value in crop genetic resources and biodiversity.[7]

At the more general level of biodiversity, the Annex to COP 8 Decision VIII/25 ("Options for the application of tools for valuation of biodiversity and biodiversity resources and functions") draws on the Millennium Ecosystem Assessment to categorize valuation tools as being based on revealed-preference methods (change in productivity; human capital approach; cost-based approaches; least-cost approaches; travel cost method; and hedonic price approaches), stated preference methods (contingent valuation and choice modelling) and "other" (benefit transfer studies).

In the specific context of agrobiodiversity valuation, Smale and Drucker (2007), Drucker *et al*. (2001) and Drucker and Scarpa (2003) review existing tools that involve: econometric methods; mathematical programming (including optimization models); Monte Carlo simulations; search theoretic frameworks; contingent valuation and choice experiments; production loss averted, opportunity cost, and least-cost methods; aggregate demand and supply (including economic surplus methods); cross-sectional farm and household methods; farm simulation and breeding programme evaluation (including aggregated productivity models); genetic production functions; market share methods; intellectual property rights (IPR) and contract values; and safe minimum standards approaches. Such valuation tools involve the identification of information requirements, data collection and econometric methods and analytical techniques. Nevertheless, important gaps remain.

COP 8 Decision VIII/25 (para. 6 of the Annex) notes that "the choice of the valuation tool or valuation tools in any given instance will be informed by the characteristics of the case, including the scale of the problem and the types of value deemed to be most relevant, and by data availability". Smale and Drucker (2007) and Drucker *et al.* (2005) consequently find it useful to carry out their analytical overview in the context of a number of key research and development questions, summarized in the following sections.[8]

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7 An annotated bibliography of related literature is available at: http://www.ifpri.org/publication/bioconserv-2nd-edition (to 2008); and http://www.mendeley.com/groups/1269631/economics-of-agrobiodiversity-conservation-and-use-bibliographic-database/ (2009 onwards).

8 All references in the following subsections are available at: http://www.bioversityinternational.org/fileadmin/bioversity/publications/pdfs/1060_Valuation_and_Sustainable_Management_of_Crop_and_Livestock_Biodiversity.A_Review_of_Applied_Economics_Literature.pdf

1.3.1 What are the costs and benefits of ex situ conservation?

Methods and tools: To estimate the benefits expected from using an additional gene bank accession in crop breeding, studies have employed mathematical programming, Monte Carlo simulations, and maximum entropy methods in a search theoretic framework, combined with partial equilibrium estimates of the productivity impact of the bred materials in farmer's fields.

Findings cannot be broadly generalized, and tools for widespread application have not yet been developed. Costs of conserving accessions have been estimated by applying the micro-economic theory of the firm and capital investment decisions. Based on these methods, tools could be developed and directly applied with spreadsheet analysis to gene bank cost data.

Findings: The expected marginal value of exploiting an individual accession in commercial agricultural use justifies the cost of conserving it in a gene bank. The costs of conserving accessions in gene banks are relatively easy to tabulate compared to the expected benefits from the accessions they conserve (Pardey *et al.*, 2001). If, as is shown in a set of studies compiled by Koo *et al.* (2004), the costs of conserving an accession are shown to be lower than any sensible lower-bound estimate of benefits, undertaking the expensive and challenging exercise of benefits estimation is not necessary to justify its conservation.

Zohrabian *et al.* (2003) found that the expected marginal benefit from exploring an additional unimproved gene bank accession in breeding resistant varieties of soybean more than justified the costs of acquiring and conserving it.[9] It has been suggested that many gene bank resources are primarily used when other options have failed, with low probabilities of success (Cox *et al.*, 1988). Since the payoff can be large for problems of economic importance when the desired traits are rare, conserving some categories of materials "untapped" for years can be justifiable; infrequent use of individual accessions by plant breeding programmes does not in itself imply that an additional accession will have low value (Gollin *et al.*, 2000).

A study of a large national gene bank indicates higher rates of direct utilization in plant breeding than suggested earlier, secondary use through sharing within and outside respondents' institutions, and proportionately higher use rates among respondents in low- and middle-income countries (Day-Rubenstein and Smale, 2004). Most plant genetic resources (PGR) conserved in gene banks reach commercially oriented farmers when they are bred into improved varieties, although there are outstanding examples of direct distribution of gene bank materials to farmers, including those that are more subsistence-oriented (Hawkes *et al.*, 2000; King, 2003).

Other than this literature, sample surveys have been conducted to assess the extent of gene bank utilization by plant breeders, other scientists, and farmers (Brennan *et al.*, 1999; Smale and Day-Rubenstein, 2002; Duvick 1984; Rejesus *et al.*, 1996). These do not apply economics analysis frameworks, although they are motivated by notions of use value, and breeder demand for and supply of materials.

Limitations: Costs and benefits estimated from detailed studies of large national and international gene banks cannot be generalized. The range in benefits is extremely sensitive to assumptions concerning the lag until variety release, and the discount rate, or time value of money. Although the statistical theory used in the search models accounts for relative abundance and the genetic differences among accessions with respect to the trait of interest, the range in simulated benefits is too wide for confidence. The cost analyses distinguish between crops and types of collections, but treat each accession as genetically equivalent.

Source: Smale, 2005.

9 A further review of search theoretic models can be found in Appendix 1.1.

1.3.2 What is the commercial value from exploiting an individual plant species or crop genetic resource?

Methods and tools: The value of diversity in crop or animal species has been modelled theoretically, supported in some cases by empirical data (Brown and Goldstein, 1984; Weitzman, 1993; Polasky and Solow, 1995; Evenson and Lemarié, 1998; Simpson *et al.*,1996; Craft and Simpson, 2001; Rausser and Small, 2000).

The global values of genetic resources, along with other ecosystem services, have been assessed in an ecological economics framework with large-scale secondary databases (Costanza *et al.*, 1997). The values of PGR and their diversity in crop breeding had been estimated by applying a combination of production economics and forms of hedonic analysis (Evenson *et al.*, 1998).

Findings: The marginal commercial value expected from an individual PGR in agricultural use will not be high enough, in general, to fund national innovation or conservation efforts at levels desirable for society. The perception that individual PGR have great commercial value is based largely on anecdotal cases in which substances identified in wild, indigenous plants have generated profits for pharmaceutical companies. Economics research has cast doubt on the likelihood that the willingness to pay for prospecting these resources in the pharmaceutical industry would be sufficient to promote the conservation of their habitats (Craft and Simpson, 2001; Simpson *et al.*, 1996; Koo and Wright, 2000). Evidence to suggest that any one landrace or improved variety will generate large commercial returns in agricultural use – and therefore huge benefits through restricting access to it – is even more modest. Gollin and Smale (1998, 244–6) cautioned against 'the myth of enormous value' associated with an individual crop genetic resource. Although there are instances in which a single plant genetic resource has proved extremely valuable, these cannot be generalized. Economists are skeptical for the following three reasons:

1. The process of plant breeding. In plant breeding, numerous genetic resources are continually shuffled and reshuffled in an uncertain search for traits that are well expressed in a crop variety destined for highly differentiated production conditions. Economically important traits are distributed statistically across PGR, with varying likelihood of encountering useful levels. The traits demanded by societies, such as resistance to plant pests and diseases, and quality attributes preferred by consumers also change frequently in response to environmental stress and economic changes, keeping plant breeders on a treadmill to surpass past accomplishments. Breeding products (crop varieties) contain many 'ingredients' that are also genetic resources, which are in turn combined with others to produce the next variety. There may be a weak result from the marginal contribution of the last resource. Attributing value to each ingredient is difficult.

2. The nature of crop production. Changes in productivity that underlie economic benefits from new varieties involve multiple factors in interaction with the seed. A well-known example is the Green Revolution in wheat. The economic benefits associated with the Green Revolution cannot be ascribed solely to the dwarfing genes, the landrace that contained them, or the scientist who initially bred it into another cultivar. An estimated 1 749 spring bread wheat cultivars were recorded as released by national breeding programmes in low- and middle-income countries from 1966 to 1997, with a growing proportion carrying the semi-dwarf genes; by 1997, 88 percent of all spring bread wheat grown by farmers in these countries was sown to semi-dwarf types (Byerlee and Moya, 1993; Heisey *et al.*, 2002). A number of farm physical, social, economic and policy factors influenced the widespread adoption of those cultivars, generating economic benefits through yield gains. Concurrently, major changes in the growing environments for varieties enhanced those yield gains, such as increased

water use, fertilizer application and the expertise of farmers. Production benefits were then distributed to society through effects on producers' and consumers' incomes.

3. The existence of substitutes. To what extent are the traits and gene complexes embodied in seed unique to one PGR? The same trait may be apparent to one degree or another in many other PGR. Seed samples of the same genetic resource may also be found in more than one *ex situ* collection, in more than one political jurisdiction. Even when rare in a given collection, accessions carrying useful traits might be duplicated among seed samples (accessions) in multiple collections. Similarly, although locally rare in farmers' fields, they could be globally abundant.[10]

The commercial value[11] of PGR in agricultural use is a relatively small component of its total economic value to society, however. Since other values are not captured well in market prices (and this is not likely to change in the near future), public investments in innovation and conservation will continue to be needed for social welfare (Brown, 1990; Swanson, 1996). Since the potential usefulness of any single genetic resource is often highly uncertain and time horizons for developing products from genetic resources are long, private investors typically under-invest in conserving them at the levels needed by society. As a consequence, the public sector has played a pivotal role in conserving these resources and will continue to do so in the foreseeable future.

Limitations: This literature has advanced the theoretical and conceptual understanding of issues. More conceptual and theoretical work is needed to develop a better understanding of feasible, cost-effective approaches to valuing multiple components of agricultural biodiversity and services (see, for example, Ceroni *et al.*, 2005).

Source: Smale, 2005.

[10] With regard to issues related to 'what to conserve?', the Weitzman approach (Weitzman, 1993 and 1998; Metrick and Weitzman, 1998) arises from a question related to the process by which it is possible to decide "which species to take on board Noah's Ark". The suggestion was that Noah should take species on board "in the order of their gains in utility plus diversity, weighted by the increase in their probability of survival, per dollar of cost". The Weitzman approach thus combines measures of diversity, current risk status and conservation costs so as to permit the identification of a cost-effective diversity-maximizing set of species/ varieties or breed conservation priorities. Hence, for any given quantity of conservation funding available, it is possible to identify a priority conservation portfolio that maximizes the diversity that can be conserved.

[11] Note that commercial value is not synonymous with – and may represent only a part of – 'direct use values'.

1.3.3 What is the rate of return to improvement of crop genetic resources?

Methods and tool: The compendium and state-of-the-art of methods used to assess the economic benefits or productivity gains are found in Alston, Norton, and Pardey (1998). Economic surplus or econometric methods are commonly used. Methodological challenges within the framework of assessing the commercial economic benefits of agricultural research are explored in a large body of literature, including Alston, Norton and Pardey (1998), Alston *et al.* (2000), and Morris and Heisey (2003).

Findings: There is ample evidence that the successive, continuous releases of improved varieties by plant breeding programmes, many of them publicly financed, have generated economic returns that far outweigh the costs of investment. The important role of PGR in the development of world agriculture is clear, both historically (Cox *et al.*,1988; Fowler 1994) and more recently (Fowler *et al.*, 2001). Economists have repeatedly demonstrated that rates of return to investment in plant breeding programmes are high (Byerlee and Traxler, 1995; Morris and López-Pereira, 1999; Alston *et al.*, 2000; Evenson, 2001; Heisey *et al.*, 2002; Evenson and Gollin, 2003), although not necessarily mean in terms of appropriable commercial profits.

Research on the farm-level adoption of these varieties was also extensive, reviewed in 1985 by Feder *et al.* (1985) and in 1993 by Feder and Umali. Although the marginal benefit that can be attributed to a single gene or genetic resource in plant breeding is likely to represent a relatively small proportion of the total, the productivity benefits accruing to society as a whole and especially to consumers in terms of lower food prices are large relative to the costs of investing in plant breeding.[12] This is particularly true in less advanced agricultural economies where consumers spend a much larger proportion of their budgets on food. Successful innovation has depended on access to a wide range of materials (for example, Smale *et al.*, 2002).

Limitations: This literature is extensive and advanced, and methods for attributing the benefits of specific plant breeding programmes continue to be refined (Pardey *et al.*, 2004). By contrast, methods for apportioning the benefits among ancestors and progenitors [13] require the imposition of unrealistic assumptions, even in highly bred crops. There are some examples of attempts to calculate these benefits in the literature (Gollin, 1998; Gollin and Evenson,1998; Johnson *et al.*, 2003). Similarly, assessing the economic benefits from crops that are not highly bred would require the use of other methods.

Source: Smale, 2005.

A further review of the economics literature related to returns to plant breeding can be found in Appendix 1.2.

12 Such benefits are generally assessed in terms of impact on overall social welfare, measured through changes in consumer or producer surplus. Where improved productivity enhances supply, consumer surplus may increase because they are able to purchase a product for a lower price than the highest price that they would be willing – or had previously been willing – to pay. Similarly, producer surplus may change where productivity improvements allow producers to benefit by selling at a market price that is higher than the least that they would be (or had previously been) willing to sell for.

13 See Appendix 1.5 for further details regarding genetic resources interdependence.

1.3.4 What is the effect of crop biodiversity on productivity, vulnerability and efficiency?

Methods: Initial attempts linked diversity in modern varieties in a partial productivity, production function framework, expanding to a mean-variance framework (Just and Pope, 1979) and a simultaneous equation system with cost shares. Data have been largely secondary, measured at the township, provincial, or regional level. Most diversity indices have been constructed from pedigree data, including a Herfindahl index, a Solow-Polasky index, and others based on the number of landrace progenitors or unique parental combinations in the genealogy. Temporal diversity indices (the area-weighted average age of varieties) and Shannon indices from agro-morphological groups calculated with biometric techniques have also been constructed (Franco *et al.*, 1998).

Findings: Studies testing the relationship of crop genetic diversity to productivity, vulnerability, and efficiency are inconclusive to date because methodologies require further development and validation. Associations are sometimes positive and sometimes negative. Findings cannot be generalized because they are specific to location, time period and cropping system. Several studies have tested the relationship of crop biodiversity to productivity, yield variability, and economic efficiency, particularly in farming systems dominated by modern varieties. Heisey *et al.* (1997) demonstrated that higher levels of latent genetic diversity in modern wheat varieties would have generated costs in terms of yield losses in some years in the Punjab of Pakistan. In others, the mix of varieties and their spatial distribution across the region generated both lower overall yields and less diversity than was feasible; that is, a yield-diversity trade-off was evident in some years, but not in others.

In another study on wheat varieties in the Punjab of Pakistan, Smale *et al.* (1998) found that the production environment determines the relationship between diversity and productivity. For instance, among rainfed districts, genealogical distance and a greater number of different varieties grown of smaller areas were associated with both higher mean yields and lower yield variability. In the irrigated areas, by contrast, a high spatial concentration of wheat area among fewer varieties, or greater genetic uniformity had an important, positive effect on expected yields. Applying a similar approach, Widawsky and Rozelle (1998) concluded that rice variety diversity reduced both the mean and the variance of yields in townships of Zhejiang and Jiangsu Provinces of eastern China. Testing the relationship of wheat variety diversity to productivity and economic efficiency in China, Meng *et al.* (2003) found that although evenness in morphological groups contributed to higher per hectare costs of wheat produced, potentially important cost savings were apparent for some inputs, such as pesticides. A greater concentration of cooperative market associations in regions of southern Italy contributed to greater diversity of durum wheat varieties, which positively affected productivity over a number of years (Di Falco, 2003).

Limitations: Temporal and dynamic concepts of resilience and stability need to be better incorporated, in addition to analyses based on expected or mean levels, to test vulnerability hypotheses. More general approaches require a more complete theoretical framework of decision-making under risk with multiple outputs and differentiated genetic inputs, estimated structurally where data permit. A wider cross-section of case studies conducted in commercially oriented, as well as mixed and or subsistence-oriented systems are required in order to generalize and validate empirical findings. The shortcoming of the primal approach is that it enables tests on technical efficiency effects, but not on effects of crop biodiversity on allocative or economic efficiency.

Source: Smale, 2005.

1.4 Benefits generated by accessing and exchanging plant genetic resources for food and agriculture under SMTAs

Having identified the types of value associated with PGR for food and agriculture, the conceptual approaches and methods to quantify such values and the associated challenges, we now turn to an analysis of the specific benefits generated through accessing and exchanging these resources under the Treaty.

For this purpose, it is useful to consider the terminology and type of benefits identified within the text of the Treaty. Article 3 of the Treaty states that its scope relates to PGR for food and agriculture, which is understood to refer to "any genetic material of plant origin of actual or potential value for food and agriculture". Such an all-encompassing scope suggests that a wide range of benefits arising from access to, exchange and use of these resources may be attributed to the Treaty, which goes well beyond the Multilateral System. Other economic benefits flow from the policy harmony promoted by the Treaty with regard to conservation and sustainable use of PGR for food and agriculture, from the development of a Global Information System to facilitate the use of all PGR of interest to food and agriculture, the technical assistance and international cooperation foreseen in several articles of the Treaty, and from the implementation of the Treaty's Funding Strategy.

Through the Multilateral System, established by Article 13, the Treaty is the first international instrument to provide a functional mechanism for benefit-sharing, including monetary benefit-sharing. Here, the Treaty notes that the Contracting Parties consider that facilitated access to Annex 1 crop germplasm itself constitutes a major benefit of the Multilateral System (Article 13.1). The Parties also agree that benefits arising from use, including commercial use, of materials under the Multilateral System shall be shared fairly and equitably through the following mechanisms: the exchange of information; access to and transfer of technology; capacity-building; and the sharing of the benefits arising from commercialization (Article 13.2). Articles 13.2a–c then provide further details regarding the information, technology and capacity-building benefit-sharing mechanisms, while Article 13.2d considers the sharing of "monetary and other benefits of commercialization" through the involvement of the private and public sectors in activities identified under this Article, through partnerships and collaboration and in research and technology development.[14]

[14] The Treaty's website further illustrates the potential range of benefits and beneficiaries, which include: (i) the scientific community, through **access** to the plant genetic resources crucial for research and plant breeding; (ii) both the public and private sectors, which are assured **access** to a wide range of genetic diversity for agricultural development; (iii) present and future generations, because of **increased food security**; (iv) consumers, because of a greater variety of foods, and of agriculture products, as well as **increased food security**; (v) the environment, and future generations, because the Treaty will help **conserve** the genetic diversity necessary to face unpredictable environmental changes, and future human needs; (vi) international Agricultural Research Centres, whose collections the Treaty puts on a **safe** and long-term legal footing; and (vii) farmers and their communities, through **Farmers' Rights (available at:** http://planttreaty.org/faq?tid=137).

In addition to the provisions of Article 13.2, voluntary monetary contributions from countries, international foundations and the private sector also support the Benefit-sharing Fund. These contributions are not a direct result of access under the Multilateral System, but part of the larger funding strategy of the Treaty, provided for in Article 18. The Governing Body has established a target for mobilizing such resources of $116 million between July 2009 and December 2014.[15]

The legal provisions whereby the **monetary benefits** deriving from access to material from the Multilateral System are shared are contained in the legal contract between the provider and the recipient, i.e. the SMTA, which creates a beneficial lien in favour of the Treaty. The SMTA provides for a mandatory payment of an equitable share of financial benefits into the Treaty's Benefit-sharing Fund whenever a commercialized product resulting from material obtained from the Multilateral System is not made freely available for further research and breeding. When the commercialized product is freely available, payment is voluntary. It is in this context that the Treaty website[16] specifically refers to "monetary benefits" as being related to the appropriable "financial benefits" deriving from such commercial product development, as well as those from voluntary contributions.

It is therefore apparent that the Treaty considers access to be a benefit *per se*. There are also references in the Treaty to monetary and other benefits of commercialization; a set of narrowly defined non-monetary benefits are also identified. Although the term 'non-monetary' *per se* is not specifically used in the Treaty, it is nonetheless used in the Treaty website.[17]

Looking at a wider range of sources relevant to PGR for food and agriculture with regard to the definition of benefits, the following should be noted:

1. The CBD also considers access itself to constitute a benefit by referring to the "sharing of the benefits arising out of the utilization of genetic resources, including by appropriate access..." (Article 1).
2. The Bonn Guidelines (p.19) define **monetary** benefits to include "special fees to be paid to trust funds supporting conservation and sustainable use of biodiversity", which would clearly encompass the Treaty Benefit-sharing Fund. **Non-monetary** benefits are defined as including *inter alia* sharing of research and development results, collaboration in scientific research, participation in product development, contributions to the local economy, and food and livelihood security benefits.
3. Raymond and Fowler (2001) classify such access-related benefits as "**non-monetary",** associated with the ability under a multilateral agreement to access more germplasm and improved material than can be found in any single country. They also link such access in the context of multilateral exchange to generating "indirect monetary"

[15] Governing Body Resolution 3/2009.

[16] Available at: http://www.planttreaty.org/content/benefits-multilateral-system

[17] Ibid.

benefits as a result of reduced transaction costs, since alternative bilateral exchange arrangements can have high costs, especially when considering monitoring and enforcement mechanisms. Such benefits are derived from the existence of the Treaty as an international policy institution.

From the above, it is clear that there are potentially inconsistent terminologies and classifications requiring further clarification.

"Monetary benefit-sharing" in the Treaty, a term used exclusively within the context of the Multilateral System, is implemented through the SMTA, and takes the form of payments due to the Benefit-sharing Fund related to the commercialization of a product that incorporated material accessed under an SMTA. The Treaty and the SMTA also provide for a narrowly defined set of non-monetary benefits, namely, the exchange of information, access to and transfer of technology and capacity building.

In the context of the Funding Strategy, that is, the wider framework of the Treaty, voluntary monetary contributions from countries, international foundations and the private sector are also made to the same Benefit-sharing Fund, and thus are used for the same purposes. Viewed in this way, the benefits being shared by the Treaty are therefore wider than those derived from access to the materials in the Multilateral System alone.

As seen above, the Treaty identifies access as a benefit in its own right. It should also be noted that these benefits are derived from the institutional role of the Treaty and its more general framework of conservation and sustainable use, in which access under the Multilateral System is only one part. Yet, in the context of the overall Treaty, such access cannot be categorized as a non-monetary benefit, as suggested by Raymond and Fowler, due to the way that the latter term has been narrowly defined within the context of the Multilateral System. At the same time, access under the Multilateral System would seem to generate more than just monetary or indirect monetary benefits in terms of reduced transaction costs, since such access also contributes to food and livelihood security improvement, economic development and environmental sustainability, as well as supporting future technological innovation. Based on the terminology of the Bonn Guidelines, we should consider at least the first two of these categories (i.e. food security and economic development) to constitute a non-monetary benefit. A similar argument can be made for what is referred to in the Treaty as "other benefits of commercialization" (encompassing partnerships and collaboration, as well as in research and technology development).

Furthermore, the definition of benefits needs to distinguish between benefits deriving from the Treaty as a whole, and within this, the generation of monetary benefits through the Multilateral System implemented by the SMTA. Moreover, these monetary benefits are subsumed into projects supported through the benefit-sharing fund, which also receives donations that do not derive from access under the SMTA. All of these may be subsequently translated into non-monetary benefits as part of the process of approving and implementing projects, with priority "given to the implementation of agreed plans and programmes for farmers in developing countries, especially in least developed countries, and in countries with economies in transition, who conserve and sustainably utilize plant genetic resources for food and agriculture".[18]

By contrast, we note that the broader economics literature tends to consider that the actual value of any type or form of "benefit" should be associated with its impact on overall social welfare as measured through changes in consumer and producer surplus. From this conceptual perspective, improved access, exchange of information, transfer of technology and capacity building leading to food and livelihood security improvement, economic development, environmental sustainability and future technological innovations would rather be considered the "results" or "outcome" of the Treaty rather than the monetary, indirect monetary or non-monetary "benefit" or social welfare impact of the Treaty per se. Instead, they should be seen as elements in a chain that may lead to improvements in overall social welfare. Similarly, the benefit associated with the Benefit-sharing Fund's income being used to finance projects would be related to its eventual impact on economic surplus measures, many of which would clearly be reflected in the market place and therefore may be considered (in this conceptual perspective) "monetary" benefits.

Although a number of studies have documented the global productivity gains in agriculture resulting from some types of crop genetic improvement in terms of economic surplus measures (see below), attributing to the Treaty the actual social welfare improvements generated would also require comparison against some kind of bilateral and/or open access counterfactual. While some studies have attempted to calculate some of the reduced transaction costs associated with the Multilateral System relative to different types of bilateral exchange regimes (see below), these studies fall short of comparing actual economic surplus measures. Further, they do not take into account additional transaction costs related to implementation, monitoring and enforcement.

Additional data requirements and the ability to model an appropriate counterfactual would be necessary to realize such work.

Furthermore, given the current institutional use (e.g. in the Treaty, Bonn Guidelines and CBD) of the term "benefits", it does not seem practical to rename these as "results" or "outcomes", even while acknowledging the conceptual shortcomings of the current terminology. We therefore continue to refer to the type or form of benefit that we are discussing (i.e. monetary, indirect monetary, non-monetary), while being aware that these are measures that are distinct from the overall social welfare impact (as expressed in economic surplus terms), which would be considered to be the true overall "benefit" arising from the existence of the Treaty.

[18] Treaty Article 18.5.

Given the above, we propose the following classification of the type of benefits arising from access to, exchange and use of PGR for food and agriculture under the Treaty. As can be seen in Table 1.1, these can be grouped across a monetary/non-monetary continuum and involve:

i) **monetary benefits**, arising from the benefit-sharing obligations of recipients of material under an SMTA, contributed to the Treaty's Benefit-sharing Fund, and disbursed through the projects funded in the context of the Treaty's Funding Strategy. These monetary benefits are a share of the revenue accruing to recipients of material under an SMTA, who commercialize a product that contains materials accessed under and SMTA;

ii) **indirect monetary benefits** and broadly defined **non-monetary benefits,** resulting from the reduced transaction costs (net of any Treaty implementation, monitoring and enforcement costs) that arise from the use of a **SMTA** rather than individually negotiated instruments, as well as the wide socio-economic impact of Treaty-facilitated access, exchange and use; and

iii) **non-monetary benefits** (narrowly defined), specific to the SMTA and recipients of material under SMTAs, related to information exchange, access to and transfer of technology and capacity building.

Each of these benefit categories may or may not be appropriable from a private/public goods perspective and may involve direct monetary flows or some other form of benefit leading to social welfare improvement.

It should also be worth noting who the beneficiaries of benefit-sharing under the Treaty are. The Treaty itself is not a beneficiary; instead it acts as a conduit to transfer these benefits to the ultimate beneficiaries, for example, recipients of project funding via the Benefit-sharing Fund, as per the details of Treaty Article 18.5 mentioned above. The multilateral nature of both access (where the materials of the Multilateral System may be accessed as a non-rival good) and benefit-sharing under the Treaty (where the immediate provider is not the immediate or ultimate beneficiary) is at the root of the difference between benefit-sharing under the Treaty, and benefit-sharing under the CBD. Access and benefit-sharing under the CBD almost invariably means having an exclusive bilateral use licence, with monetary payment to the provider, who is the ultimate beneficiary. In the multilateral Treaty, the provider is not the ultimate beneficiary of these monetary benefits, but rather, those who receive support under the projects (as well as those beneficiaries of the cascade of non-monetary benefits generated that go beyond the immediate recipients of project support). Hence, all the monetary benefits are subsequently transformed so as to generate benefits in line with Articles 5 and 6 of the Treaty, and form part of its wider Funding Strategy.

Each of these benefit types are discussed in further detail below.

1.4.1 Monetary benefits

Monetary benefits generated by the access, exchange and use of SMTA materials result in projects funded with the mandatory and voluntary payments made to the Benefit-sharing Fund. Depending on the types of project funded, the benefits derived from such projects may be privately appropriable or not.

Understanding the potential magnitude of such direct benefits is directly related to understanding the likely payments into the Treaty Benefit-sharing Fund over time. The legal obligation to make payments is assigned to the recipients of materials under SMTA conditions, who commercialize products containing these materials. In the case of any such product that is not freely available without restriction to others for further research and breeding, a mandatory payment of 1.1 of gross sales (minus 30 percent to cover marketing costs) is required (Article 6.7 of the SMTA).[19] If a final product is instead available without restriction to others for further research and breeding, the recipient is only encouraged to make a voluntary payment into the Benefit-sharing Fund (Article 6.8 of the SMTA). As an alternative to these payment options, recipients may choose instead to pay a discounted rate to 0.5 percent of their gross sales of a particular crop or crops, regardless of whether the products are available without restriction, and whether or not they incorporate materials accessed from the Multilateral System[20] (Article 6.11 of the SMTA). Payments are generated not only by the initial product developed incorporating materials under SMTA conditions, but also all the future products derived from it (Article 6.1 of the SMTA).

Such voluntary and mandatory payments result from the direct use value of genetic resources arising from their effective commercialization and farmers' adoption of improved crop genetic resources.

Currently, the Treaty estimates that, on average, around 800 SMTA materials are transferred every day, but it is uncertain what part of these transfers results in a product incorporating such materials. The CGIAR collections are important in this context, given that they hold at least 50 percent of all Multilateral System materials. From August 2008 to January 2010 (latest available figures), the collections maintained by the CGIAR distributed more than 600 000 samples of SMTA materials; 71 percent of the distributed samples were improved material and were accessed mainly by developing countries (ITPGRFA, 2011).

[19] The level of payment is stipulated in Annex 2 of the SMTA as follows: "If a Recipient, its affiliates, contractors, licencees, and lessees, commercializes a Product or Products, then the Recipient shall pay one point-one percent (1.1) of the Sales of the Product or Products less thirty percent (30); except that no payment shall be due on any Product or Products that: "(a) are available without restriction to others for further research and breeding in accordance with Article 2 of this Agreement; (b) have been purchased or otherwise obtained from another person or entity who either has already made payment on the Product or Products or is exempt from the obligation to make payment pursuant to subparagraph (a) above; (c) are sold or traded as a commodity."

[20] "The discounted rate for payments made under Article 6.11 shall be zero point five percent (0.5%) of the Sales of any Products and of the sales of any other products that are Plant Genetic Resources for Food and Agriculture belonging to the same crop" for which the Recipient has accepted Article 6.11 in the context of an SMTA.

Table 1.1 Typology of benefits associated with the Treaty

Continuum of monetary and non-monetary benefits	Type of benefit	Benefits generated by the Treaty as a whole	Benefits generated under the MLS	Mechanism through which benefits are shared	Type of economic value
	Monetary[1]	**Payments and contributions by various donors** to the Treaty's Benefit-sharing Fund. Activities undertaken by third parties, within the framework of the Funding Strategy, e.g. the Global Crop Diversity Trust and the Svalbard Seed vault.		Projects funded through the Benefit-sharing Fund of the Treaty. Activities of the Global Crop Diversity Trust (GCDT)[2] and conservation safety back-up facilities provided by the donor (Norway) at Svalbard.	Use and non-use values. Appropriable and non-appropriable use and non-use values are generated through the Funding Strategy. Option/existence values are secured by the GCDT, and the Svalbard facilities.
			Generation of monetary benefits paid to the Benefit-sharing Fund, by recipients commercializing products containing SMTA materials.[3]	Projects funded through the Benefit-sharing Fund of the Treaty.	Use values. Appropriable and non-appropriable use values are generated through such projects.
	Indirect monetary AND	Food and livelihood security improvement, economic development[4] environmental sustainability and future technological innovations (arising not just from SMTA materials). Free and equitable access (pooled goods, level playing field).	Reduced transaction costs[5] through facilitated **access** to Annex I crops under a **Standard MTA.** Food and livelihood security improvement, economic development, environmental sustainability and future technological innovations (arising from SMTA materials).	Access at reduced transaction costs results automatically in higher levels of germplasm exchange and use.	Use values and non-use values. Mixed private and public goods. Option and non-use existence and bequest values are also secured through maintenance of *ex situ* collections, including through interactions with complementary *in situ* conservation activities.

	Non-monetary (**broadly** defined)		"Other benefits of commercialization" (encompassing partnerships and collaboration, as well as in research and technology development).		
	Non-monetary benefits (MLS, **narrowly** defined)		Exchange of information, access to and transfer of technology and capacity-building (arising from SMTA materials).	See Appendix 1.4 for an outline of benefit-sharing mechanisms/activities.	Use values Appropriable and non-appropriable use and non-use values generated through such mechanisms/activities.

Source: Authors.

1. The Bonn Guidelines (p. 19) define monetary benefits as including "special fees to be paid to trust funds supporting conservation and sustainable use of biodiversity".
2. The Relationship Agreement between the Governing Body of the Treaty and the Trust was formally approved in Madrid, June 2006, and recognizes the Trust as an essential element of the funding strategy, in regards to the *ex situ* conservation and availability of PGR for food and agriculture. The Trust has established, *inter alia*, in-perpetuity support (i.e. grants funded through the Trust's endowment) for collections of a number of crops, as well as providing support to developing countries and international agricultural research centers to deposit seed samples in the Svalbard Global Seed Vault. A global programme to find, gather, catalogue and save the wild relatives of 22 major food crops is also underway.
3. The Multilateral System relates only to Annex I crops. However, a number of Contracting Parties, as a decision outside the workings of the Multilateral System, are releasing non-Annex I crops under the terms and conditions of the SMTA, which will create a further stream of monetary benefits.
4. Without the possibility for countries to easily access the PGR, they need to improve their crops, agriculture and food security would suffer at both global and national levels (Moore and Tymowsky, 2005, p.103)
5. This ssumes that transaction costs net of implementation, monitoring and enforcement costs are in fact lower than under bilateral and/or open access regimes.

Aware that plant breeding is a slow process and that the build-up of a steady stream of monetary benefits from the use of the SMTA is likely to take many years (at the time of writing, no single such payment had yet been received), the Governing Body has established a target for the Benefit-sharing Fund of mobilizing $116 million by 2014 through voluntary contributions, and not directly deriving from access under an SMTA. Contributions are actively encouraged from Contracting Parties and International Institutions, such as the United Nations Development Programme (UNDP) and the International Fund for Agricultural Development (IFAD), as well as foundations and private donors. Voluntary contributions from several countries have allowed the Benefit-sharing Fund to significantly exceed the target for 2010, and have enabled the Treaty to fund a number of projects in developing countries, supported with these monies.

Also not directly deriving from access under an SMTA,[21] in 2009, Norway decided to donate a sum equal to 0.1 percent of all annual seed sales in the country to the Fund. In March 2008, the Norwegian Minister of Agriculture estimated that if all Contracting Parties that are Organisation for Economic Co-operation and Development (OECD) countries donated the same percentage of their national seed sales, the Fund would have an annual budget of around $20 million. This amount corresponds to an estimated OECD Annex 1 germplasm market size of approximately $20 billion.[22] The Governing Body "commended the Norwegian decision to provide 0.1 percent of the annual value of all seed sold in its territory as an example of innovative approaches to allow for the provision of resources to the Benefit-sharing Fund on a regular and predictable basis".[23]

Table 1.2 Average no. of US patents related to rice, wheat and corn genetic resources per month

Time period	Rice	Wheat	Corn
1981–85	1.0	1.2	2.1
1986–90	2.6	3.1	4.5
1991–95	6.9	8.3	13.6
1996–2001	44.0	47.4	73.0
Jan. 2002 – Oct. 2009	175.1	149.8	289.3
Nov. 2009 – Nov. 2011	252.3	205.1	410.5

Note: Applications containing the terms rice, wheat, or corn, as well as the term gene.

Source: Gotor *et al.*, 2010 (available at: www.uspto.gov).

21 Available at www.ip-watch.org/weblog/2009/01/14/fao-plant-treaty-to-operationalise-benefit-sharing-fund/

22 Note that Srinivasan suggests in Chapter 3 that the value of the global seed market (not just OECD) ranges from US$36.1 billion to US$42 billion (GIA, 2010; ISF, 2011). As concerns the Annex I crops, the seed market value Is estimated as equal to US$19.4 billion.

23 IT/GB-3/09/Report, para. 27.

As previously noted, although building up a steady stream of monetary benefits from commercialization may take many years, it is likely that the number of mandatory payments will grow in the future. This expectation may be supported by the fact that the US Patent and Trademark Office has documented a steady increase in patent applications and grants for genetic resources (see Table 1.2) following the ratification of the CBD (Falcon and Fowler, 2002; Gotor *et al*., 2010). Such an expected growth in mandatory payment requirements may, however, be moderated by attempts – especially by larger commercial companies who are some of the main potential users of crop genetic resources – to avoid materials that fall under the Multilateral System (Michael Halewood, personal communication, 2012). This outcome is also confirmed by results of the survey of plant-breeding experts (see Annex), suggesting that commercial breeding programmes are avoiding the use of SMTA material. (See also footnote 42 regarding the potentially dynamic nature and implications of avoidance.)

1.4.2 Indirect monetary and non-monetary (broadly defined) benefits

Indirect monetary benefits derive from the effective and less confrontational international policy framework provided by the Treaty as an institution, which is considered to have greatly reduced many of the international tensions that had resulted in diminished access to PGR for food and agriculture. This is one reason for which the Contracting Parties consider that facilitated access to Annex 1 crops itself constitutes a major benefit of the Multilateral System (Article 13.1). The institutional value of the Treaty may consequently be expected to have a positive impact on the demand and utilization of crop genetic resources, thereby causing changes in overall social welfare as measured through changes in economic surplus measures[24] and contributing to the attainment of non-monetary benefits (broadly defined, as per Bonn Guidelines and others).

Indirect monetary benefits also derive from the reduced transaction costs[25] associated with the use of a **Standard** MTA, rather than an instrument that needs to be separately negotiated for separate transfers, in bilateral negotiations for access.

Broadly defined non-monetary benefits generated by accessing, exchanging and using SMTA materials are related to the public and global benefits resulting from food and livelihood security improvement, economic development and environmental sustainability. They also establish the basis for future technological innovations in agriculture. The Treaty's institutional framework has recognized the importance of the role of the CGIAR, in the conservation and sustainable utilization of PGR for food and agriculture. Additional

[24] Strictly speaking and as noted previously, it is in fact these changes that economists would associate with the generation of benefits, rather than access itself, i.e. the input or institutional arrangement.

[25] Moore (2010) has partially estimated such Multilateral System transaction costs relative to a bilateral system of exchange as resulting in an annual saving of $19.5–73 million (Moore, 2010); Visser *et al. (2000) arrived at similar figures ($20.8–76.1 million).*

benefits arising from CGIAR's *ex situ* collections, for which the Treaty has now provided on an internationally agreed legal status (see Appendix 1.3), are identified as being related to health, self-sufficiency and conflict/disaster recovery. Non-use existence and bequest values are also secured. Such benefits may be difficult to observe over the short term, but their economic impact is cumulative over the long term (Wale, 2011). In addition, there is reason to believe that such social welfare impacts are significant, as previously noted, as a result of the productivity benefits accruing to society as a whole and especially to consumers in terms of lower food prices (Smale, 2002).

A part of the indirect monetary and broadly defined non-monetary benefits also corresponds to the real added value, arising from the effective use of PGR for food and agriculture promoted by the Treaty, analysed through the market prices of commercial seeds. As suggested by Smolders (2005), landraces or unimproved materials are perceived as having little economic value for commercial companies, because their development into breeding lines is costly, time-consuming and with low chances of success. Smolders (2005) estimates that payment, if any, for a sample of exotic and unadapted material, and even pre-bred materials will normally not exceed a nominal fee, such as $5 to $20, while improved materials in advanced development stages, showing interesting traits, may be valued by commercial companies in the range of $5 000–50 000. Clearly, many factors will influence the marketable value arising from the utilization of SMTA materials, depending on the chance of success, the length of the development cycle and the final economic return of the materials. Furthermore, the factors are crop-specific and depend on the state of development of the materials. Similar results of the value of a commercial trait are reached by Evenson and Gollin (1997). Focusing on IRRI germplasm, the authors estimated the present value, not wholly privately appropriable, of a single accession bred successfully into a modern rice variety to be worth nearly $50 million, and that 1 000 catalogued accessions accounted for $325 million, corresponding to $3 250 for an accession. Finally, Smolders indicates for a successfully implemented trait, a potential range of 10–60 percent added value (around 10–20 percent for corn and 50–60 percent for cotton in the United States).

A number of studies have documented the global productivity gains in agriculture resulting from crop genetic improvement. For example, Johnson *et al*. (2003) find that nearly 50 percent of increased US yields during 1930–1980 may be attributed to genetic resources. Similarly, Thirtle (1985) values the long-term economic contribution of 'biological change' including genetic enhancements, estimating the production function of five major U.S food crops during the period 1939–1978. The author, nesting CES and Cobb-Douglas production functions, infers that the biological component has assured a yield improvement on average of 1 percent per year, or nearly 50 percent of the total yield growth observed.

PGR for food and agriculture also continue to play a leading role in confronting environmental and agricultural challenges such as climate change and in ensuring current and future food security for a growing world population. As stated by Asfaw and Lipper (2011), the broadening of the genetic resource base has allowed farmers to successfully address changing climatic conditions, as well as to protect and improve the livelihoods of the poor. It is well known that genetic erosion increases households' vulnerability (Table 1.3) to pedoclimatic stresses and to world crop price fluctuations, undermining the stability of rural household livelihood, especially in developing countries (Thrupp, 2000; Gore, 1992).

Global impacts of close collaboration between the National Systems and CGIAR are to be found in the development of the Green Revolution varieties of wheat and rice for South Asia and later in the development of high-yielding maize varieties in Africa. The importance and utility of the germplasm distributed by the CGIAR in the development of improved varieties in different developing countries has been well documented (Hossain *et al*., 2007; Bellon *et al*., 2007; Dixon *et al*., 2006, Lantican *et al.,* 2005). The development of the Green Revolution varieties was largely made possible by the free flow of PGR between national and international research centres, facilitated by the CGIAR Centres. Many National Agricultural Research Systems (NARSs) have relied and continue to rely heavily on breeding lines provided by CGIAR Centres to develop locally adapted improved varieties. CGIAR germplasm has been an important source of desirable traits sought by National Systems for their plant breeding programmes.

Table 1.3 Genetic erosion-related agricultural impacts

Date	Location	Crop	Effects
1846	Ireland	Potato	Famine
1800s	Sri Lanka	Coffee	Farms destroyed
1940s	U.S.A	Various	Crop loss to insects doubled
1943	India	Rice	Famine
1960s	U.S.A	Wheat	Rust epidemic
1970	U.S.A	Maize	$1 billion loss
1970	Philippines, Indonesia	Rice	Tungo virus epidemic
1974	Indonesia	Rice	3 million tons destroyed
1984	Florida, US	Citrus fruits	18 million trees destroyed

Source: Thrupp, 2000.

Varieties developed by CGIAR Centres have been directly transferred for commercial cultivation in developing countries; for example, "62 percent of the wheat area in the developing world is estimated to be planted to varieties with CIMMYT ancestry" (Heisey *et al*., 1999). Similarly, material developed at IRRI is estimated to figure in the pedigree of 70 percent of commercially successful rice varieties grown in developing countries: according to Evenson and Gollin (1997), "for varieties released in 1981-90, IRRI delivered 72 percent of ancestors". Major impacts have been seen in terms of conservation, crop improvement and production, with consequent improvement in economic or environmental conditions. In order to assess these benefits in economic terms, Evenson and Gollin (1997) evaluated the economic role of IRRI in improving rice cultivars. IRRI's activities include germplasm collection and exchange, and direct supply of bred varieties to farmers. A genealogical analysis was conducted to highlight progenitor traits in 20 improved modern varieties. IRRI's global economic impact was estimated through an econometric analysis aimed at determining the contribution of accessions to the average value of modern rice varieties. Using a conservative discount rate, over a period of 20 years, the IRRI impact was estimated at approximately $1.9 billion.

More recently, a study by Brennan and Malabayabas (2011) revealed that, since 1985, the impact of IRRI's germplasm contribution to rice varietal yields in the Philippines, Indonesia and Viet Nam have ranged from 1.8 percent in northern Viet Nam to 9.8 percent in southern Viet Nam, 6.7 percent in the Philippines and 13.0 percent in Indonesia; in 2009, it averaged 11.2 percent. The economic benefits have therefore been estimated at approximately $1.46 billion per year across the three countries. Further examples of the critical role played by the CGIAR collections in the development of new varieties with desirable characteristics are shown in Appendix 1.3.

1.4.3 Non-monetary benefits

The Funding Strategy of the Treaty (Article 18) is seen as crucial for non-monetary benefit sharing, because it seeks to mobilize a wide range of resources, from a wide range of stakeholders for priority activities, plans and programmes (Visser *et al*., 2005). However, the Treaty addresses non-monetary benefit-sharing according to three narrowly defined categories (see Appendix 1.4), which are as follows; they are largely associated with public and global good use values:

- *Exchange of information*, which may involve catalogues and inventories, information on technologies, and results of research relevant to the PGR for food and agriculture under the Multilateral System.
- *Access to and transfer of technology*, including access to materials and access to relevant technologies for the characterization, evaluation and utilization of PGR for food and agriculture.
- *Capacity-building*, which may include programmes for scientific and technical research, education, and training in conservation and sustainable use of PGR for food and agriculture, and for developing and strengthening relevant facilities.

Visser *et al*. (2005) provide a series of recommendations to the Governing Body regarding the sharing of such non-monetary benefits, as follows:

1. The development of the Global Information System, provided for in Article 17 of the Treaty, including the establishment of a Focal Point for Good Practices.
2. The provision of information to agencies that may want to contribute to the implementation of the Treaty through the provision of non-monetary contributions.
3. The strengthening of regional networks and national capacities in developing countries using available expertise in national and international organizations, including the CGIAR Centres.
4. The strengthening of national capacities for needs assessments regarding the conservation and utilization of PGR.

In the context of PGR in general, Ten Kate (1995) notes that information can be exchanged through multilateral channels such as the Treaty's Global Information System and the CBD's Clearing-House Mechanism, through publications, or communicated between individual organizations. By contrast, technology transfer, joint research and capacity building can occur through courses, staff exchanges and conferences and by sponsoring students or research at academic institutions or within communities (e.g. supporting the work of shamans, documenting local knowledge, or creating community gene banks) and by supporting institutions such as *ex situ* collections. It can be carried out by individual partners, or by joint efforts through networks, for example, placing students in industry. Collectors and companies will need the help of local communities and organizations to identify suitable communities and institutions to receive benefits such as equipment and training.

1.5 Potential methods for Treaty benefit quantification

The above typology of Treaty benefits provides some indication of the types of economic tools and methods that could be used to support the quantification of benefits arising from the Treaty.

A. With regard to the **monetary benefits** arising from commercialization of products incorporating material accessed under an SMTA, benefits are expressed as a percentage of the sales value. As such, the actual total economic value of the genetic resource is not directly relevant, and a modelling approach (see Chapter 3) to estimate existing and future SMTA material commercialization is required.

Such modelling will have to contend with the fact that there is little systematic information and no developed methodology to provide a fair projection of what monetary benefits are actually likely to result from the access, exchange and use of SMTA material.

Among the specific challenges to be confronted, there is uncertainty about what proportion of existing SMTA transfers result in products incorporating material accessed under a SMTA. There is also no current basis for assessing the ratio of products from which a mandatory payment would be due (because the product is not freely available to others for research and breeding) compared to those for which voluntary payments would be due (because the product is freely available for such purposes). It is also likely that crop differences will have to be accounted for. Furthermore, there is as yet no estimate of what proportion of materials used in plant breeding is being accessed under an SMTA, and what proportion from other sources, as well as of relevant practices of entities engaged in breeding activities.

The mathematical model developed by Stannard, Caracciolo and Hillery (see Chapter 3) aims to identify and define these and other variables that need to be taken into account for the empirical modelling of the expected contributions. Moving from a model to an empirical investigation of likely future payments to the Treaty's Benefit-sharing Fund will require investigating, *inter alia,* trends in the exchange of materials under an SMTA, including: the crops and type of genetic resources being exchanged; between whom these exchanges are taking place (countries, researchers, farmers and breeders); the degree to which such resources are being used to develop products; the type of products likely to be developed and the length of the product development cycles; as well as the timing of the likely build-up of contributions to the Benefit-sharing Fund.

On this basis, a methodology would first be developed through which a more precise projection of the likely income over time of the Benefit-sharing Fund could be attempted. In the process, the adequacy of current information for such purposes can be assessed and proposals advanced as to how the information base can be improved for future analyses. It must be noted, however, that much of the information required for this purpose is held by private entities that do not accept to make it public, for trade confidentiality reasons.

It should nonetheless be appreciated that even in the presence of perfect information regarding present and future SMTA payments, such monetary payments may be translated, through Benefit-sharing Fund project funding, into non-monetary goods and services at a regional, national or local level. Multiplier effects and the generation of a broad range of non-monetary benefits would then ideally need to be taken into account through an assessment of the impact on social welfare, including relative to a counterfactual. Nevertheless, estimation of possible or probable Benefit-sharing Fund income would at least constitute a first step in this process.

In terms of future modelling approaches, given the current possibility for breeders and breeding companies to gain access to alternate sources of certain genetic resources that would otherwise have to be accessed through the SMTA, and the impact this may have on incentives to avoid SMTA materials and therefore generate payments into the Benefit-sharing Fund, game theory approaches to exploring payments under a range of access, use and exchange scenarios with different implicit costs might be worth considering.

B. The **indirect monetary benefits** have been defined in terms of reduced transaction costs and, again, a modelling approach is the most appropriate way to estimate such benefits. As previously noted, Moore (2010) and Visser *et al.* (2000), among others, have partially estimated such transaction costs under the Multilateral System relative to alternative systems of exchange. Given that Moore found, relative to a bilateral system of exchange, annual savings of $19.5–73 million, it is clear that this benefit category may be substantial even once implementation, monitoring and enforcement costs have been accounted for.

Broad non-monetary benefits were identified as being largely related to food and livelihood security improvement, economic development, environmental sustainability and support for future technological innovations. As may be appreciated from the literature reviewed in sections 1.3 and 1.4.2, these values may also be very substantial. However, in determining the actual Treaty-related impact on overall social welfare, it would be necessary to compare this impact against some hypothetical (non-Treaty) alternative in order to appreciate how indirect and non-monetary benefits as well as impact may arise from changes in institutional arrangements. A number of bilateral exchange scenarios considered by Moore (2010) – i.e. purely bilateral, only CGIAR collections and national cereals in the Multilateral System, CG collections and national collections of cereals and grain legumes in the Multilateral System, and all food crops covered by the Multilateral System – could be considered for this purpose, as could an open access scenario. Under each of these scenarios, broadly defined transaction costs (i.e. implementation, monitoring and enforcement) need to be accounted for, since they would also need to be under assessments of the Treaty.[26] As noted previously, intervention would only be justified where net benefits are generated. The degree to which Benefit-sharing Fund financed projects contribute to ensuring that the net economic impact is positive would certainly be expected to contribute to encouraging widespread participation in the Multilateral System.

With regard to assessing food/livelihood security improvement and economic development, it is noted in section 1.3 that studies seeking to estimate benefits expected from using an additional gene bank accession in crop breeding have employed

26 Of further relevance to the consideration of the relative benefits and costs is the uptake of genetic material under the Treaty. The Treaty effectively involves resources that were previously free being subject to a positive price. Conceptually it can be expected that less genetic material will be used with the positive price. Users of operations such as the CGIAR network's breeding programmes may then be expected to decline or alternative mechanisms for developing improved varieties will be found. That is, economizing will occur and cheaper substitutes will be found. The process of developing those substitutes will be accelerated. For instance, the manipulation of genetic material 'in-silica' may be enhanced. This means that the Treaty may have the unintended consequence of reducing the activities of operations such as the CGIAR Centre initiatives. This raises concern when the goal of the CGIAR is to produce 'international public goods'. Charging for the genetic material (previously an international public good) will reduce the benefits of plant varieties compared with what would have otherwise been the case (J. Bennett, personal communication, May 2012). Whether the social welfare improvements associated with the funding of projects from the Treaty Benefit-sharing Fund can outweigh such a reduction in benefits remains to be demonstrated.

mathematical programming, Monte Carlo simulations, and maximum entropy methods in a search theoretic framework, combined with partial equilibrium estimates of the productivity impact of the bred materials in farmers' fields (Smale, 2005). However, such studies generally refer to monetary benefits arising from commercialization rather than broadly defined non-monetary benefits. This is in part related to the argument that the costs of conserving accessions in gene banks are relatively easy to tabulate compared to the expected benefits from the accessions they conserve (Pardey *et al.,* 2001), while Koo *et al.* (2004) consider that in many cases, undertaking the expensive and challenging exercise of benefits estimation is not necessary to justify conservation.

The commercial value of PGR for food and agriculture has been shown to be only a relatively small component of its total economic value to society. By contrast, the productivity benefits accruing to society as a whole (a broadly defined non-monetary benefit) and especially to consumers in terms of lower food prices are large relative to the costs of investing in plant breeding, particularly in less advanced agricultural economies. Such benefits are distributed to society through effects on producers' and consumers' incomes. The literature of relevance to this type of benefit valuation is extensive and advanced, and methods for attributing the benefits of specific plant breeding programmes continue to be refined (Pardey *et al*., 2004).

For other types of non-monetary benefits, such as those associated with environmental sustainability, and with particular regard to ecosystem service provision, Ceroni *et al.* (2005), note that the relevant valuation methods need to be supported by a better understanding of the relationships between agrobiodiversity and ecosystem functions. In terms of the climate change adaptability ecosystem service, Asfaw and Lipper (2011) argue that much of the current understanding of the potential effectiveness of PGR management for adaptation is based on simulation model results. However, the benefits of adaptation activities, which should be measured against a counterfactual, are often highly uncertain and thus very difficult to estimate reliably *ex ante* (Lecocq and Shalizi, 2007).

C. **Narrow non-monetary benefits** were identified by the Treaty as being related to the exchange of information, access to and transfer of technology and capacity-building. Specific recommendations regarding mechanisms for the sharing of such non-monetary benefits were made by Visser *et al.* (2005). They also note that since "non-monetary" does not mean without financial cost to the provider, there would appear to be some scope for identifying the magnitude of such costs as a lower bound for the value of such non-monetary benefits.

The work presented in Chapter 4 in fact suggests one promising way in which such an approach might be implemented. This would involve drawing on the relevance of scientometrics or bibliometrics (the analysis of scientific literature), as published research is generally the outcome of monetary investments in particular research projects, which can be accounted for in national systems and by research organizations. Given that research on PGR for food and agriculture is typically international in nature, and publications frequently involve collaborations between countries and organizations, these networks can be mapped using network visualization tools such as Gephi. As shown in Chapter 4, it appears to be increasingly possible to identify non-monetary benefits in terms of actual collaborations between researches, and the training and exchange of students, postdoctoral researchers and staff between institutions. These collaborations embody knowledge exchange and transfers within networks and can be considered a major component of non-monetary benefit-sharing. The potential application of this approach is further discussed in Chapter 4.

Chapter 2

ASSESSING THE POTENTIAL FOR MONETARY PAYMENTS FROM EXCHANGE OF PLANT GENETIC RESOURCES UNDER THE MULTILATERAL SYSTEM OF THE INTERNATIONAL TREATY ON PLANT GENETIC RESOURCES FOR FOOD AND AGRICULTURE

C.S. SRINIVASAN

2.1 Introductory note

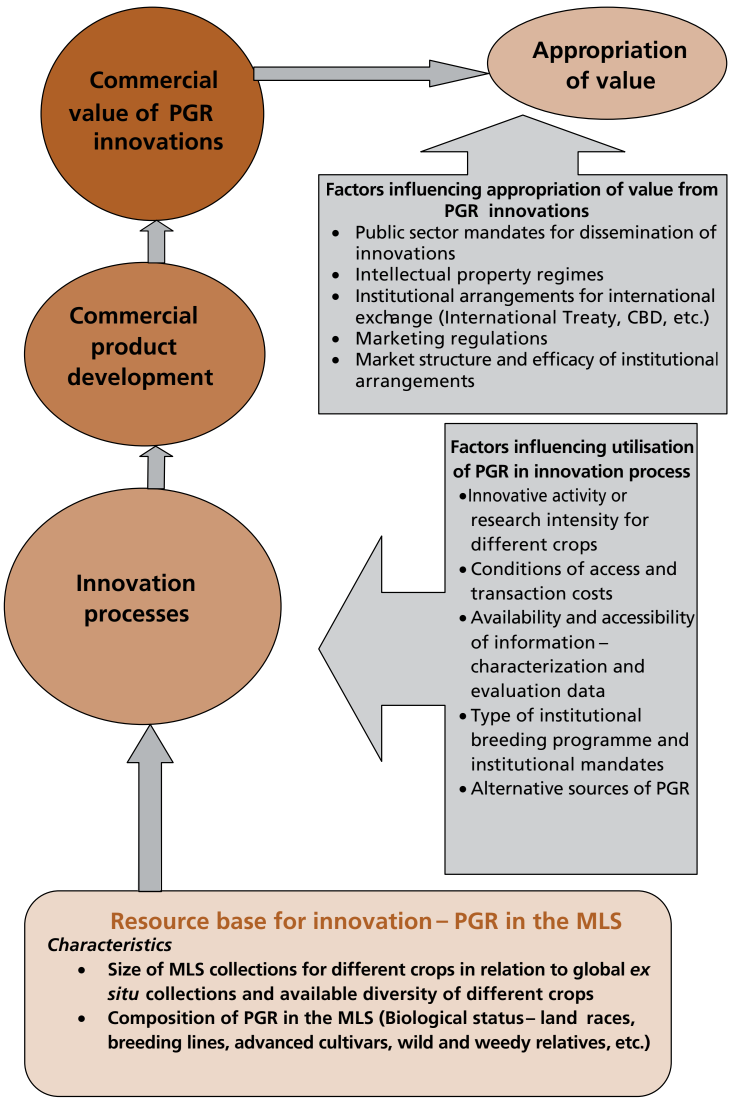
The aim of this chapter is to develop an approach to the quantitative assessment of benefit-sharing flows from the exchange of PGR through SMTAs under the Treaty based on an analysis of the economic values of global seed production and their distribution across crops, regions and countries. A macro-level approach will be followed, starting with an assessment of the overall value of seed production at the global and regional levels, and identifying components of the aggregate economic value that may potentially be appropriated under benefit-sharing provisions of the SMTAs under a range of scenarios for Treaty implementation.

Section 2.2 explains the conceptual framework on which this chapter is based. The following sections 2.3 and 2.4 will carry out an empirical assessment of the different elements of the framework drawing inferences for the magnitude of potential flows into the Benefit-sharing Fund of the Treaty. These empirical assessments also provide some important parameters for the micro-level model presented in Chapter 3 to simulate the magnitude of flows into the Benefit-sharing Fund under different scenarios. The detailed empirical assessments are focused on three major crops – wheat, rice and maize – owing to data availability constraints. Section 2.5 explains the methodology used for assessing the use of PGR exchanged under SMTAs in the development of final product innovations. Section 2.6 develops estimates of the value of the global commercial market for seeds related to Annex 1 crops. Sections 2.7 and 2.8 provide an assessment of the potential flows of mandatory and voluntary payments into the Benefit-sharing Fund as a result of the use of PGR from the Multilateral System (MLS) of the Treaty in product innovations. Section 2.9 develops information methodologies for assessing the use of MLS material exchanged through SMTAs in commercial innovations while Section 2.10 presents the main conclusions of this chapter.

2.2 Conceptual Framework

The approach used here is underpinned by a conceptual framework (Figure 2.1) that views PGR available for exchange through the MLS primarily as a resource for plant variety innovations. The utilization of this resource in innovation processes generates products with commercial value. Institutional arrangements, which include market structures and intellectual property regimes, determine how the commercial value of innovations is appropriated by different actors. SMTA-mediated PGR exchange under the Treaty is part of the institutional architecture that determines the appropriation of value and the magnitude of flows into the Benefit-sharing Fund.

Figure 2.1 Conceptual framework for assessment of benefit-sharing flows from PGR exchange



2.2.1 Resource base for innovation

From the perspective of institutional or community-based plant breeding programmes, the sources of PGR for innovation can divided into *ex situ* and *in situ* resources. *Ex situ* sources of PGR are mainly national and international gene banks, and other institutional repositories where PGR collected from the field are stored under controlled conditions to maintain viability, and may be regenerated periodically. *Ex situ* collections are generally maintained with information relevant for the identification of individual accessions ('passport data') and their potential use (e.g. agronomic traits and agro-climatic adaptability), although the level of detail and comprehensiveness of information may vary considerably both within and across gene banks and repositories. *In situ* PGR refers to PGR found in the wild or on farmers fields, and may not have been systematically identified, explored on characterized. On-farm *in situ* PGR may have been selected, conserved and developed by farmers over generations and may be constantly evolving. The PGR included under the MLS of the Treaty is a subset of the *ex situ* sources of PGR that breeding programmes – both institutional programmes in the public and private sectors as well as community-based participatory breeding programmes – may aim to access. It should be noted that there may be a considerable degree of overlap between MLS and non-MLS sources of PGR since the duplication of PGR across multiple collections implies that some PGR may be available in both MLS and non-MLS collections.

The content of PGR that is now included in the MLS has been shaped by a number of factors, some of the most important being: (i) the historical legacy of PGR exchange between countries that goes back centuries; (ii) the international exchange regime for PGR and paradigms that were prevalent prior to the Treaty and the CBD; (iii) the international collaboration in agricultural research facilitated by the International Agricultural Research Centres (IARCs) of CGIAR; and (iv) the progressive application of intellectual property rights to PGR innovations over the last four decades in developed countries and the extension of intellectual property rights (IPR) regimes in developing countries following the Agreement on Trade-Related Aspects of Intellectual Property Rights (TRIPs Agreement) under the World Trade Organization (WTO). Finally, the boundaries of the MLS have been defined by the provisions of the Treaty, which represented the outcome of an extended and complex political negotiating process (Frison *et al*., 2011).

2.2.2 Utilization of PGR

The key factors influencing the use of PGR included in the MLS in innovation processes (development of new varieties of plants through plant breeding programmes) are discussed below.

(a) *Size of PGR collections in the MLS in relation to all of the available PGR*: For any given crop, the reliance of breeding programmes on PGR from the MLS is likely to be greater if the MLS includes a significant portion of the total agro-biodiversity of that crop. The use of MLS-PGR in breeding programmes will depend on the relative size of the MLS collection, as well as on whether they contain critical traits of interest to breeders.

(b) *Composition of PGR collections in the MLS*: For any crop, the PGR included in the MLS may consist of several different elements such as:

- Wild/weedy relatives
- Traditional cultivars /landraces
- Breeding lines/research material
- Advanced improved cultivars.

The composition of PGR will influence the uptake of material by breeding programmes, which may also change over time. The demand for traditional cultivars and wild/weedy relatives may decrease as their useful traits are incorporated into breeding lines and advanced cultivars, although breeding programmes may occasionally be forced to recur to weedy relatives or traditional cultivars for relevant traits as new pathogens emerge or as agro-climatic adaptation needs change. The time lag between the use of PGR in a programme and the development of a commercial product (variety) will also depend on the type of PGR accessed. Breeding lines may be transformed fairly quickly into a commercial variety whereas landraces or wild/weedy relatives may take much longer to be incorporated into commercial varieties.

(c) *Innovative activity related to the crop*: The demand for PGR from the MLS in breeding programmes is likely to vary with the amount of innovation activity that a particular crop attracts. This in turn is likely to be influenced by the size of the commercial market and the research capacity available for this crop, the research priorities and mandates of institutional breeding programmes, and the incentives for innovation offered by intellectual property regimes.

(d) *Conditions of access and transaction costs*: The demand for PGR from the MLS is likely to be influenced by the ease of access and the related transaction costs. Although one of the main objectives of the Treaty is to facilitate access to PGR included in the MLS through standardized terms and conditions, in practice, the ease of access, the speed of access, and associated transaction costs can vary across Contracting Parties and institutions depending on the effectiveness of implementation of the Treaty. The performance of individual Contracting Parties in giving effect to the Treaty (e.g. in designating and notifying PGR available under the MLS, facilitating administrative arrangements for access) will play a major role in determining the quantum of PGR from the MLS (MLS-PGR) that is actually available for use in the innovation process.

(e) *Availability of information*: PGR in *ex situ* collections is of little use to breeding programmes unless passport data and characteristic information on agronomic traits, agro-climatic adaptability and susceptibility to diseases and pathogens are available and accessible. The use of PGR in the MLS will depend on the extent to which critical characteristic information is accessible to potential users. This may vary by crop, country and institution hosting the collection. Even large, diverse and accessible collections may not be utilized unless supported by availability of relevant information.

(f) *Type of institution*: The use of PGR from the MLS may also be different between public sector (national or international) and private sector research institutions. Private sector institutions that seek to appropriate returns from their innovations by seeking IPR protection may seek to avoid the use of PGR subject to SMTA conditions that would force them to share the benefits of commercialization with the providers of PGR. Private sector breeding programmes may have incentives to adopt breeding strategies that avoid the use of MLS-PGR or access the material from non-MLS sources.

(g) *Alternative sources of PGR*: The availability of and access to non-MLS sources of PGR for plant breeding programmes is also an important determinant of the demand for MLS-PGR. While the availability of non-MLS PGR will vary by crop, little information is available on the size and coverage of these collections. Access to private sector collections may be feasible only within a network of affiliated or group companies, or it may have to be negotiated on a contractual basis within research collaboration agreements. Access to *in situ* sources of PGR will be increasingly governed by biodiversity access legislation developed in conformity with the CBD, especially in developing countries.

2.2.3 Innovation process

The innovation process related to PGR takes place in a number of settings. The IARCs under the auspices of the CGIAR, the NARSs in developed and developing countries and the private sector (including global seed companies as well as independent domestic seed companies) are the major institutional players, while community-based participatory breeding programmes bringing together the expertise of crop scientists and farmers are also emerging as engines of innovation. The relative importance of institutional players in the innovation process differs by country and crop, and has changed significantly over the last three decades (Pardey *et al*., 1991; Anderson *et al*., 1994). In most developing countries, the public sector has been and remains the dominant player in plant breeding research, although the private sector has started to play an increasing role in several crops (Morris, 1998). In developed countries, the role of the public sector in 'near-market' plant breeding research has declined over the last two decades with the private sector playing a dominant role in the breeding of new varieties of key crops (e.g. maize in the United States), particularly those involving the application of biotechnology (Alston *et al*., 1998). These different institutional players may have different propensities for demanding and using PGR from the MLS for their breeding programmes. For the purpose of this chapter, the innovation process can be segmented into two components – one which utilizes PGR from the MLS, and another that proceeds without the use of MLS-PGR. The innovation processes produce innovations that will be selected (depending on market potential and the availability of infrastructure for scaling up multiplication and distribution) and marketed on a commercial scale. It is important to note that only a fraction of the new innovations developed through the innovation processes will be eventually marketed commercially, while others will be discarded. The innovations that are commercialized contribute to the overall value of the commercial seed market.

2.2.4 Value of the commercial seed market

The volume of seed sold commercially in most countries is much smaller that the volume of seed used by farmers. This is due to the use of farm-saved seed for planting, a well-established traditional practice in agriculture. The use of farm saved seed for planting is generally infeasible in the case of hybrid varieties, where farmers are required to procure fresh seed every year.[1] The volume of seed sold commercially is related to the volume of seed used by farmers through the seed replacement rates (SRRs), which measure how often farmers replace their seed stocks using fresh bought-in seed. In many developing countries, the volume of seed sold commercially may be less than 10–15 percent of the volume of seed used for planting. SRRs are higher in developed countries than in developed countries. However, even in developed countries SRRs may be 50 percent or less for non-hybrid crops such as wheat.

For our purposes, the value of the commercial seed market can be divided into three components:

- value of established varieties developed prior to the implementation of the Treaty/ SMTAs;
- value of new varieties commercialized post-Treaty involving the use of SMTA/MLS material;
- value of new varieties commercialized post-Treaty not involving the use of SMTA/ MLS material.

Since it has only been five years since the Treaty has been implemented, components 2 and 3 will be small in relation to component 1. As newer varieties replace established varieties in the commercial seed market, the value of component 1 relative to components 2 and 3 will decline. However, it is only component 2 that will attract the benefit sharing

[1] The use of farm-saved seed may also be infeasible in the case of varieties covered by utility patents (mostly GM varieties developed through biotechnology) in some countries where the contractual terms of seed sales may preclude the use of farm-saved seed by farmers.

provisions of the SMTAs. Therefore, the inflows into the Benefit-sharing Fund through voluntary or mandatory payments can be expected only from a small, albeit growing, proportion of the value of the commercial seed market.

2.2.5 Appropriation of value – flows into the Benefit-sharing Fund

The commercialization of innovations involving the use of PGR exchanged through SMTAs can give rise to (i) mandatory payments and (ii) voluntary payments depending on the nature of IPRs sought for the innovation. Article 6.7 of the SMTA provides that if the commercialized innovation is not freely available for further research and development, then it will attract mandatory payments into the Benefit-sharing Fund. In practice, this implies that only commercialized innovations (involving the use of PGR exchanged under SMTAs) that are protected by patents (with limited or no experimental use exemptions) will trigger mandatory payments. But if these commercialized varieties are not subject to IPRs or are subject only to PVP, which generally allows unrestricted research exemption or 'breeders exemption'), then they will give rise to only voluntary payments under Article 6.8 of the SMTA. Therefore, the proportion of commercialized plant variety innovations that are subject to patents will be an important determinant of the potential payments into the Fund. It is important to note that utility patents for plant varieties are presently available only in a limited number of countries. On the other hand, plant variety innovations developed by NARS in developing countries are generally not subject to any form of protection and may only be subject to PVP as and when PVP regimes are established and implemented in these countries. The SMTA also allows institutions accessing PGR from the MLS to opt for a 'discounted' payment (Article 6.11). Under this option, institutions accessing SMTA-PGR related to a crop can opt to make a payment (at a lower rate of 0.1 percent) on all commercial sales of seeds of that crop – instead of making payments on individual commercialized innovations. This option may be advantageous for relatively heavy users of PGR, whose commercial seed sales of varieties incorporating SMTA-PGR exceed 65 percent of their seed sales of a crop, and does not call for information on the use of SMTAs and their incorporation in commercialized products. The prevalence of use of this option by institutions accessing PGR from the MLS will also be a determinant of the flows into the Benefit-sharing Fund. The magnitude of the flows of mandatory and voluntary payments will also depend significantly on the effectiveness of Treaty implementation by the Contracting Parties. The policies adopted with regard to voluntary payments (especially those related to SMTA-PGR use by public research institutions), information and data flows on commercialization of innovations using SMTA-PGR and the visibility of these innovations in international trade and domestic seed markets will be key elements influencing the magnitude of potential mandatory and voluntary payments realized in practice.

2.3 PGR in the MLS as a resource base for innovation

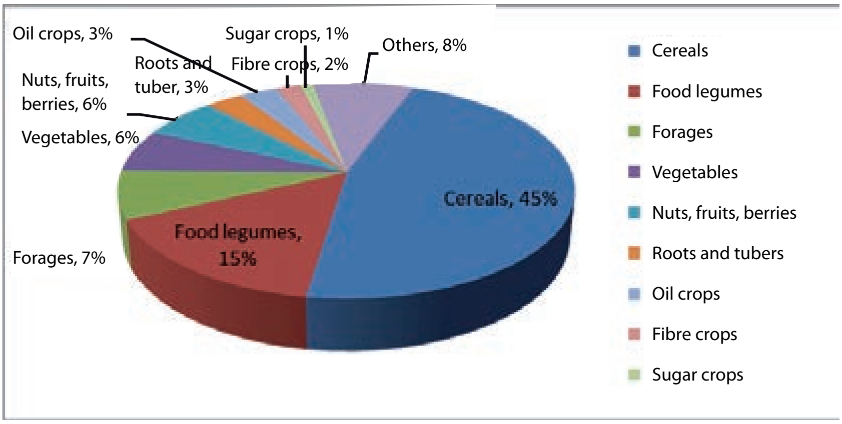
The size, composition and characteristics of PGR in the MLS for different crops in relation to the global *ex situ* holdings of PGR and the available diversity of individual crops are important determinants of the use of MLS-PGR in the development of plant variety innovations. FAO's Reports on the State of the World's Plant Genetic Resources for Food and Agriculture of 1997 and 2010 (hereinafter referred to as 'SoWPGR-1' and 'SoWPGR-2', respectively) provide one of the few authentic sources of information on the global holdings of PGR in *ex situ* collections. SoWPGR-2 (FAO, 2010) estimates that in 2009, there were more than 1 750 gene banks[2] with approximately 130 holding more than 10 000 accessions each. These 1 750 gene banks include international, regional, national and sub-national gene banks located on all continents in a variety of institutional formats of ownership and management. The Report estimates that approximately 7.4 million accessions are currently maintained globally, of which between 25–30 percent are distinct (1.9–2.2 million accessions), with the remaining ones being duplicates mostly held in different collections (including safety back-up collections). Of the global holdings of 7.4 million accessions, it is estimated that 4.6 million accessions are related to Annex 1 crops and are conserved in 1 240 gene banks worldwide; of these accessions, approximately 51 percent are conserved in 800 gene banks of the Contracting Parties of the Treaty and 13 percent are stored in the collections of the IARCs of the CGIAR. Therefore, the MLS covers approximately 64 percent of the global holdings of the PGR of Annex 1 crops. The inclusion of the nearly two-thirds of the global holdings of the PGR of Annex 1 crops in the MLS, however, does not translate into 'facilitated access' to all these accessions because this depends on how effectively Contracting Parties to the Treaty participate in the MLS. SoWPGR-2 also estimates that of the total 7.4 million accessions, national governments conserve about 6.6 million, of which 45 percent is held in only seven countries. The concentration of PGR holdings in a few countries underlines the importance of mechanisms of facilitated access such as that provided by the MLS.

A key feature of the MLS is that some of the largest collections within it are held by CGIAR gene banks which have implemented robust systems to provide 'facilitated access' to their holdings. These collections have been built up over the last four decades and are held 'in-trust' by the CGIAR for the world community. In 1994, the CGIAR Centres signed agreements with FAO, bringing these collections into an international network of *ex situ* collections. These 'in-trust' collections have been brought under the purview of the Treaty. While the share of CGIAR gene banks in global collections varies by crop, it is particularly strong for wheat (17 percent), rice (14 percent), maize (8 percent) and Phaseolus (beans) (14 percent).

The crop species coverage of global *ex situ* holdings of PGR based on information from the FAO's WIEWS database is presented in Figure 2.2.

[2] The coverage of *ex situ and working collections of the private sector appears to be limited in the assessments of ex situ holdings made in the SoWPGR reports.*

Figure 2.2 Crop species coverage of global *ex situ* holdings of PGR (2008)



Source: FAO, 2010.

Figure 2.2 shows that 45 percent of the accessions in the world's gene banks are of cereal crops, followed by food legumes, at nearly 15 percent of all accessions, while vegetables, fruits and forage crops account for 6–9 percent each; roots and tuber crops as well as oil and fibre crops account for 2–3 percent each. The distribution of global *ex situ* holdings of PGR of 50 major selected (Annex 1 and non-Annex 1) crops are shown in Table 2.1.

Table 2.1 Global ex situ PGR holdings of 50 major crops

Genus (crop)	Crop group	Status	No. of accessions
Triticum (wheat)	Cereal	Annex 1	856 168
Oryza (rice)	Cereal	Annex 1	773 948
Hordeum (barley)	Cereal	Annex 1	466 531
Zea (mays)	Cereal	Annex 1	327 932
Sorghum (sorghum)	Cereal	Annex 1	235 688
Avena (oat)	Cereal	Annex 1	130 653
Pennisetum (pearl millet)	Cereal	Annex 1	65 447
Aegilops (wheat)	Cereal	Annex 1	40 926
x Triticosecale (wheat)	Cereal	Annex 1	37 440
Phaseolus (bean)	Food legume	Annex 1	261 963
Cicer (chickpea)	Food legume	Annex 1	98 313
Pisum (pea)	Food legume	Annex 1	94 001

Genus (crop)	Crop group	Status	No. of accessions
Vigna (cowpea)	Food legume	Annex 1	65 323
Lens (lentil)	Food legume	Annex 1	58 405
Vicia (faba bean)	Food legume	Annex 1	43 695
Medicago (medicago)	Forage	Annex 1	91 922
Trifolium (clover)	Forage	Annex 1	74 158
Festuca (fescue)	Forage	Annex 1	33 008
Dactylis (grasses)	Forage	Annex 1	31 394
Malus (apple)	Fruit	Annex 1	59 922
Musa (banana)	Fruit	Annex 1	13 486
Helianthus (sunflower)	Oilseed	Annex 1	39 380
Beta (sugarbeet)	Others	Annex 1	22 346
Solanum (potato)	Root and tuber	Annex 1	98 285
Ipomoea (sweet potato)	Root and tuber	Annex 1	35 478
Manihot (cassava)	Root and tuber	Annex 1	32 442
Dioscorea (yam)	Root and tuber	Annex 1	15 903
Colocasia (taro)	Root and tuber	Annex 1	7 302
Total Annex 1 crops			**4 111 459**
Panicum (millet)	Cereal	non-Annex 1	17 633
Eragrostis (millet)	Cereal	non-Annex 1	8 820
Gossypium (cotton)	Fibre	non-Annex 1	104 780
Psophocarpus (bean)	Food legume	non-Annex 1	4 217
Prunus (prunus)	Fruit	non-Annex 1	69 497
Vitis (grape)	Fruit	non-Annex 1	59 607
Mangifera (mango)	Fruit	non-Annex 1	25 659
Glycine (soybean)	Oilseed	non-Annex 1	229 944
Arachis (groundnut)	Oilseed	non-Annex 1	128 435
Elaeis (oil-palm)	Oilseed	non-Annex 1	21 103
Olea (olive)	Oilseed	non-Annex 1	2 629
Hevea (rubber)	Others	non-Annex 1	73 656
Saccharum (sugar cane)	Others	non-Annex 1	41 128
Coffea (coffee)	Others	non-Annex 1	30 307
Theobroma (cocoa)	Others	non-Annex 1	12 373
Corylus (nut)	Others	non-Annex 1	2 998
Bactris (peach palm)	Others	non-Annex 1	2 593
Pistacia (pistachio)	Others	non-Annex 1	1 168
Lycopersicon (tomato)	Vegetable	non-Annex 1	83 720
Capsicum (capsicum)	Vegetable	non-Annex 1	73 518
Cucurbita (cucurbita)	Vegetable	non-Annex 1	39 583
Chenopodium (chenopodium)	Vegetable	non-Annex 1	16 263
Total non-Annex 1 crops			**1 049 631**
Total for all 50 crops			**5 161 090**

Source: FAO, 2010.

The 50 major crops in the Table 2.1 account for a total of 5.16 million accessions, more than two-thirds (70 percent) of the global holdings of 7.4 million. Among these major crops, Annex 1 crops account for nearly 80 percent of the holdings, while non-Annex 1 crops account for 20 percent. Among Annex 1 crops, cereals are predominant, accounting for 57 percent of the holdings of major crops, followed by food legumes accounting for 12 percent; forage and root and tuber crops account for 4 percent each, while fruits and oilseed account for 1 percent. Among non-Annex 1 crops, the important crop groups are oilseed crops (7 percent) and vegetable crops (8 percent).

The type of material available in the MLS, whether it is advanced cultivars, breeding lines, landraces or wild relatives, etc., has implications for the potential use of the material in breeding programmes and the speed with which they are likely to be incorporated into final products. Thus, breeding lines are likely to be transformed into 'finished' varieties relatively quickly, while landraces may go through several rounds of breeding and transformation before they are incorporated into final products. Information about the biological status of material conserved *ex situ* is currently available only for half of global accessions. Information from the FAO's WIEWS database is presented in Table 2.2.

Table 2.2 Biological status of ex situ PGR of crop groups

Commodity group	No. of accessions	Wild species (%)	Landraces (%)	Breeding materials (%)	Advanced cultivars (%)	Others (%)
Cereals	3 157 578	5	29	15	8	43
Food legumes	1 069 897	4	32	7	9	49
Roots and tubers	204 408	10	30	13	10	37
Vegetables	502 889	5	22	8	14	51
Nuts, fruits and berries	423 401	7	13	14	21	45
Oil crops	181 752	7	22	14	11	47
Forages	651 024	35	13	3	4	45
Sugar crops	63 474	7	7	11	25	50
Fibre crops	169 969	4	18	10	10	57
Medicinal, aromatic, spice and stimulant crops	160 050	13	24	7	9	47
Industrial and ornamental plants	152 325	46	1	2	4	47
Other	262 993	29	4	2	2	64
Total/overall mean	**6 998 760**	**10**	**24**	**11**	**9**	**46**

Source: FAO, 2010.

It may be seen from Table 2.2 that the proportion of different types of material varies by crop group. On average, for accessions for which biological status is known, nearly 17 percent are advanced cultivars; 22 percent, breeding lines; 44 percent, landraces; and 17 percent, wild and weedy relatives.

The poor state of documentation and characterization of PGR in the MLS has been recognized as a serious obstacle to its utilization in plant breeding programmes (FAO, 2010). Plant breeding programmes are unlikely to access PGR from the MLS unless they can access information on the traits and adaptation of the accessions. For plant breeding programmes to utilize PGR from the MLS, not only must characterization and evaluation data be available, but they also must be standardized and made available in a form that is accessible to programmes worldwide, for example, in an electronic format. Information on the extent of characterization of some CGIAR collections and selected national collections is presented in Tables 2.3 and 2.4.

Table 2.3 Extent of characterization for selected CGIAR and AVRDC PGR collections

Crop groups	Percentage of accessions characterized (%)	Total no. of accessions	Reporting centres
Cereals	88	292 990	6
Food legumes	78	142 730	4
Vegetables	17	54 277	1
Fruits (banana)	44	883	2
Forages	45	69 788	3
Roots and tubers	68	25 515	3
Total	**73**	**586 193**	**11**

Source: FAO, 2010.

Table 2.4 Extent of characterization and evaluation in national collections of 40 countries

Crop groups	Percentage of germplasm holdings (%)						
	Characterized	Evaluated				Total no. of accessions	
	Morphologically	Agronomically	Biochemically	For abiotic factors	For biotic factors	Accessions	Reporting countries
Cereals	63	44	10	13	23	410 261	34
Food legumes	67	56	14	13	20	139 711	33
Vegetables	65	44	12	7	14	48 235	27
Oil crops	63	42	52	11	17	40 700	18
Fibre crops	89	84	9	19	18	37 879	15
Fruits, nuts and berries	66	54	12	24	30	31 838	26
Forages	43	50	15	13	15	27 120	20
Roots and tubers	66	54	13	17	24	22 834	27
Spices	82	81	39	7	22	755	10
Stimulants	53	64	20	22	35	413	15
Sugar crops	46	80	22	36	57	413	14
Medicinal plants	65	64	24	11	43	744	7
Ornamental plants	74	23	0	48	47	622	8
Others	34	85	3	8	22	20 189	11
Total	**64**	**51**	**14**	**14**	**22**	**319 528**	**40**

Among CGIAR collections, cereals and food legumes are well characterized, but vegetables, fruits, forages, and roots and tubers much less so. Only two-thirds of national collections are characterized on average, with considerable variation among crop groups. Only half of national collections have been evaluated agronomically, while biochemical evaluation for biotic and abiotic factors has only been conducted on a limited scale.

The data presented in this section show that, although the MLS covers nearly two-thirds of the global *ex situ* holdings of Annex 1 crops, its utilization in crop improvement programmes may be constrained by the lack of effective access to PGR held by Contracting Parties and by inadequate characterization and evaluation information on PGR that is accessible. It is extremely difficult to assess what proportion of the total agro-biodiversity of different crops is covered by the MLS and the extent to which PGR currently in the MLS is accessible from alternative (non-MLS sources). Both these factors are important determinants of the extent to which plant breeding programmes will need to rely on the MLS. SoWPGR-1 (FAO, 1997) estimated that *ex situ* collections hold 95 percent of all landraces and 60 percent of wild species for wheat, 95 percent of landraces and 10 percent of wild species for rice, and 95 percent of landraces and 15 percent of wild species for maize. Efforts have been made under the auspices of the Global Crop Diversity Trust to develop crop conservation strategies[3] based on the identification of major gaps in *ex situ* collections as identified by different stakeholder groups. With the exception of gaps in the coverage of wild species and cultivars, an important gap in the MLS collections is likely to be in the coverage of breeding lines and cultivars developed by the private sector.

It should be noted that the potential for payments into the Benefit-sharing Fund of the Treaty arises not only from the exchange of PGR of Annex 1 crops under SMTAs, but also from the exchange of PGR of non-Annex 1 crops under SMTA conditions. This may arise in a number of different ways. Under Article 15.1 of the Treaty, the non-Annex 1 PGR accessions of CGIAR Centres acquired before the commencement of the Treaty are to be exchanged under material transfer agreements (MTAs) that conform to the benefit-sharing provisions of the Treaty. Similarly, under Article 15.5 of the Treaty, international institutions can opt to place their collections within the MLS, which may bring some of their non-Annex 1 material (acquired prior to coming into force of the Treaty) under the purview of benefit-sharing arrangements. International institutions that have entered into agreements with the Governing Body of the Treaty under Article 15.5 include:

- Tropical Agricultural Research and Higher Education Centre
- International Coconut Gene bank for Africa and the Indian Ocean
- International Coconut Gene bank for the South Pacific
- Mutant Germplasm Division of the FAO/IAEA Joint Division
- Centre for Pacific Crops and Trees (CePACT) – SPC Community.

It is also open to international gene banks and repositories to make their exchanges of PGR (even those that do not come under the purview of the MLS) subject to SMTAs applicable to Annex 1 crops. This practice appears to have been adopted on a significant scale by many European gene banks for the exchange of PGR of vegetable crops (not included in Annex 1).[4] An important contribution of the Treaty to international exchange of PGR may be in the creation of a widely accepted template for exchanges that could be applied to PGR not formally included in the MLS. The potential for benefit-sharing payments from the exchange of non-Annex 1 PGR brought within the purview of the MLS and the use of SMTAs in the exchange of PGR not included in the MLS may be significant.

[3] See crop strategy documents, available at www.croptrust.org.

[4] When PGR of non-Annex 1 crops are exchanged subject to SMTAs at the discretion of providing institutions, it may not be possible to use the enforcement mechanisms available in the Treaty.

Dissemination of plant genetic resources in the MLS

Information on the dissemination of PGR in the MLS by gene banks is a very useful indicator of the potential use of PGR by different groups of users. Dissemination of PGR by gene banks may take place for a number of reasons, all of which may not be related to their use in the innovation process. For instance, some exchanges of PGR may be for safety duplication or repatriation of PGR to countries of origin. The focus in this chapter will be on the dissemination of PGR by gene banks to plant breeding programmes for crop improvement.

SoWPGR-2 (2010, p. 83) notes the limited availability of data at the level of national and sub-national gene banks. It notes that even in cases where some information on the dissemination of PGR is available, it is often not broken down by crop or by the type of germplasm, and little information is available on the nature of the providing or recipient institution. Information on these factors is necessary to enable a better understanding of the patterns of use. Comprehensive data on the distribution of PGR are available only for gene banks of the IARCs of the CGIAR. The SoWPGR-2 notes that over the 1996–2007 period, the CGIAR Centres and The World Vegetable Center (AVRDC) distributed nearly 1.1 million samples, 5 615 000 of which (nearly 50 000 per year) went to external recipients. In general, total distribution has remained steady over the period 1996–2007 at about 100 000 accessions each year [p. 83]. The figures are similar to those reported for the period 1993–1995 in SoWPGR-1 (FAO, 1997).

The distribution of PGR from the gene banks of the IARCs of the CGIAR over the 1996–2008 period is summarized in Table 2.5. The pattern of distribution by type of PGR and type of recipient institution is presented in Figures 2.3 and 2.4.

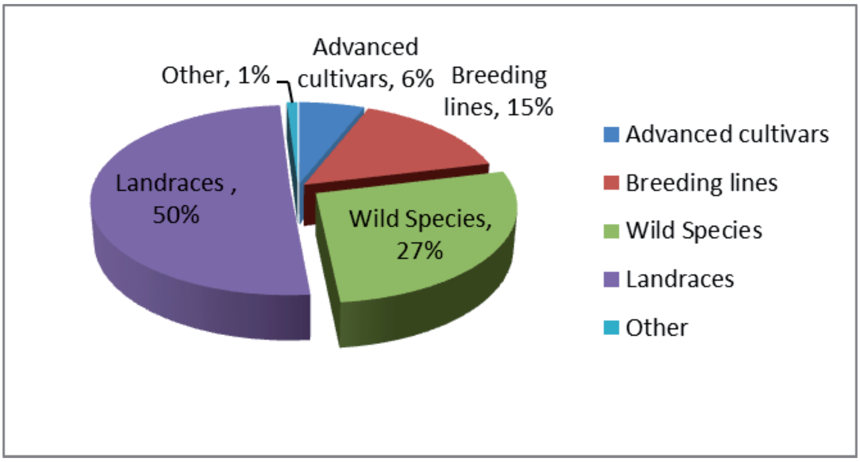
Table 2.5 Distribution of PGR from gene banks of IARCs of the CGIAR, 1996–2008

Type of accession	Within/ between IARCs (%)	NARS developing countries (%)	NARS developed countries (%)	Private sector (%)	Others (%)	Total no. of accessions	Percentage of total (%)
Landraces	57.9	48.5	45.0	51.7	65.7	194 546	51
Wild species	29.2	19.0	40.5	7.1	19.1	104 982	27
Breeding lines	8.5	23.1	5.4	36.0	6.5	56 804	15
Advanced cultivars	3.5	8.0	9.1	5.1	8.6	24 172	6
Others	0.9	1.4	0.1	0.1	0.1	3 767	1

Source: FAO, 2010.

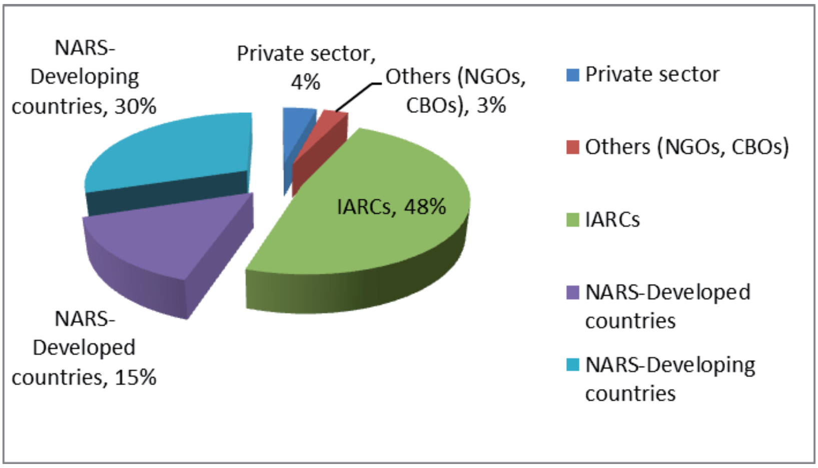
5 It is not possible to estimate the number of accessions distributed because the same accessions may be distributed to several recipients.

Figure 2.3 Distribution of germplasm held by IARCs by type of germplasm, 1996-2007



Source: FAO, 2010.

Figure 2.4 Distribution of germplasm held by IARCs by type of recipient institution, 1996-2007



Source: FAO, 2010.

Figure 2.3 shows that the largest proportion of PGR distributed by the IARCs are landraces, followed by wild species, breeding lines and advanced cultivars. Figure 2.4 shows that nearly half the PGR distributed by IARCs was within the Centres, while 30 percent went to developing country NARS. Developed country NARS accounted for 15 percent and private sector recipients for around 4 percent. Developing country NARS mainly requested breeding materials and advanced cultivars, whereas developed country NARS requested mainly landraces. Wild species were requested equally by most types of institutions. The pattern of distribution of PGR by type of recipient institution described above is similar to a more detailed break up of distribution of 'in-trust' accessions by CGIAR Centres reported from the System-wide Information Network for Genetic Resources (SINGER) database in Table 2.6.

Table 2.6 Distribution of CGIAR in-trust accessions, 1994–2008

In-trust accessions distribution to:	In-trust samples	Percentage (%)
CGIAR Centres	690 721	42.4
National Agricultural Research Systems	499 492	30.6
Universities	304 586	18.7
Gene banks	31 222	1.9
Germplasm network	28 607	1.8
Commercial company	27 183	1.7
Unknown	14 599	0.9
Other	11 235	0.7
Regional organization	9 699	0.6
Non-governmental organizations	6 371	0.4
Farmers	4 372	0.3
Individuals	1 958	0.1
Other categories	107	0.0
Total	**1 630 152**	**100.0**

Source: Gotor *et al.*, 2010.

It is estimated that CGIAR Centres annually distribute about 10 percent of their accessions, a rate that is likely to be much higher than that for national gene banks (FAO, 2010). Thus, for PGR in the MLS as a whole, the annual distribution is likely to be lower than 10 percent of accessions. The limited distribution of PGR in the MLS reflects the inadequate information systems for PGR – particularly the lack of characterization and evaluation data on accessions and the means for accessing/disseminating the data where they exist. It also reflects the fact that despite a wide range of genetic resources being available nationally and internationally, plant breeding programmes may prefer to select a majority of their parental material from their own working collections.[6] The legacy of international exchange through CGIAR Centres and national gene banks over the last several decades may result in a good proportion of valuable PGR that is now in the MLS being incorporated in the working collections of plant breeding programmes, reducing the need for directly accessing the MLS. These previous exchanges of PGR may have created alternative sources of PGR that may be outside the purview of the MLS. This affects the potential for benefit-sharing payments arising from the use of MLS-PGR. When plant breeding programmes rely on their working collections or on non-MLS sources of PGR in the development of plant variety innovations, no obligations for benefit-sharing payments arise.

One of the striking features of the data presented above is that nearly half of PGR exchanges from CGIAR Centres take place within or between these Centres. These exchanges of PGR between CGIAR Centres for use in their own breeding programmes will not be expected to give rise to any benefit-sharing payments until the breeding lines or advanced cultivars developed by the Centres are transmitted to other national-level institutions for further development of commercial cultivars. Developing country NARS are the largest users of breeding lines and advanced cultivars from CGIAR Centres and, therefore, have the largest potential for generating innovations derived from PGR exchanged under SMTAs. However, innovations developed by developing country NARS may not be subject to IPRs and may give rise only to voluntary payment obligations. Developed country NARS appear to rely on the MLS mainly for landraces, possibly for traits that may not be available in their own working collections or gene banks. The use of PGR from the MLS by developed country NARS is likely to be farther away from final product development than in developing country NARS. This implies that the lead times for generation of benefit-sharing payments following the exchange of PGR under SMTAs is likely to be greater in the case of developed country NARS. The use of MLS material by the private sector has an important bearing on the potential magnitude of benefit-sharing payments. This is because of the increasingly important role being played by the private sector in the breeding of Annex 1 crops and the likelihood of private sector innovations being subject to stronger forms of IPRs that give rise to mandatory payment obligations. The direct access of PGR in the MLS by the private sector appears to be very low – with the private sector accounting only for 4 percent of the accessions distributed by the CGIAR Centres. However, as seen in the later sections of this chapter, the proportion of private sector varieties in wheat, rice and maize incorporating CGIAR germplasm is much higher than what would be implied by the figure of 4 percent. This suggests that the private sector may have alternative sources of access to PGR in the MLS, including through incorporation of MLS-PGR in their working collections as a result of previous exchanges over the last few decades. It may also suggest the use of breeding strategies that purposively avoid the direct use of MLS material to circumvent benefit-sharing obligations.

It must be noted that data on the 'first round' distribution of PGR in the MLS by national and international gene banks may provide only a limited/partial picture of the

[6] It may easier for plant breeders to transfer traits from 'adapted' materials.

utilization of PGR in the innovation process. PGR exchanges proceed through a complex maze of transactions between different institutions within and across national borders. The incorporation of PGR exchanged under an SMTA may take place at a point in the transaction chain that is far removed from the original recipient. Assessing the extent of MLS-PGR use in final product innovations, therefore, requires the analysis of the entire chain of transactions, which may extend over several years, and information on how transformation/development of PGR at each stage.

2.4 Research intensity for different crops

It is noted in Section 2.2 that a key factor influencing the use of PGR from the MLS (and hence the potential for benefit-sharing payments) is the innovative activity attracted by crops included in the Annex 1 of the Treaty. The innovative activity or research effort attracted by each crop is likely to depend on the commercial potential (size of the market) for variety innovations of the crop, the research priorities and mandates of public research institutions, and the incentives for innovation afforded by intellectual property and regulatory regimes. In this section, the relative research intensity of different Annex 1 crops and the research intensity of Annex 1 crops in relation to that of non-Annex 1 crops will be examined.

The research effort for plant breeding in different crops in most countries will be spread over a range of institutions in the public and/or private sector. Research expenditures and research personnel (plant breeders and other scientists) deployed for plant breeding are the most relevant indicators of research effort. Availability of data on these indicators of research effort at the crop level is very limited in both developed and developing countries. For most developed countries, the OECD Science and Technology Indicators[7] provide comparable time-series of research expenditure and personnel at the sectoral level (e.g. for agricultural research) by type of institution. However, it is not feasible to identify plant breeding expenditures from such data because aggregate sectoral data cover several different types of research activities. For agricultural research, sector-level data may cover research on agro-chemicals and agricultural mechanization, and plant breeding expenditures may be only a small part of aggregate agricultural research expenditures. For developing countries, the Agricultural Science Technology Indicators (ASTI) database[8] developed by the International Food Policy Research Institute (IFPRI) provides data on agricultural research expenditures and scientists deployed in NARS of these countries. Here again, the identification of plant breeding expenditures at the crop level may not be feasible. Even where research expenditure data are available at the level of institutions, it may be difficult to identify expenditures devoted to different crops or activities. FAO's Global Partnership Initiative for Plant Breeding Capacity Building (GIPB)[9] is building up a database of plant breeding effort (financial and

7 Available at: www.oecd.org/document/26/0,3746,en_2649_34451_1901082_1_1_1_1,00.html

8 Available at:_www.asti.cgiar.org/timeseries.aspx

9 Available at: http://km.fao.org/gipb

scientific resources devoted to plant breeding) in developing countries through a detailed plant breeding survey; to date this database has been completed in 42 countries.

In the absence of data on direct indicators of research effort, the research intensity for different crops may have to be inferred from indirect indicators constructed for the purpose. In developed countries, where the application of IPRs to plant variety innovations is nearly universal, IPR grants provide a fairly robust indicator of the outputs of plant breeding effort in different crops. Most plant variety innovations in developing countries are protected through PVP systems. Although utility patents are applied to plant variety innovations in some countries (and are being increasingly applied to transgenic varieties), plant variety patents still constitute a very small fraction of all protected plant variety innovations. Therefore, for developed countries, we propose to use the grants of PVP certificates for different crops as a measure of research intensity. It must, however, be noted that the relative number of new varieties protected by PVP in any crop may not reflect the relative commercial value of innovations in that crop. The value of a new cereal variety protected by PVP is likely to be very different from the value of a protected ornamental variety. For developing countries, we propose to use an indicator derived from the plant breeding capacity assessment survey conducted by FAO's GIPB in a number of developing countries. The indicator of research effort is the weighted full-time equivalents (FTE) of plant breeding personnel devoted to a crop in each country – i.e. the FTEs scientific personnel deployed for research in each crop weighted by the resources allocated for plant breeding in that crop.

The research intensity for Annex 1 and non-Annex 1 crops in developed countries based on the grants of PVP certificates are summarized in Table 2.7. The data are derived from the PLUTO database of the International Convention for the Protection of New Varieties of Plants (UPOV) on PVP certificates granted in member-countries of UPOV. The cropwise distribution of PVP certificates of Annex 1 crops in UPOV member countries is presented in Appendix 2.

Over the 1960–2010 period, Annex 1 crops accounted for only 34 percent of all the PVP certificates granted in UPOV member countries. Food crops accounted for 30 percent of all PVP certificates, with cereals being the largest category accounting for 15 percent. The most striking feature of the data presented above is that non-Annex 1 crops account for two-thirds of all PVP certificates. The coverage of crops in Annex 1 of the Treaty, therefore, leaves out nearly two-thirds of the research effort in plant breeding from its purview. Research effort in non-Annex 1 crops and resulting innovations will not translate into benefit-sharing payments. The share of Annex 1 crops in research effort has also been declining over time, with their share in PVP certificates dropping from 75 percent in the 1960s to less than one-third in 2010. Over time, an increasing share of plant breeding research effort has been applied to non-Annex 1. This is the result of the increasing research effort attracted over the last two decades by crops such as soybean, cotton and sugarcane, which are not included in Annex 1. The share of these crops in the value of the global commercial seed market is also increasing. The limited coverage of crops in Annex 1 and the exclusion of certain major crops that have attracted considerable research effort in recent years severely constrain the potential for generation of benefit-sharing payments through exchange of PGR under SMTAs.

Table 2.7 Research intensity of Annex 1 and non-Annex 1 crop groups in developed countries based on no. of PVP grants

Crops	1960–64	1965–69	1970–74	1975–79	1980–84	1985–89	1990–94	1995–99	2000–04	2005–09	2010–14	Total	Share of total PVP certificates
Annex 1 crops													
Food crops	2	77	518	1095	2 087	3 323	6 517	8 967	8 933	9 322	3 243	44 084	30
Cereal	1	44	192	514	1 095	1 575	3 320	4 392	4 724	4 804	1 582	22 243	15
Fruit		2	31	40	108	227	490	694	740	758	215	3 305	2
Oilseed	0	1	18	75	173	443	909	1510	1 147	1 269	537	6 082	4
Pulse			7	17	50	102	138	179	173	279	72	1 017	1
Root and tuber	1	22	104	142	267	366	678	1154	931	1 103	412	5 180	3
Vegetable	0	8	166	307	394	610	982	1038	1 218	1 109	425	6 257	4
Forage crops	1	12	90	203	378	594	835	1186	1 228	1 146	304	5 977	4
Grass	1	12	63	172	314	487	623	833	929	894	240	4 568	3
Legume			27	31	64	107	212	353	299	252	64	1 409	1
Total Annex 1 crops	3	89	608	1 298	2 465	3 917	7 352	10 153	10 161	10 468	3 547	50 061	34
Non-Annex 1 crops	1	35	357	1 015	3 095	6 366	12 770	18 763	23 035	25 131	7 774	98 342	66
All crops	4	124	965	2 313	5 560	10 283	20 122	28 916	33 196	35 599	11 321	14 8403	100
Share of Annex 1 crops	75	72	63	56	44	38	37	35	31	29	31	34	

Source: UPOV PLUTO PVP database.

The research intensity of different crops in developing countries expressed in terms resource-weighted FTEs devoted to plant breeding by NARSs derived from GIPB's plant breeding survey is presented in Table 2.8. It should be noted that the correspondence between the crop categories used in the plant breeding survey and Annex 1 crops is not exact. Certain categories used in the plant breeding survey include both Annex 1 and non-Annex 1 crops, and it has not been feasible to separate the FTEs devoted to Annex 1 and non-Annex 1 crops in all the categories. The figures are, however, useful for providing an understanding of the research priorities in developing countries at the crop group level.

FTEs devoted to plant breeding in the NARS of developing countries have shown a marginal decline over the period from 1985 to 2003–05. It may be seen from Table 2.8 that the research effort in developing countries is focused on Annex 1 crops to a much greater extent than in developed countries – and the share of Annex 1 crops in the plant breeding research effort has shown a marginal increase over the last 25 years. Nearly 83 percent of the research effort in 2003–05 was devoted to Annex 1 crops with cereals accounting for 55 percent. The three principal food crops, wheat, rice and maize, account for nearly 38 percent of the research effort. The potential for generation of innovations in Annex 1 crops as a result of PGR exchanges under SMTAs appears to be greater in developing countries. This is reinforced by the pattern of distribution and use of PGR in the MLS discussed in the previous section. But if these innovations are produced mainly in the public sector in developing countries, then they are unlikely to be subject to strong forms of IPRs such as patents due to public sector mandates to encourage the widespread adoption of improved varieties. The greater potential for innovation in Annex 1 crops in developing countries may, therefore, not translate into potential for a larger flow of mandatory and voluntary payments.

Table 2.8 Research intensity of Annex 1 and non-Annex 1 crops in developing countries based on resource-weighted full-time equivalents devoted to plant breeding

Status	Category	Crop or crop group	1985	1990	1995	2000–01	2003–05	Share 2003–05 (%)
Annex 1	Cereal	Barley	130	117.3	134	121.3	124.7	2
Annex 1	Cereal	Buckwheat	12.1	2.1	1.5	5.3	8.2	0
Annex 1	Cereal	Maize	801	792.7	688.9	648	596.2	11
Annex 1	Cereal	Oats	16.4	18.5	26.9	16.4	10.6	0
Annex 1	Cereal	Grain legumes	283.2	287.5	349.4	353.4	392.7	7
Annex 1	Cereal	Small grains	200.7	170.8	183.4	192.4	228.2	4
Annex 1	Cereal	Rice	266.1	298	294.9	305.6	357.2	7
Annex 1	Cereal	Sorghum and millets	182.2	198.1	173.2	169.4	142.7	3
Annex 1	Cereal	Unknown	4.6	4.3	6.9	5.3	5.3	0
Annex 1	Cereal	Wheat	987.7	991.9	945.8	946.4	1 088.8	20
Annex 1	Horticulture	Fruits	221.1	213.2	193.9	176.6	156	3
Annex 1	Horticulture	Vegetables and Fruits	688.7	715.5	739.9	731.1	767	14
Annex 1	Oilseed	Oilseed	281.2	372.3	323.5	341.3	321.6	6
Annex 1	Roots and tubers	Roots and tubers	271.2	300.2	269.2	246.5	288.6	5
Total Annex 1			4 346.2	4 482.4	4 331.4	4 259	4 487.8	83
Non-Annex 1	Fibre	Fibre crops	355.3	350.6	355.3	376.1	329.3	6
Non-Annex 1	Forage	Forages	289.3	274.4	269.6	275.3	260.1	5
Non-Annex 1	Forage	Perennial legumes	36.2	15	4.6	18.6	13	0
Non-Annex 1	Horticulture	Chilli	0.0	0.0	1.4	1.1	0.7	0
Non-Annex 1	Horticulture	Grape	371.6	351.9	293.8	228.6	187.1	3
Non-Annex 1	Horticulture	Onion	2.3	2.0	3.5	2.0	1.1	0
Non-Annex 1	Ornamental	Ornamental	27.1	31	20.9	25.5	57.1	1
Non-Annex 1	Sugarcane	Sugarcane	68.7	75.9	82.2	80.9	84.6	2
Total non-Annex 1			1 150.5	1 100.8	1 031.3	1 008.1	933	17
All crops			5497	5583	5363	5267	5 421	100
Share Annex 1			79	80	81	81	83	
Share non-Annex 1			21	20	19	19	17	

Source: FAO GIPB Plant Breeding Survey.

2.5 Assessing the use of SMTA-PGR in product innovation

Voluntary or mandatory payments under SMTAs arise when SMTA-PGR are used in the development of commercial innovations that are *themselves a PGR* (Article 6.8).[10] The product innovation space relevant for payments is that of new varieties of plants of Annex 1 crops that are marketed commercially. The potential for benefit-sharing payments is, therefore, related to the use of SMTA-PGR in plant breeding. Plant breeding programmes aim to develop new varieties of plants with desirable characteristics that may include higher yield potential, specific agronomic traits, resistance to pathogens and diseases, adaptation to agro-climatic conditions, and resistance to biotic and abiotic stresses. It may involve the use of PGR related to the crop accessed from diverse sources for extraction of useful traits to be incorporated in the final product (variety). The product development cycle may involve several rounds of breeding extending over several years. The time lag between the access and use of specific PGR and the development of the final variety can be large, ranging from five to 20 years (Brennan, 1992), depending on the crop, and possibly longer for certain horticultural crops. When a new plant variety is developed incorporating PGR from diverse sources, one question that arises is the extent of contribution made by specific PGR to the development of the variety. Several different methodologies or algorithms have been suggested in the literature to assess the genetic contribution of ancestral PGR to a new variety (Pardey *et al*., 1996). But the extent of contribution of SMTA-PGR to the development of a new variety is not relevant to the benefit-sharing payments under SMTAs. Under SMTAs *any* use of SMTA-PGR in the development of a commercial innovation will give rise to payment obligations, irrespective of the extent of the contribution.

The identification of the use of SMTA-PGR in new plant varieties, therefore, requires detailed information on breeding histories of new varieties, including information on PGR used in different stages of the breeding cycle. Genealogy information is essential for assessment of the use SMTA-PGR in the development of new plant varieties. SMTA-PGR may not appear in the immediate parental ancestry of a variety – the pedigree of a variety may have to be traced back several generations in the breeding cycle to identify the use of SMTA-PGR. The non-availability or inadequate availability of genealogy information for new commercial varieties is possibly the most important constraint on reliable assessments of SMTA-PGR use. The availability of genealogy information for varieties in the public domain varies considerably across NARS and crops. Relatively good information appears to be available for varieties, breeding lines or crosses made by IARCs of the CGIAR. The CGIAR has set up fairly extensive genealogy databases for four to five major crops through the International Crop Information System (ICIS). The ICIS focuses on crop varieties in countries that have seen extensive collaboration between CGIAR and NARS. An important issue is the non-availability of pedigree information of proprietary varieties development by the private sector. When IPR protection is sought for new plant varieties through PVP or patents, there is generally no obligation to disclose the full breeding history or genealogy of

[10] Innovations that are not in the nature of PGR, e.g. pharmaceuticals, will not attract the provisions of SMTAs.

the variety. Under both PVP and patents, the requirement for 'disclosure' of an invention (a pre-requisite for obtaining IPR protection) is met by the deposit of the seeds of the variety and/or the parental material in a national repository. Breeding histories (or 'description of an invention') provided in PVP or patent applications will generally not be adequate for identifying the source of the PGR used in the breeding (including use of PGR accessed under SMTAs). The 'closed' pedigrees of proprietary varieties in the private sector render the assessment of the use of SMTA-PGR extremely difficult. The empirical assessment of the use of SMTA-PGR in new plant varieties requires information to be brought together from product innovation databases, genealogy databases and PGR databases. In Section 2.9, some methodologies for assessment of SMTA-PGR use in product innovations using such an approach are suggested.

The implementation of the Treaty, including the use of SMTAs developed under the Treaty, is only around six years old. Given the long lags between PGR access and final product development, and the data constraints discussed above, very little information is currently available about the incorporation of SMTA-PGR in commercial plant variety innovations. In this section, we therefore propose to assess the potential use of SMTA-PGR in product innovations based on the historical patterns of use of PGR developed by CGIAR institutions and distributed through institutional arrangements similar to the MLS.[11] The mandate of CGIAR institutions has been to assist developing countries in increasing agricultural productivity. To this end, CGIAR institutions have undertaken extensive plant breeding programmes in collaboration with NARS in developing countries and facilitated the international exchange of PGR in their gene banks. They have developed improved cultivars that have been directly released by NARS in developing countries, but more importantly, have made crosses to develop breeding lines for use by NARS in their own breeding programmes. The material developed by CGIAR institutions (now part of the MLS) has remained freely available to private sector institutions in developed countries and there is evidence of the substantial use of CGIAR material in private breeding programmes (Pardey *et al*., 1996). The use of CGIAR material in the development of new varieties is therefore a good indicator of the potential use of PGR from a large international 'commons' that remains accessible to all countries (subject now to the conditions of SMTAs). It should be emphasized that the historical pattern of use that have emerged over a period of three decades may not necessarily be an accurate indicator of the use of SMTA-PGR in product innovations at the time of writing (2012). The extent of use of CGIAR PGR in new varieties is an indicator of the level of use of SMTA-PGR that may build up over a period of time. There are certain factors that may contribute to future patterns of use being different from historical patterns. The MLS is a much larger collection that the CGIAR collections, although the CGIAR collections represent a component that is relatively well-documented and easily accessible. As more Contracting Parties take steps for the effective implementation of the Treaty, the pool of PGR effectively available for international exchange will increase. This implies that the use of MLS material in innovations may be larger than the use of

[11] The reference here is to arrangements for international exchange of PGR that preceded the MLS. The gene banks maintained by CGIAR have served as hubs of international PGR exchange over the last four decades.

CGIAR material in variety innovations in the past. At the same time, the use of avoidance strategies in relation to MLS material by private sector breeding programmes (deterred by benefit-sharing provisions in SMTAs) may lead to a decline in the use of MLS material in product innovations, especially those subject to stronger forms of IPRs. Nevertheless, historical patterns of use provide a benchmark for assessing the potential use of SMTA-PGR in plant variety innovations over time. Summarized below are the available data on the historical patterns of use of CGIAR PGR in wheat, rice and maize, principally drawn from periodic impact assessment studies undertaken by the CGIAR.

2.5.1 Wheat

Wheat is a crop where the public sector has been dominant in plant breeding in developing countries. This was also true of developed countries until the late 1980s, when the private sector started to play a more important role in the development of new varieties. CIMMYT is the principal CGIAR institution involved in wheat development and its role in international wheat research, and the 'Green Revolution' in wheat has been well documented in the literature (Evenson and Gollin, 2002). An impact assessment study conducted by CIMMYT in the late 1990s (Pingali, 1999) found that over the period 1966–1997, the NARS of developing countries had released 2 200 wheat varieties, a quarter of them released between 1991 and 1997. The use of CIMMYT-related PGR in the varieties released from 1991–1997 is summarized in Table 2.9.

Table 2.9 Use of International Wheat and Maize Improvement Centre germplasm in wheat variety releases of developing countries, 1991–1997

International Wheat and Maize Improvement Centre (CIMMYT) plant genetic resources	Spring bread wheat (%)	Spring durum wheat (%)	Winter wheat/ facultative wheat (%)
CIMMYT crosses	56	77	19
NARS crosses with at least one CIMMYT parent	28	19	13
NARS crosses with CIMMYT ancestry	5	2	9
NARS semi-dwarfs with other ancestry	8		41
Tall varieties	3	2	18

Source: Pingali, 1999.

The study found that with the exception of China, which used its own material to a considerable extent), almost all developing countries made substantial use of CIMMYT material. CIMMYT's contribution was relatively low for temperate zone wheats (winter/ facultative wheat). The study noted that NARS in developing countries such as India and China had improved their ability to make their own crosses and were relying less on the direct use of CIMMYT crosses. However, the use of CIMMYT material in their breeding programmes remained high.

The study noted that although the public sector was dominant in wheat research in developing countries, private wheat improvement programmes were strong in Latin American countries such as Argentina and Brazil. Nearly 50 percent of private wheat varieties in Latin America had incorporated CIMMYT material. In Argentina, nearly 60 percent of the wheat varieties protected by PVP had CIMMYT ancestry, while it was 45 percent in the case of protected varieties in Chile. Therefore, there is evidence to suggest that private sector wheat breeding programmes have also been significant users of CIMMYT material.

In terms of area, it has been estimated that nearly 80 percent of the wheat area in developing countries is planted to improved or modern varieties (Heisey *et al.*, 2002); 62 percent of the wheat area in developing countries is estimated to be planted with varieties with CIMMYT ancestry. Slightly less than half of wheat area is planted to varieties produced from crosses made by CIMMYT or that has at least one parent from CIMMYT. Table 2.10 summarizes the area planted to different wheat types by the type of cross or source of germplasm.

Table 2.10 Area grown to different wheat types by origin of germplasm, 1997 (million ha)

		NARS crosses						
Wheat type	**International Wheat and Maize Improvement Centre (CIMMYT) cross**	**CIMMYT parent**	**CIMMYT ancestor**	**Other semi-dwarf**	**Tall**	**Land races**	**Unknown cultivars**	**All**
Spring bread wheat	17.8	22.4	12.6	7.7	5.2	1.4	1.0	68.1
Spring durum wheat	3.4	1.2	0.02	0.11	0.3	1.5	0.1	6.7
Winter/facultative bread wheat	0.6	1.9	4.2	11.6	2.2	4.1	2.6	27.2
Winter/ facultative durum wheat	0.0	0.0	0.0	0.1	1.0	0.1	0.0	1.2
All wheat types	21.8	25.5	16.8	19.5	8.7	7.0	3.8	103.2

Source: Pingali, 1999.

It should be noted that from the perspective of benefit-sharing payments under SMTAs, the different types of CIMMYT contribution to varieties would all be treated alike. A direct

CIMMYT cross released as a variety and variety with some CIMMYT material in its ancestry (accessed through SMTAs) would give rise to the same payment obligation.

For developed countries, no recent estimates of the use of CIMMYT material in variety releases or the area share of varieties with CIMMYT ancestry. An earlier assessment made by CIMMYT in the 1990s is summarized in Table 2.11.

Table 2.11 Estimates of area sown to wheat varieties containing CIMMYT germplasm in some industrialized countries

Country	Year	Wheat area (million ha)	Percentage of area with International Wheat and Maize Improvement Centre (CIMMYT) germplasm (%)	Total area with CIMMYT germplasm (million ha)
Australia	1990	8.7	85	7.4
Italy (durum only)	1990	1.7	60	1.0
New Zealand	1987	0.04	79	0.03
South Africa	1990	1.6	60	1
United States of America	1984	25.5	34	8.7
Western Canada	1992	12.3	28	3.5
Total		**49.9**		**21.5**

Source: Byerlee and Moya, 1993.

Byerlee and Moya (1993) found that by the early 1990s, nearly 40 percent of the area planted to wheat in developed countries was sown to varieties with CIMMYT ancestry and that the proportion was rising. The increasing role of the private sector in wheat breeding in developed countries over the last two decades may mean that the share of area sown to varieties with CIMMYT ancestry may be lower at present. However, two points need to be noted. The first is that most wheat area in developed countries is in temperate production environments where the contribution of CIMMYT germplasm has been lower. At the same time, data for Latin America show that private wheat breeding programmes have also made substantial use of CIMMYT germplasm. Many of the international companies that are holders of PVP certificates in Latin America are also the leading breeders of wheat in the United States and Europe (e.g. Monsanto). Therefore, it would be reasonable to assume that CIMMYT germplasm would have diffused through the breeding pools of these companies and found its way to wheat varieties released in developed countries. A pedigree analysis of leading (winter) wheat varieties in the United Kingdom (Srinivasan *et al.,* 2003) showed that private sector varieties, which had acquired dominant market share by the late 1990s, incorporated significant proportions of CIMMYT germplasm.

Table 2.12 Contribution of different sources of germplasm in leading UK wheat varieties (pedigree expansion to five generations)

Country/source of parent	Varieties (%)								
	Apollo	Cappelle-Desprez	Galahad	Maris Huntsman	Mercia	Norman	Riband	Slepjner	Av. contrib.
France	12.52	18.76	18.77	18.77	18.77	3.13	12.52	6.26	13.69
UK			25	12.51		25	12.5	12.5	10.94
CIMMYT	9.39		12.52	21.9	12.52	6.26	12.52		9.39
Netherlands								62.5	7.81
USA	3.13		3.13	15.63	3.13	3.13	9.39	3.13	5.08
Belgium	6.25		6.25			6.25	6.25	6.25	3.91
Germany	3.13		6.26	3.13		3.13	6.26	3.13	3.13
Canada	6.26			3.13	3.13		6.25	3.13	2.74
UK/France	3.13			3.13	3.13		3.13	3.13	1.96
Japan			3.13		3.13	3.13			1.17
Australia				6.25					0.78
USA/France					3.13				0.39
Sweden				3.13					0.39
Russian Federation				3.13					0.39
Denmark				3.13					0.39
Unknown	56.25	81.25	25	6.25	53.13	50	31.25		37.89
Total	**100**	**100**	**100**	**100**	**100**	**100**	**100**	**100**	**100**

Source: Srinivasan *et al*., 2003.

Table 2.12 shows that although the contribution of CIMMYT germplasm to selected UK wheat varieties is only around 10 percent when pedigrees are expanded to five generations, six out of eight varieties have CIMMYT ancestry. In the absence of recent data on the area share of varieties with CIMMYT ancestry in developed countries, an estimate of 20–30 percent appears to be a reasonable conservative figure for use in our simulations of potential benefit-sharing payments under SMTAs.

2.5.2 Rice

Developing countries are predominantly the major producers of rice. Only two developed countries – Japan and the United States – figure among major rice producers. The public sector has remained dominant in rice breeding in developing countries, although in some countries the private sector has started to play a significant role in the development of hybrid rice. IRRI is the principal CGIAR institution[12] for the development of rice, and its activities

[12] West Africa Rice Development Association (WARDA) has a mandate for rice development in West Africa.

have focused on the major rice-producing areas in South and Southeast Asia, where it has made a significant contribution to the Green Revolution in rice. A key feature of IRRI's contribution to rice research and development has been the extensive direct use of IRRI-bred varieties (e.g. IR-8, IR-64) in many of the countries with which IRRI has collaborated (Evenson and Gollin., 2002). Several impact assessment studies have been conducted (e.g. Hossain *et al*., 2002; Brennan and Malabayabas, 2011) to assess the contribution of IRRI to rice varietal development and productivity gains since the mid-1960s. We propose to rely on these impact assessment studies to derive empirical estimates of the use of IRRI germplasm in rice variety innovations.

Hossain *et al.* (2002) analysed 2040 varieties released in 12 countries of South and Southeast Asia over the period 1970–1999. Table 2.13 shows the breakdown of these varieties by country.

Table 2.13 Contribution of IRRI to rice varieties released in South and Southeast Asia, by country

	Percentage of total releases (%)			
Country	**IRRI crosses released as varieties**	**Varieties with an IRRI parent**	**Varieties with IRRI material in previous ancestors**	**Released varieties linked with IRRI materials**
Bangladesh	11.0	46.0	8.0	65.0
Cambodia	23.8	7.2	0.0	31.0
India	5.2	33.1	9.5	47.8
Indonesia	10.0	42.0	16.0	68.0
Lao PDR	4.8	38.1	0.0	42.9
Malaysia	11.5	28.9	7.7	48.1
Myanmar	23.9	20.2	0.7	44.8
Pakistan	22.2	25.0	0.0	47.2
Philippines	26.6	38.2	4.7	69.5
Sri Lanka	2.7	30.7	21.3	54.7
Thailand	0.0	10.7	4.9	15.6
Viet Nam	20.5	28.8	3.7	53.0
Total	**10.7**	**31.1**	**7.9**	**49.7**

Source: Hossain *et al*., 2002.

Of the 2040 varieties for which pedigree information was available, 219 were identified as IRRI lines released directly (without further breeding) in the countries, constituting approximately 11 percent of the releases. Including the varieties with IRRI parents and varieties with IRRI material in previous ancestry, the share of varieties with IRRI linked materials was almost 50 percent. Within the aggregate data, however, there were important differences across countries. The contribution of IRRI to released varieties in South and Southeast Asia by time period is summarized in Table 2.14.

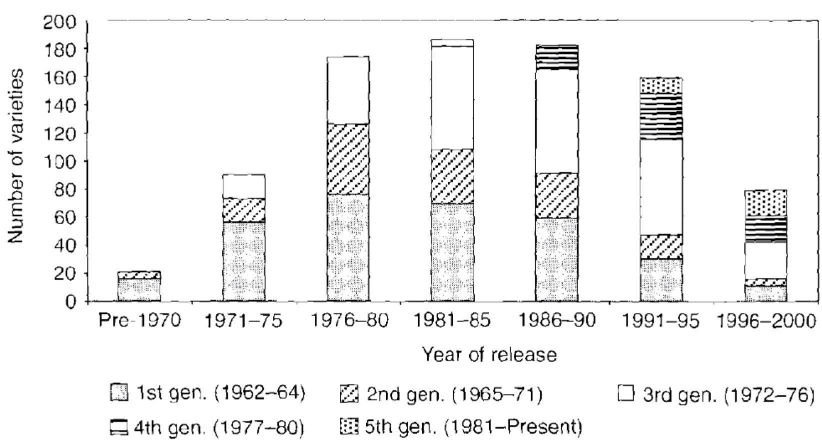
Table 2.14 Contribution of IRRI to rice varieties released in South and Southeast Asia, by time period

Time period	IRRI crosses releases as varieties	Released varieties with IRRI parents	Released varieties with IRRI ancestry
Pre-1970	11.6	15.6	16.0
1971–75	16.9	59.1	61.0
1976–80	17.7	60.4	64.7
1981–85	11.9	42.8	54.7
1986–90	10.7	40.2	49.6
1991–95	3.3	35.9	49.3
1996–99	3.1	45.8	54.2
Total	**10.7**	**41.8**	**49.7**

Source: Hossain *et al*., 2002.

The data in Table 2.14 suggest that, as a percentage of released varieties, IRRI developed varieties reached their highest level (about 18 percent) in 1976–80 and declined thereafter. However, the overall contribution of IRRI germplasm increased from 16 percent in the 1960s to over 60 percent in the 1970s and thereafter remained at a level of 50 percent. The vintage of IRRI germplasm used in varieties released during different time periods is summarized in Figure 2.5.

Figure 2.5 Vintage of IRRI germplasm used in rice varieties released in different time periods



Source: Hossain *et al*., 2002.

In Figure 2.5, successive waves of IRRI germplasm can be seen in the released varieties of different periods. A key feature of the data is the continuing importance of first and second generation IRRI germplasm. The more recent vintages of IRRI germplasm appear to be following essentially the same pattern as earlier vintages. The newer material is being used but it takes at least ten years for it to show up in any substantial number of released varieties.

In terms of area, it is estimated that by the late 1990s, 75 percent of rice area in Asia was planted to improved or high-yielding varieties (HYVs). Hossain *et al.* (2002) also analysed the area share of the five leading varieties in each of the 12 countries of South and Southeast Asia (listed in Table 2.13) and found that the leading varieties accounted for 45 percent of the total rice production. Of the 55 varieties observed in 11 countries, 36 varieties had some IRRI ancestry and accounted for nearly 30 percent of the rice area in these countries. Hargrove and Cabanilla (1998) noted from a similar study that 30 percent of widely grown varieties were introduced from IRRI, 60 percent were locally developed and 10 percent were from other countries. Locally developed varieties incorporated varying degrees of IRRI germplasm in them.

A more recent assessment of IRRI's contribution to rice varieties yield improvement in Southeast Asia (Brennan and Malabayabas, 2011) has examined IRRI's contribution in three countries – the Philippines, Indonesia and Viet Nam. Previous studies (e.g. Hossain *et al*., 2002) have classified varieties into:

- IRRI crosses released as varieties;
- varieties released by NARS with an IRRI parent;
- varieties released by NARS with IRRI material among previous ancestors;
- other varieties without IRRI connection.

In this study, as a quantitative measure of IRRI's contribution to new varieties, a rule of thumb based on attribution for the parentage and pedigree was used. Varieties with two IRRI lines as parents were calculated as having 100 percent IRRI contribution, whereas with one parent this contribution was 50 percent. The contribution is estimated as 25 percent when there are no IRRI parents, but IRRI lines appear in the ancestry. The contribution of IRRI to each variety was then weighted by the area share of the variety to derive an index of IRRI's contribution. Table 2.15 shows the IRRI contribution to varieties released in terms of numbers using the categories described above, in the Philippines, Indonesia and Viet Nam over different time periods.

Table 2.15 IRRI contribution to rice varieties released in Philippines, Indonesia and Viet Nam, by time period

	1980–89	1990–99	2000–09	Total 1980–2009
Philippines				
Total no. of varieties released	22	43	83	148
IRRI releases	14	22	33	69
IRRI parent	1	13	11	25
IRRI ancestor	1	0	8	9
Total IRRI link	16 (73%)	35 (81%)	52 (63%)	103 (70%)
Indonesia				
Total no. of varieties released	70	41	83	194
IRRI releases	17	2	0	19
IRRI parent	34	25	49	108
IRRI ancestor	12	7	26	45
Total IRRI link	63 (90%)	34 (83%)	75 (90%)	172 (89%)
Viet Nam				
Total no. of varieties released	60	98	68	226
IRRI releases	28	21	8	57
IRRI parent	20	51	28	99
IRRI ancestor	4	5	8	17
Total IRRI link	52 (87%)	77 (79%)	44 (65%)	173 (77%)

Source: Brennan and Malabayabas, 2011.

In the Philippines, the average share of IRRI linked varieties over the period 1980-2009 was 70 percent, although there has been a decline in recent years to 63 percent. In Indonesia, the share of varieties with IRRI links has remained at a high level of around 90 percent. In Viet Nam, the average share of IRRI linked varieties has been 77 percent (1980-2009), although the share has declined to 65 percent in recent years. The area weighted share of IRRI's contribution to varieties over the same time period is summarized in Table 2.16.

Table 2.16 Area weighted index of IRRI contribution to rice varieties released in Philippines, Indonesia and Viet Nam, by time period

	IRRI contribution (%)		
Year	**Philippines**	**Indonesia**	**Viet Nam**
1985	73	47	59
1990	90	70	59
1995	81	73	73
2000	95	73	62
2005	87	75	51
2009	60	69	35

Source: Brennan and Malabayabas, 2011.

In the Philippines, IRRI's area weighted contribution to varieties has declined from 73 percent in 1985 to 60 percent in 2009, while in Indonesia, it has increased from 47 to 69 percent over the same time period. In Viet Nam, IRRI's contribution has declined from 59 percent in 1985 to 35 percent in 2009.

It must be noted that the classification of varieties based on the extent of IRRI contribution is not relevant from the perspective of benefit-sharing payments under SMTAs, since the incorporation of *any* IRRI material obtained under SMTAs would give rise to payment obligations. From the data examined above, it would appear that 30 percent would be a fairly conservative estimate of the area share of IRRI linked varieties in South and Southeast Asian countries that have seen IRRI contribution to rice varietal development.

2.5.3 Maize

In relation to the other two crops considered in this chapter – wheat and rice – maize has a certain distinctive characteristics. Unlike wheat and rice, which are self-pollinated crops, maize is an open-pollinated variety (OPV). A key feature of maize breeding has been the development of hybrid varieties that have come to dominate maize area in developed countries and have acquired significant market shares in developing countries (Morris, 1998). The development of maize hybrids has facilitated the participation of the private sector in maize breeding programmes. The private sector is now the dominant player in maize breeding in developed countries and is playing an increasingly important role in developing countries. In developed countries, maize is grown mainly in temperate environments, while in developing countries it is grown mainly in non-temperate regions. This difference has important implications for the flows of PGR and improved technology in maize breeding. Maize germplasm that performs well in temperate regions generally cannot be introduced into non-temperate regions; consequently, maize varieties developed for the United States and Europe are of little direct use to developing countries. CIMMYT has been the principal CGIAR institution[13] for maize development, and its breeding efforts have focused on non-temperate production environments (Morris *et al.*, 2002).

We propose to base our assessment of the use of MLS material in variety development on the use of CIMMYT germplasm in the development of maize varieties for developing countries, drawing mainly on a number of maize research impact studies conducted by the CGIAR (Morris, 1998, 2001 and 2002).

Table 2.17 presents the trends in public sector maize variety releases in developing countries and the estimated share of varieties incorporating CIMMYT germplasm.

Table 2.17 Trends in public sector maize variety releases in developing countries and contribution of CIMMYT germplasm

	1966–1970	1971–1975	1976–1980	1981–1985	1986–1990	1991–1995	1996–1999	1966–1999
Total no. of varietal releases	97	114	137	205	216	266	137	1 172
Type of material								
Open-pollinated varieties (OPVs) (%)	0.69	0.57	0.69	0.65	0.69	0.50	0.48	0.61
Hybrids (%)	0.31	0.43	0.30	0.35	0.32	0.50	0.52	0.39
Containing CIMMYT germplasm								
All materials (%)	0.41	0.28	0.50	0.58	0.65	0.56	0.64	0.54
Non-temperate materials (%)	0.45	0.29	0.50	0.60	0.67	0.68	0.73	0.59

Source: Morris, 2001.

OPVs have constituted the dominant proportion of public sector releases. On average, 59 percent of varieties for non-temperate environments have incorporated CIMMYT germplasm. The share of varieties incorporating CIMMYT germplasm has also shown an increasing trend from 45 percent in the period 1966-70 to nearly 73 percent in the period 1996-99. While no time-series data was available for private sector varietal releases, the data on private sector maize variety releases in different developing country regions for 1997 is presented in Table 2.18.

[13] The International Institute of Tropical Agriculture (IITA) also has a mandate for maize development, among other crops.

Table 2.18 Maize variety releases by private sector in developing countries, 1997

	Latin America	Eastern and Southern Africa	South, East, and Southeast Asia	All regions
Total no. of varieties	498	25	330	853
Type of material				
Open-pollinated varieties (OPVs) (%)	0.03	0.08	0.00	0.02
Hybrids (%)	0.97	0.92	1.00	0.98
Containing CIMMYT germplasm				
All materials (%)	0.73	0.21	0.19	0.58
Non-temperate materials (%)	0.89	0.15	0.18	0.70

Source: Morris, 2001.

The variety releases by the private sector are almost entirely concentrated in hybrids (97 percent share). There appears to be significant use of CIMMYT germplasm by the private sector in developing countries – although the share of varieties incorporating CIMMYT germplasm varies widely, from 15 in Eastern and Southern Africa to 89 percent in Latin America. The private sector also produces a larger share of varieties intended for temperate environments. It is important to note that the use of CIMMYT germplasm in private varieties remains high even when varieties for temperate environments are included in the analysis.

In terms of area, it has been estimated nearly 62.4 percent of the maize area was planted to improved varieties in the late 1990s (Morris, 2001) and this proportion is likely to have increased over the last decade. The share of area planted to improved OPVs and hybrids and the share of commercial seed in maize area for different developing country regions is summarized in Table 2.19.

Table 2.19 Maize area planted to improved open-pollinated varieties and hybrids in developing countries, late 1990s

			Area planted using commercial seed		
	Total maize area (million ha)	**Area planted using farm-saved seed (%)**	**Open-pollinated varieties (OPVs) (%)**	**Hybrids (%)**	**All modern varieties (MVs) (%)**
Latin America	27.1	55.1	5.0	39.9	44.9
w/o Argentina	24.5	59.6	5.3	35.1	40.4
Eastern and Southern Africa	14.9	47.5	6.9	45.7	52.6
w/o South Africa	10.9	64.1	8.3	27.6	35.9
Western and Central Africa	8.2	63.2	33.1	3.7	36.8
East, South and South-East Asia	42.3	17.6	12.3	69.6	82.4
w/o China	20.5	35.3	22.1	42.6	64.7
All regions	94.2	37.6	11.5	51.0	62.4
All non-temperate regions	65.7	52.8	14.8	32.4	47.2

Source: Morris, 2002.

For all regions taken together, 62.4 percent of the maize area was planted to commercial seed, while for non-temperate regions, the share was 47.2 percent. In non-temperate regions, the share of area planted to hybrids was 32.4 percent, while the area planted to OPVs (with commercial seed) was 14.8. Commercial seed is therefore used for nearly half the area planted to maize in developing countries.

The share of maize planted to varieties incorporating CIMMYT germplasm in developing countries in the late 1990s is presented in Table 2.20.

Table 2.20 Maize area planted to modern varieties with CIMMYT material, late 1990s

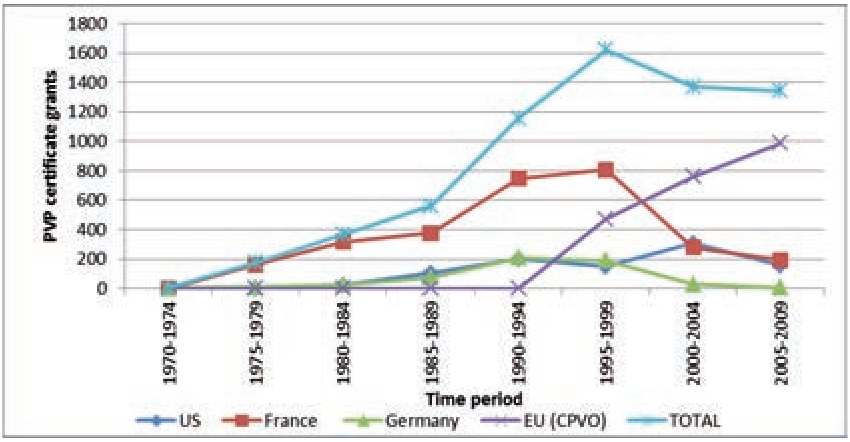
	Maize area (million ha)	**Maize area under modern varieties (MVs) (%)**	**Maize area under MVs ('000 ha)**	**Seed with CIMMYT germplasm (%)**	**Maize area under MVs with CIMMYT germplasm ('000 ha)**
Latin America	27.1	44.9	12 171	80.9	9 842
w/o Argentina	24.5	40.4	9 899	92.8	9 183
Eastern and Southern Africa	14.9	52.6	7 834	20.8	1 630
w/o South Africa	10.9	35.9	3 910	36.7	1 433
Western and Central Africa	8.2	36.8	3 013	67.0	2 019
East, South and Southeast Asia	42.3	82.4	34 851	20.7	7 222
w/o China	20.5	64.7	13 244	38.2	5 062
All regions	94.2	62.4	58 805	36.1	21 210
All non-temperate regions	65.7	47.2	31 001	58.7	18 195

Source: Morris, 2002.

CIMMYT-linked varieties had a share of 58.7 percent in non-temperate regions, which fell to 36.1 percent when all regions (including temperate regions) were considered.

We do not have variety release data for developed countries similar to that for developing countries. But since most developed countries have adopted PVP systems for over three decades, and it is generally the practice for both public and private sector institutions to protect their varieties, the trends in PVP grants can provide an indicator of new maize varieties bred in developed countries.[14] The trends in grants of PVP certificates in three major maize-producing developed countries – United States, France and Germany – and for the European Union (EU)[15] are presented in Figure 2.6.

Figure 2.6 Trends in PVP certificates for maize varieties in the United States, France and Germany



Source: UPOV Plant Variety Database.

It must be noted that that development of transgenic varieties in the United States is not reflected in the Figure 2.6 because the latter are generally are protected by utility patents and not by PVP. The private sector is dominant in the ownership of maize varieties in developed countries, and the pedigrees of private varieties are often 'closed' (i.e. not disclosed publicly). Therefore, it is difficult to assess the use of CIMMYT germplasm in

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14 Not all protected varieties are eventually sold commercially; some protected varieties may never be marketed commercially.

15 The Community Plant Variety Office (CPVO) of the EU grants PVP certificates that are valid in the whole of the EU. CPVO came into existence only in 1995. National PVP grants cannot be held simultaneously with a CPVO grant for the same variety. In recent years, the use of national PVP systems in France and Germany has declined as breeders switch to seeking EU-wide protection for new varieties through the CPVO.

maize breeding programmes in developed countries. However, there is evidence of the significant use of CIMMYT germplasm in the United States (Pardey *et al.*, 1996), even though CIMMYT breeding programmes are mainly oriented to non-temperate environments. It may therefore be reasonable to assume that the use of CIMMYT germplasm in developed country maize varieties can be conservatively approximated by the share of CIMMYT-linked varieties for temperate regions in developing countries (around 11 percent).

2.6 Value of global commercial seed market

Payment obligations under SMTAs are related to the commercial sales of product innovations incorporating SMTA-PGR. The value of global commercial seed sales, therefore, provides a useful starting point for the assessment of potential benefit-sharing payments. In this section we will attempt an estimation of the global commercial seed sales related to Annex 1 crops. In the following section, we will attempt to identify the components of the global commercial seed sales that could be attributed to product innovations incorporating SMTA-PGR for three major food crops – wheat, rice and maize.

2.6.1 Data sources and constraints

An accurate assessment of the value of the global commercial seed market is a difficult exercise because of the lack of reliable and consistent data sources across countries. In almost all countries, the extensive use of farm-saved seed for different crops implies that commercial seed use is a fraction of the total seed use. The proportion of commercial seed use to total seed use is reflected in the SRRs, which vary widely across crop, type of variety (hybrid versus non-hybrids) and countries and over time. Thus, even where reliable estimates of seed use are available from crop production data, the estimation of the volumes of commercial seed requires information on seed replacement patterns adopted by farmers. Derivation of the value of commercial seed sold from volume data further requires information on seed prices which are also subject to wide variation across individual varieties and countries.

Commercial seed is sold in seed markets by public and private sector companies of varying sizes – from small independent seed companies producing and marketing seed locally to giant global companies that market seeds across continents. While published reports and accounts may provide some information on the seed sales of these companies, there is no organized statistical system for the collection and consolidation of seed sales data at the provincial or national level in most countries. The information from published reports of seed companies may not provide information on the value of seed sales by crop. Variety-level information, critical for assessment of payment obligations under SMTAs, is invariably never provided as companies regard variety level data to be commercially sensitive. For large global companies operating in several countries (often through a web of affiliated, 'group' or subsidiary companies) and covering several different types of agricultural inputs, the assessment of the value of commercial seed sales by crop from published reports may be infeasible or very complex. Seed industry association at the national or international level do often compile seed sales of members – but again, data coverage of crops and industry segments varies considerably and data may not be made available publicly at a disaggregated level. Variety information is again not available. In seed markets characterized by intense competition for market share, industry players have few incentives to disclose variety-level information.

Commercial seed is sold in national jurisdictions subject to marketing and quality control regulations. The data generated in the enforcement of these regulations provide the most reliable data on commercial seed use at the crop (and at times, variety) level. In countries with variety registration systems,[16] commercial seed can be sold only if a variety has been registered or inscripted in a national register. In the EU, varieties of agricultural plant species and vegetable seed can be marketed only if they are inscripted in the EU common catalogue of varieties, which is updated every year. Many countries also have variety release procedures or a list of recommended varieties, which are in the nature of recommendations to farmers for adoption. Variety registration systems and recommended variety lists are, therefore, an authentic source of information on the varieties that can be commercialized in different jurisdictions. Most countries also operate seed certification systems for quality control that may be mandatory or optional. In most EU countries, seed certification is compulsory, which implies that all commercial seed sales must be subject to seed certification. In countries where seed certification is compulsory, seed certification statistics provide authentic data on on volumes, per variety, of commercial seed produced.[17] However, in other countries such as the United States and many developing countries, seed certification may be optional or may apply only to a set of varieties (e.g. released varieties) brought under the purview of quality control regulations. In such cases, seed certification statistics may provide only a partial view of the commercial seed market, although leading varieties may be covered. The OECD operates a certification scheme[18] for seeds of selected cereal, forage and vegetable crops moving in international trade; 58 countries (including some non-OECD countries) participate in these schemes. The list of varieties eligible for certification under the OECD schemes is a useful source of information on varieties moving in international trade for the crops covered. Although the OECD collects information on the volume of certified seeds traded under the scheme, variety-level information is not published.

International seed trade statistics are another potential source of information on the size of the global commercial seed market, although, by definition, trade statistics exclude

16 Registration systems may require a variety to be evaluated for distinctness, uniformity and stability (DUS) and also for value in cultivation and use (VCU).

17 Some countries (e.g. France), however, do not publish seed certification statistics at the variety level but only at the crop level.

18 For details of OECD certification schemes, see www.oecd.org/document/7/0,3746, en_2649_33905_39574151_1_1_1_1,00.html. Currently, around 43,000 varieties are eligible for certification under the OECD scheme.

commercial seed produced and sold in domestic markets. The availability of data on seed trade at the crop level for different countries depends on the level of detail in the classification of goods adopted for generating international trade data. Trade statistics are recommended to be compiled under the Harmonized Commodity Description and Coding System (HS) of tariff nomenclature, an internationally standardized system of names and numbers for classifying traded products developed and maintained by the World Customs Organization (WCO), an independent intergovernmental organization with over 170 member countries based in Belgium. The HS system at the six-digit level[19] does not distinguish between seed and grain for most crops (i.e. the trade in seed is clubbed with trade in grain). However, some countries – including all EU countries, the United States, China and India – have extended the classification to nine or ten digits (i.e. incorporated additional sub-categories), which allows 'seeds for planting' to be distinguished as a separate category. Therefore, the data on imports and exports of seeds at the crop level are available only for some countries that have gone beyond the mandatory six-digit classification of traded goods. Trade statistics on seeds, even when they are available, do not, however, provide any variety-level information. Estimation of commercial seed volumes/value from international trade statistics is also confounded by the problem of import and re-export of seeds, which is a significant phenomenon for seeds of several crops (e.g. forage crops).

Data on the global commercial seed market are also available from a number of commercial market research reports and seed market databases.[20] These reports and databases are mainly intended to assess market opportunities and competition in different markets, and vary greatly in their scope and coverage of crops, countries and companies, often focusing on the largest player in the market. For this analysis, the authors have principally relied on information provided by ISF, which is the international industry association of the seed industry, and a global seed industry report prepared by Global Industry Analysts, Inc. (GIA, 2010).

2.6.2 Value of global commercial seed market of Annex 1 crops

There are several estimates of the value of the global seed market, which range from US$36.1 billion (GIA, 2010) to US$42 billion of the ISF. The differences in the estimates from different sources arise on account of the categories of crops included and the methods and coverage of data collection. The ISF estimates of the size of the domestic seed markets in selected countries are presented in Table 2.21.

[19] To ensure harmonization, the Contracting Parties must employ all 4- and 6-digit provisions and the international rules and notes without deviation, but are free to adopt additional subcategories and notes.

[20] Examples include the Global Seed Market Database of The Context Network (www.contextnet.com/seed-industry.cfm), Seed Services of Phillips McDougall (www.phillipsmcdougall.com/seedservice.asp) and GfK Kynetec's database on biotech seeds (www.gfk.com/imperia/md/content/gfkkynetec/gfk_kynetec_traittrak_final_12-3-09.pdf).

Table 2.21 Estimated value of the domestic seed market in selected countries (US$ million), 2011

Country	US$ million	Country	US$ million	Country	US$ million	Country	US$ million
USA	12 000	South Africa	370	Morocco	140	Bolivia	40
China	6 000	Mexico	350	Bulgaria	120	Columbia	40
France	2 400	Netherlands	317	Chile	120	Slovenia	40
Brazil	2 000	Czech Rep.	300	Nigeria	120	Peru	30
India	2 000	Hungary	300	Serbia	120	Zimbabwe	30
Japan	1 400	Taiwan	300	Switzerland	118	Libya	25
Germany	1 261	Poland	260	Slovakia	110	Saudi Arabia	20
Italy	780	Greece	240	New Zealand	100	Zambia	20
Argentina	600	Sweden	240	Ireland	80	Ecuador	15
Canada	550	Romania	220	Paraguay	80	Tanzania	15
Russia	500	Belgium	185	Portugal	80	Malawi	10
Spain	450	Denmark	185	Algeria	70	Uganda	10
Australia	400	Finland	160	Uruguay	70	Dominican Republic	7
Korea	400	Austria	150	Kenya	60		
Turkey	400	Egypt	140	Iran	55		
United Kingdom	400	Tunisia	45	Israel	50		

Source: ISF, 2011.

The selected 61 countries account for US$37.8 billion of the estimated US$42 billion value of the global commercial seed market. The United States has the largest commercial seed market valued at nearly US$12 billion, followed by the EU at nearly US$8 billion. However, cropwise estimates of the value of the global commercial seed market are not available from ISF data. The GIA study provides some breakdown of the global commercial seed market at the level of major crop groups, which is summarized in Table 2.22.

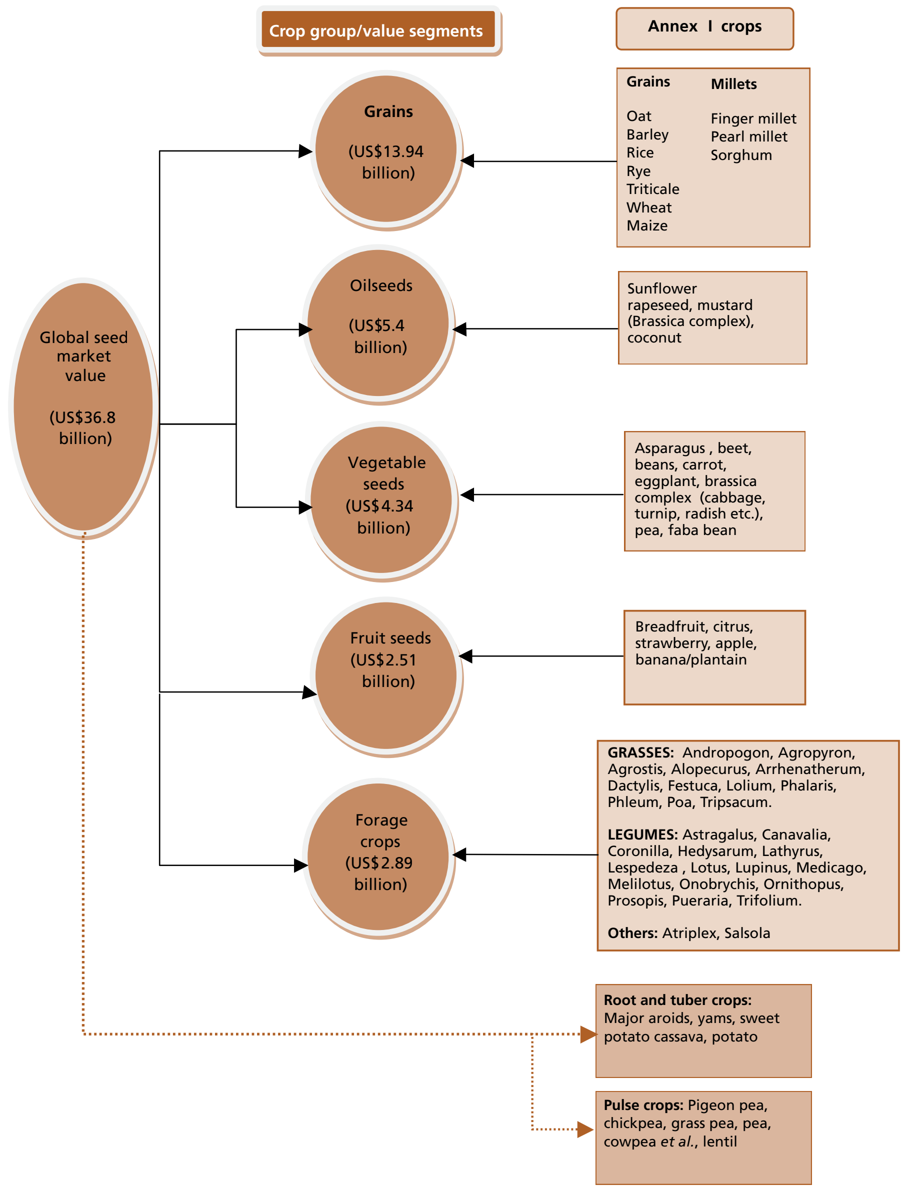
Table 2.22 Global seed market – breakdown of value sales by crop type

Crop group	Share (%)	Value (US$ billion)
Grain seeds	37.89	13.94
Horticulture seeds	20.40	7.51
- Flower seeds	12.55	4.62
- Lawn/grass seeds	7.86	2.89
Oilseeds	14.69	5.41
Vegetable seeds	11.80	4.34
Fruit seeds	6.83	2.51
Miscellaneous seeds	8.39	3.09
Total	**100**	**36.8**

Source: GIA, 2010.

Even the disaggregation of the value of the global commercial seed market into major crop groups does not allow to estimate the value of the commercial seed market attributable to Annex 1 crops. In Figure 2.7, the authors attempted to map Annex 1 crops to the crop group/value segments of the seed market shown in Table 2.22. It must be noted that not all Annex 1 crops can be readily mapped to the crop group/value segments used in the GIA study; tuber crops including potatoes and pulse crop do not map on to any of the value segments and have been shown separately.

Figure 2.7 Global commercial seed market (2010) and Annex I crops



Note: It is not clear under which crop/value segments identified in the GIA (2010) report, root and tuber crops and pulse crops can be classified. However, the overall global commercial seed market value includes the value of commercial seed of these crops.

To assess the relative important of Annex 1 crops in the respective crop/value segments, the relative share of Annex 1 crops in the area harvested and production of these segments from FAOSTAT data for 2010 have been estimated, as shown in Table 2.23.

Table 2.23 Share of Annex 1 crops in global seed market crop group/value segments

Crop group/ value segment	Share of Annex 1 crops in total area harvested (2010) (%)	Share of Annex 1 crop in total production (2010) (%)	Commercial seed market for crop group/value segment (US$ billion)	Commercial seed market value for Annex 1 crops (US$ billion)
Cereals/grains	99.5	99	13.94	13.8
Pulses and lentils	92	92	n.a	n.a
Roots and tubers	98	98	n.a	0.2*
Oilseeds	33	17	5.40	0.9
Vegetable seeds	20	19	4.34	0.8
Fruit seeds	42	54	2.51	1.4
Forage seeds	n.a	n.a	2.89	2.3**
Total				

Source: Calculated from FAOSTAT data.
*Represents value of annual exports of potato seeds based on average international export prices.
** Based on the assumption that temperate forages seeds account for 80 percent of commercial seed sales.

Table 2.23 shows that for cereals and root and tuber crops, Annex 1 crops account for nearly the entire area and production of the respective crop groups. Annex 1 crops of pulses and lentils also account for a 92 percent of the share of area and production in the crop group. The share of Annex 1 crops in area and production is much lower for other crop groups. In oilseed crops, the exclusion of major oilseed crops such as soybean from Annex 1 accounts for the lower share of Annex 1 crops (17 percent of production) in this segment. The area and production share of Annex 1 vegetable crops is less than 20 percent. Due to the inclusion of important fruits such as banana/plantains, strawberry and apple in Annex 1, the share of Annex 1 fruits in area and production is much higher compared to vegetables.

For roots and tubers, no data on the size of the commercial market for seed are available. For the seed potato market, it is estimated that annual world exports are around one million tonnes, with the Netherlands accounting for nearly 70 percent of the world exports.[21] We have used the value of world exports as a proxy for the size of the commercial market for seed potato. For other tuber crops, the commercial market for propagating material appears to be limited, with farmers predominantly using farm-saved tubers or improved varieties multiplied and distributed through national extension programmes. No data appear to be available for the commercial seed markets of pulse and lentil crops.

For forage crops, it must be noted that Annex 1 includes mainly temperate forages, while tropical forages are excluded. No data are available on the area coverage of temperate and tropical forages. But the GIA (2010) study estimates that the share of the United States, Canada, Japan and Europe, which are the leading producers of temperate forages, account for nearly 80 percent of the value of the forage (grass) seed markets. This figure of 80 percent can be taken as a reasonable estimate of the share of Annex 1 temperate forages in the global commercial forage seed market.

If the relative share of Annex 1 crops in the value of the related crop groups/value segments broadly corresponds to their share in the total production (or is estimated separately as indicated above for roots and tubers and forages), then the value of the global seed market attributable to Annex 1 crops will be as indicated in the last column of Table 2.23. The total value of the commercial seed market of Annex 1 crops is estimated at $19.4 billion. Cereals account for the dominant share of this value (71 percent), while other significant contributors are vegetable (12 percent) and fruit seeds (7 percent).

The value of the global commercial seed market for Annex 1 crops does not allow to assess the potential magnitude of payments under SMTAs because this requires the identification of seed sales attributable to varieties that have incorporated SMTA-PGR. However, the value of the global commercial seed market for Annex 1 crops can be used to estimate the upper bound for potential mandatory and voluntary payments. As seen earlier, if over 65 percent of the value of seed sales is attributable to varieties incorporating SMTA-PGR, which is highly unlikely in the foreseeable future, then it will be beneficial for recipients to opt for the 'discounted' payment option under Article 6.11 of SMTAs at the rate of 0.5 percent of the entire commercial seed sales of the crops to which the SMTA-PGR relates. If we assume that SMTA-PGR is utilized for the development of new varieties of all Annex 1 crops and further, that all recipients opt for discounted payment option under Article 6.11, then the application of this rate of 0.5 percent to the global commercial seed market value of Annex 1 crops gives us the upper bound for payments into the Benefit-sharing Fund. Given the value of $19.4 billion of the commercial seed market of Annex 1 crops, this would translate into an upper bound of $100 million for benefit-sharing payments related to SMTAs. It should be emphasized that this upper bound figure does not reflect a realistic assessment of potential benefit-sharing payments, but is only indicative of the broad orders of magnitude relevant for discussion of the impact of access and benefit-sharing arrangements introduced by the Treaty.

[21] Source: Netherlands Potato Consultative Foundation, available at www.nivaa.nl

2.7 Assessing potential for mandatory payments

Mandatory payments into the Benefit-sharing Fund arise when PGR exchanged under an SMTA are used by the recipient to develop products (that are themselves PGR) that are not "available without restrictions to others for further research and development". In such cases, Article 6.7 of the SMTA provides for a mandatory annual payment of 1.1 percent less 30 percent of the total sales of the product into the Benefit-sharing Fund by the recipient. It must be noted that Article 6.11 allows a recipient to opt for an alternative payment scheme under which an annual payment can be made in respect of any product or products of the crop to which SMTA-PGR relates, independent of whether or not these are available without restriction. The rate of payment prescribed under this option is 0.5 percent of the entire sales of products (seeds) of the crop to which the PGR accessed relates. The expression "available without restriction to others for further research and development" refers to the nature of IPR protection applied to the innovation developed using SMTA-PGR. As discussed earlier, the implication of Article 6.7 is that mandatory payments will not be triggered if the product innovation derived from the use of SMTA-PGR is not subject to any form of IPR protection (e.g. where a NARS institution releases a new variety without subjecting it to IPRs), or if the product is only subject to PVP where breeders' exemption provisions allow the product to be freely used without restrictions in the development of follow-on innovations. In practice, therefore, mandatory payments are likely to accrue only when product innovations derived from SMTA-PGR are subjected to stronger forms of intellectual property protection such as patents that allow for only very limited experimental (research) use exemptions.

Utility patents for plant varieties are available only in a limited number of countries,[22] which include the United States, Australia, Japan and Republic of Korea. The present legislative framework in the European Union (EU) does not allow the patenting of plant varieties nor do developing countries allow plant variety innovations to be patented. Therefore, the large majority of plant variety innovations developed in both developed and developing countries through the use of SMTA-PGR will not attract mandatory payments. However, there is one group of plant variety innovations that is rapidly growing in importance in the global seed economy and that may give rise to mandatory payments – the GM varieties of important crops that are developed through the application of biotechnology. GM varieties are invariably protected through utility patents (in countries where such patents are available) and are often sold subject to conditions that preclude the use of farm-saved seed by farmers. They may also involve the payment of a separate 'technology fee' in addition to the basic cost of the seed. It is the current and prospective use of SMTA-PGR in GM varieties that is potentially the most important source of mandatory payments. The extent of use of SMTA-PGR in the development of GM varieties, where the private sector

22 Hungary had a plant patent system prior to its accession to the European Union. After accession to the EU, its intellectual property laws have been revised to align them with those of other EU members. Hungary now has a PVP law for the protection of new varieties of plants.

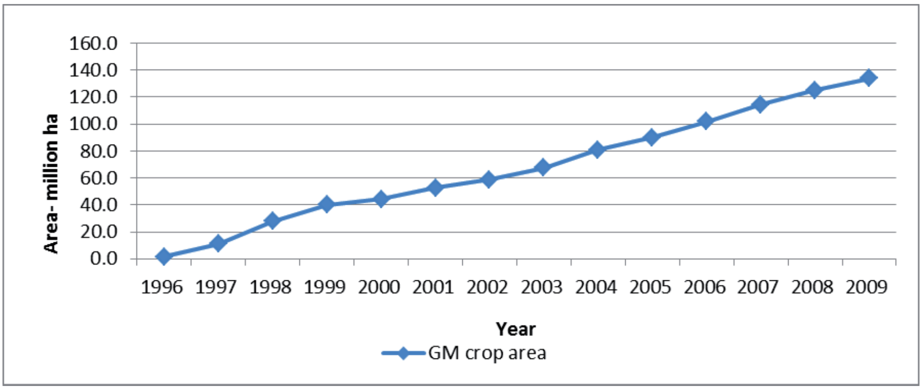
has been dominant, is, however, an empirical question. In a later section, information methodologies that could be employed to reliably assess the use of MLS material in the development of GM varieties are suggested.

Starting from the mid-1990s, there has been a remarkable surge in the application of biotechnology to plant breeding and the commercialization of GM crops in both developed and developing countries. ISAAA (2009) estimates that "a record 14 million farmers in 25 countries planted 134 million ha in 2009" to GM crops. However, the commercialization of GM crops has been confined to a fairly narrow range of crops. The main crops that have seen the application of biotechnology for the production of GM varieties are:

1. Soybean
2. Maize
3. Cotton
4. Canola
5. Alfalfa.

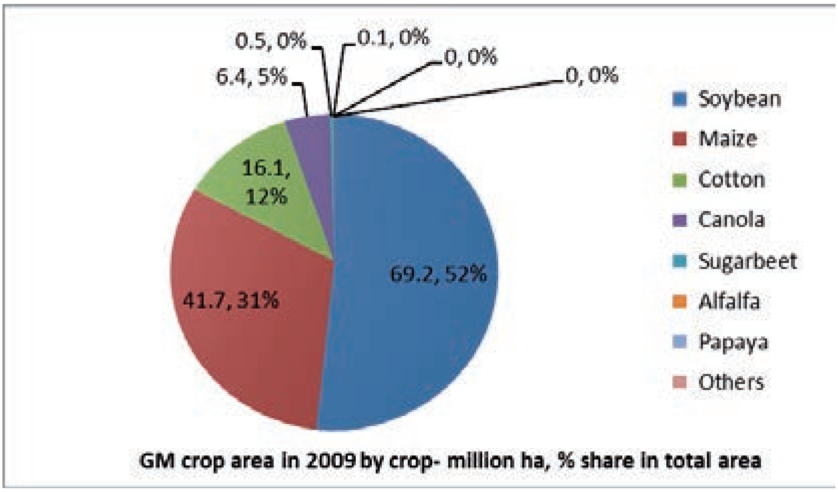
Figure 2.8 shows the dramatic increase in the area under GM crops over the period 1996–2009, while Figure 2.9 shows the share of different crops in the global GM area. Soybean (69.2 million ha), maize (41.7 million ha), cotton (16.1 million ha) and canola (6.4 million ha) account for nearly the entire GM area globally. Figure 2.10 shows the global adoption rates for the principal GM crops in relation to the total global area. The share of GM varieties in the total global area is the highest for soybean (77 percent) and cotton (49 percent), and is relatively lower for maize (26 percent) and canola (21 percent).

Figure 2.8 Growth in global GM crop area



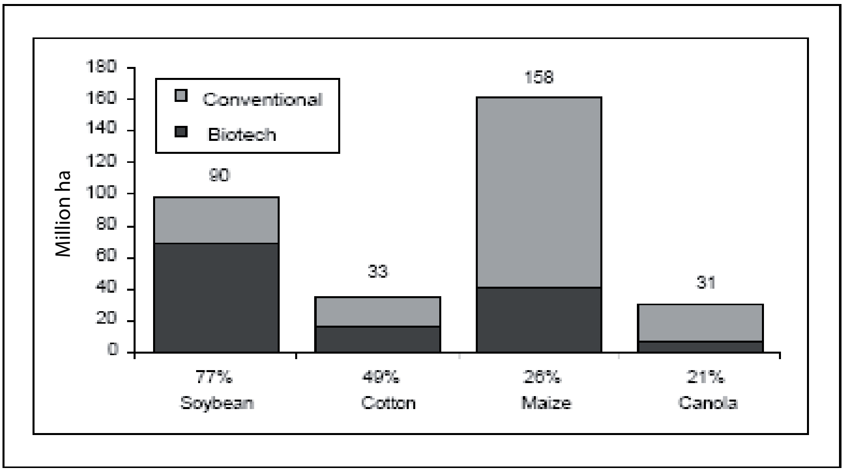
Source: ISAAA, 2009.

Figure 2.9 Share of crops in GM area in 2009



Source: ISAAA, 2009.

Figure 2.10 Global adoption rates for principal biotech crops, 2009 (million hectares)



Source: ISAAA, 2009.

Given the environmental, ecological and human health concerns associated with the use of GM crops, most countries have devised policies regarding the cultivation and use of GM crops and separate regulatory mechanisms for the approval of GM varieties in cultivation and use, which are different from those that apply to conventionally bred varieties. Consequently, policies related to GM crops and the nature of regulatory processes for approval of GM varieties, their complexity and speed of operation have become key determinants of the adoption of GM varieties in different countries. While the trends in utility patents for GM varieties may provide an indicator of innovative activity for genetic modification in different crops, it is the number of approvals given for the commercialization of GM varieties in different countries that may better reflect the commercial growth potential of GM variety innovations. Table 2.24 presents the approvals for commercialization of GM varieties by crop and country.

Table 2.24 Regulatory approvals for GM varieties by crop and country, 2010 (no. of GM varieties approved)

Country/crop	Maize	Cotton	Soybean	Potato	Argentine Canola	Sugar beet	Tomato	Alfalfa	Rice	Papaya	Squash	Polish Canola	Tobacco	Wheat	Total
USA	56	15	11	11	10	3	5	2	2	2	2		1	1	121
Japan	50	21	7	10	14	3	1	3	2	1					112
Canada	47	11	9	10	10	2	4	2	1	1	2	2			101
Mexico	37	18	7	7	4	1	3	3	1						81
Republic of Korea	40	17	5	9	6	1									78
Philippines	39	8	6	10	1	2		2							68
Australia	22	16	9	9	8			2	1						67
New Zealand	20	9	7	7	7	2		1	1						54
Taiwan	39		7												46
EU	25	7	3	1	4	1							1		42
China	12	7	3		7		3		1	1					34
Brazil	17	9	5												31
Colombia	15	9	3			1			1					1	30
Argentina	18	3	3												24
South Africa	11	6	2		4										23
Costa Rica		17	2												19
Russian Federation	10		4	2		1			1						18
Uruguay	7		1												8
India		6													6

Country/crop	Maize	Cotton	Soybean	Potato	Argentine Canola	Sugar beet	Tomato	Alfalfa	Rice	Papaya	Squash	Polish Canola	Tobacco	Wheat	Total
Honduras	4														4
Singapore	2	1				1									4
Malaysia	3		1												4
Switzerland	3		1												4
Chile	1		1		1										3
El Salvador	3														3
Czech Republic	1		1	1											3
United Kingdom	2		1												3
Turkey			3												3
Thailand	1		1												2
Spain	2														2
Paraguay		1	1												2
Egypt	1														1
Burkina Faso		1													1
Bolivia			1												1
Sweden				1											1
Pakistan		1													1
Netherlands	1														1
Slovakia	1														1
Iran									1						1
Germany				1											1
Romania	1														1
Poland	1														1
Portugal	1														1
Myanmar		1													1
Total	**493**	**184**	**105**	**79**	**76**	**18**	**16**	**15**	**12**	**5**	**4**	**2**	**2**	**2**	**1 013**

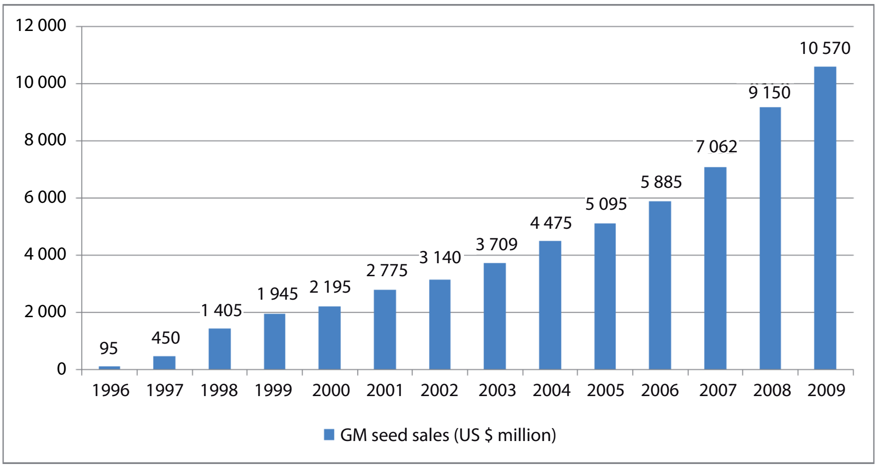
Source: Calculated from the GM Approval Database at www.isaaa.org.

The data presented in Table 2.24 show that nearly 44 countries have permitted the commercialization of some GM varieties. The pattern of approval is uneven across countries, and there are also wide variations in terms of the crops where they allow GM varieties and the uses (planting, processing, food, feed, etc.) that are permitted. Notwithstanding the impressive growth in area under GM crops over the last decade, less than 25 percent of the countries in the world currently permit the commercialization of GM varieties. Regulatory approvals are also concentrated in the key GM crops listed above.

2.7.1 Implications for benefit-sharing flows

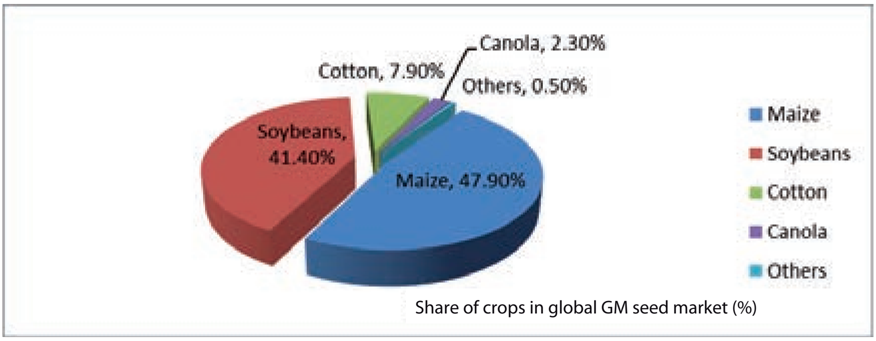
Among the crops that have seen significant application of biotechnology and commercialization of GM varieties, only maize and canola are Annex 1 crops with significant acreage. Other crops such as rice, wheat, alfalfa, potato and sugar beet are Annex 1 crops, but their area under GM varieties is presently insignificant. An important implication is that there will be no potential benefit flows from non-Annex 1 crops such as soybean and cotton, which been the subject of significant biotechnology based innovation and have witnessed the most rapid growth in area coverage and seed (product innovation) markets. For maize and canola, any estimation of potential mandatory payments has to be related to the size of the GM seed markets in these crops. The size of the global transgenic (GM) seed market is estimated in 2010 at nearly $11 billion and has seen significant growth over the last decade (Figure 2.11). The share of different crops in the global transgenic seed market is presented in Figure 2.12.

Figure 2.11 Growth of global GM seed market



Source: Phillips McDougall, 2010.

Figure 2.12 Share of crops in global GM seed market



Source: Phillips McDougall, 2010.

The current size of the market (2010) for the transgenic seeds of Annex 1 crops is, therefore, estimated at $5.063 billion for maize and $0.26 billion for canola. These markets are expected grow at a rate of around 5 percent over the next decade (GIA, 2010).

2.7.2 Assessing the use of SMTA-PGR in genetically modified Annex 1 crops

The development of GM varieties of crop plants involves the genetic transformation of conventionally bred varieties using biotechnology tools and techniques. Conventionally bred varieties, therefore, provide the foundation for GM innovations. Varieties that are agronomically superior and are well adapted to local agro-climatic conditions are often the best candidates for genetic transformation. It is quite common for leading commercial (conventionally bred) varieties to be selected for genetic modification and incorporation of additional traits of interest. The use of SMTA-PGR in GM varieties is likely to arise through their use in the development of conventionally bred varieties that are subject to genetic modification. The additional step of genetic modification does imply that the time lag between the use of SMTA-PGR in the breeding programme and the development of the innovation are likely to be greater for GM varieties than for conventionally bred varieties.
The exchange of PGR under SMTAs commenced only in 2007 following the entering into force of the Treaty. Given the length of the crop breeding cycle for major food crops that can range from seven to 15 years, it may be too early to identify the use of SMTA-PGR in GM varieties that have been protected by utility patents. However, the potential use of SMTA-PGR in GM varieties over time can be approximated by the extent of use of PGR accessed from the gene banks of the IARCs of CGIAR, which were available for free

international exchange even prior to the implementation of the Treaty, in the development of conventionally bred varieties by the private sector. It is the private sector that has been dominant in the development of GM varieties. The authors propose to rely on the use of CGIAR/IARC PGR in the development of conventionally bred varieties by the private sector as the indicator of the potential use of SMTA-PGR in the development of GM varieties.

As discussed in the previous section, CIMMYT has made a series of assessments of the use of PGR accessed from it for the development of maize varieties in different regions of the world by the private sector, as part of its global maize impact studies in the 1990s (Morris, 2002). These assessments suggest that during the late 1990s, on average, 58 percent of private sector maize varieties contained CIMMYT germplasm, with the proportion being much higher in some regions of the world. Discussed below are some reasons for which the use of SMTA-PGR in the development of GM varieties may be lower than the use of CIMMYT material in conventionally bred private sector varieties of maize. Taking these factors into account, a conservative estimate of the potential use of SMTA-PGR in GM maize varieties would be approximately 10–25 percent of GM varieties. If one further assumes that variety shares translate approximately into seed market shares for GM varieties, then the potential for mandatory payments into the Benefit-sharing Fund under different scenarios will be as summarized in Table 2.25.

Table 2.25 Potential for mandatory payments into the Benefit-sharing Fund for GM maize

Value of global GM maize market (2010)			
US$5 billion			
	Market share scenarios for GM varieties using SMTA-PGR		
	10%	15%	25%
Potential payments into Benefit-sharing Fund (1.1% of seed sales less 30%)	US$3.85 million	US$5.8 million	US$9.7 million

The potential for mandatory payments under Article 6.7 of the SMTAs, assuming GM maize varieties incorporated SMTA-PGR, would be in the range of US$3–10 million. If companies producing GM maize varieties were to opt for the payment option under Article 6.11 of the SMTAs, then the potential payments into the Fund would be US$25 million. But the seed industry companies are unlikely to opt for the payment option under Article 6.11 until the share of GM varieties using SMTA-PGR exceeds the threshold of 65 percent of their sales, which is quite unlikely in a highly concentrated market dominated by four or five large global companies.

There are a number of reasons for which the potential for mandatory payments from GM maize varieties is relatively modest (under US$10 million) in relation to the size of the global maize seed industry, notwithstanding the significant previous use of CIMMYT material by the private sector in both developed and developing countries:

(i) CIMMYT's maize breeding programmes are largely intended for the tropical production environments in developing countries and the contribution of CIMMYT germplasm to varieties suited to temperate production environments found in most developed maize-producing countries may be lower.

(ii) There is evidence of the substantial use of CIMMYT germplasm by the private sector in the United States, which is one of the largest producers of maize and where private sector hybrid varieties have been dominant (Pardey, 1996), even prior to the introduction of GM varieties in the 1990s. However, the use of PGR accessed from the MLS by the private sector prior to the implementation of the Treaty (and hence not subject to SMTAs) will not give rise to any payments to the Benefit-sharing Fund. The PGR accessed from the MLS prior to the implementation of the Treaty continue to be available to the private sector and may have been assimilated into the collections maintained by the private sector. The key traits extracted from such PGR may have been incorporated into proprietary varieties/ breeding lines, and the traits of interest may be available to GM maize breeding programmes through these proprietary varieties or breeding lines. The private sector may no longer need to access this PGR under the terms of SMTAs in order to utilize the traits of interest in the GM breeding programmes. Thus, the access afforded to the private sector prior to PGR in the MLS prior to the implementation of the Treaty may have considerably reduced the need for and dependence on SMTA-mediated access to the same PGR.

(iii) The pre-Treaty flows of PGR in the four decades prior to the Treaty through national and international gene banks, and the PGR flows prior to the application of intellectual property rights on PGR innovations and emergence of CBD paradigms may have created large pools of PGR outside the purview of the MLS, providing the private sector with alternative sources of access to PGR of interest. The availability of alternative sources of access has significant implications for the potential flow of payments into the Benefit-sharing Fund.

(iv) The emergence of the CBD, the extended negotiation process leading to the Treaty and the uncertainties surrounding the nature of PGR exchange regime that would eventually emerge may have created strong incentives for private sector breeding programmes to avoid the use of PGR that require the economic returns from innovations to be shared with resource providers. There does appear to be some evidence of the private sector breeding programmes explicitly avoiding the use of PGR (see Annex) that may be subject to benefit-sharing provisions, although much of it appears to be anecdotal.

Another key factor influencing the potential for the mandatory payments flowing from GM maize varieties is the concentration of the GM maize seed industry, both in terms of the IPR ownership of varieties and of seed market share. Table 2.26 shows the share of the top companies in utility patents granted for maize varieties in the United States. In terms of market share in GM area planted in the United States, the two top companies Monsanto and Du Pont/Pioneer account for nearly 70 percent of the market (with a share of nearly one-third of the market for each company), followed by Syngenta, which accounts for nearly 10 percent of the market (GIA, 2010).

Table 2.26 Share of top companies in utility patents for GM maize varieties, 1995–2009

Company	Share (%)
Du Pont	45.7
Monsanto	34.7
Syngenta	9.3
Dow	2.3
Other private	7.7
Public	0.3
Total	**100**

Source: Calculated from USPTO data.

The high degree of concentration in the GM maize seed industry may influence the speed of diffusion of SMTA-PGR in private breeding programmes. The concentration of innovative activity in a few large firms may mean that the diffusion of SMTA-PGR in the gene pools of private breeding programmes may be much faster than if the innovative activity were to be spread over a much larger number of firms. If one of the leading companies would have access to SMTA-PGR, the probability of incorporation of that material in a commercially successful product would be greater. However, the uptake of SMTA-PGR in private breeding programmes would be considerably limited if the major players were to adopt explicit or implicit avoidance strategies regarding the use of PGR from the MLS in their breeding programmes.

We have not examined the potential for mandatory payments from GM canola, because it appears to be insignificant given the current size of the GM canola seed market (around US$250 million) and the very small base of canola-related PGR in the MLS.

2.8 Assessing the potential for voluntary payments

Voluntary payments under SMTAs arise when SMTA-PGR is used in the development of commercial innovations (new plant varieties), which then remain freely available without restrictions for further research and development. Such payments may arise when public research institutions develop and release commercial varieties using SMTA-PGR without subjecting them to any form of IPR protection. Voluntary payments also arise when commercial PGR innovations are developed by public or private sector institutions and are subjected to IPR protection only through PVP. Innovations protected under PVP systems remain available for further research and development under the breeders' exemption clause in PVP legislation. PVP protected innovations, therefore, do not attract mandatory payments.

Incentives for making voluntary payments are likely to differ between public and private sector institutions, and between developed and developing countries. Voluntary payments by the private sector are likely to be motivated by the desire to maintain unrestricted access to MLS-PGR and to avoid the emergence of a highly restrictive international PGR exchange regime. Voluntary payments by NARS/public research institutions are likely to be governed by the policy mandates or directives that they may receive from governments. Developed country governments may offer voluntary payments (with or without contributions from the seed industry) to sustain the international PGR regime introduced by the Treaty and to underline the potential efficacy of the benefit-sharing arrangements put in place by the Treaty. In developing countries, the mandates for voluntary payments are likely to be driven by the perceived dependence of the national plant breeding programmes on foreign PGR and concerns about the incidence of the fiscal burden that such payments may entail and the likely impact on the prices at which innovations can be offered to farmers. In developing their mandates, developing countries are also likely to compare the costs and benefits of access and benefit-sharing arrangements facilitated by the Treaty with alternative regimes that may prevail/emerge in the absence of the Treaty. Finally, for all participants, voluntary payment decisions will be influenced by the prospects of voluntary payments being converted into mandatory payments, following the review envisaged under Article 13.2 d(ii)[23] of the Treaty.

2.8.1 Methodology for assessment

In this section the potential flows of voluntary payments are assessed with respect to three major food crops – wheat, rice and maize. The framework used to assess the potential for voluntary payments is described in Figure 2.13. For any crop, we start with the estimates of global seed use for that crop (or seed use in the top producers of the crop accounting

[23] This Article provides for "[a]ssessment, within a period of five years from the entry into force of the Treaty, of whether the mandatory payment requirement in the SMTA shall apply also in cases where such commercialized products are available without restriction to others for further research and breeding".

for 80–90 percent of global production). The global seed use is then split into seed use by developed and developing countries because the pattern of commercial seed use differs considerably between these countries. The seed use in developing countries is further divided into the following categories:

- seed use related to traditional varieties;
- seed use related to improved (or 'modern') varieties.

Seed use related to improved varieties is further divided into the following categories as appropriate:

- seed use related to transgenic (GM) varieties (if relevant);
- seed use related to improved varieties not incorporating MLS-PGR;
- seed use related to improved varieties incorporating MLS-PGR.

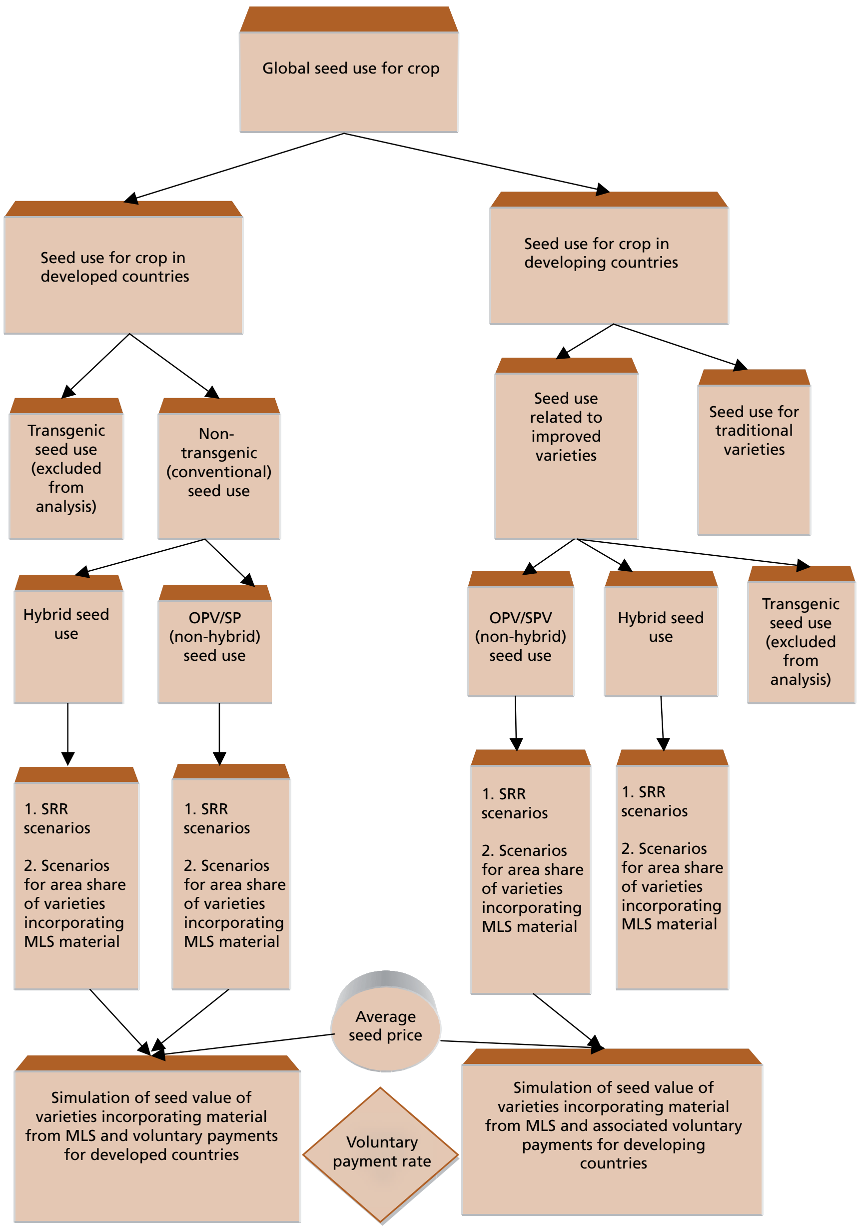
The share of seed use in different categories is derived based on estimates of the area under different types of varieties drawn largely from CGIAR/IARC assessments. Transgenic (GM) varieties are excluded from the analysis because they are generally protected by patents and will give rise to mandatory payments if they incorporate SMTA material. Similarly, seed use of improved varieties not incorporating MLS material will also not give rise to voluntary payments. It is only the *commercial* seed use of varieties incorporating MLS material that has the potential to give rise to voluntary payments.

The estimation of the use of commercial seed in relation to total seed use in any category depends on the SRR for that category. The SRR varies considerably between crops, between developed and developing countries, and between the types of variety used (hybrid, improved non-hybrid, transgenic or traditional variety). Transgenic and hybrid varieties involve an SRR of 100 percent since farmers are required to buy fresh seed of these varieties every season.[24] We use estimates of SRRs to derive the quantity of commercial seed use of varieties incorporating MLS material. The quantity of the commercial seed of these varieties is multiplied by the average global prices of seeds of respective crops (from international trade data) to derive the value of seed sales and the potential for voluntary payments. Some estimates of SRRs are available from the literature and/or study reports for some countries and some crops but tend to vary considerably. Similarly, estimates of area shares of varieties incorporating MLS material may also be changing rapidly and may be subject to large margins of error. We therefore simulate a range of values of these two parameters (around the best estimates) to derive a range of values for potential voluntary payments.

For developed countries, a similar approach is followed, except that we assume that the use of improved varieties is universal and that the relevant categories would be transgenic, hybrid and non-hybrid varieties (depending on the crop). Most varieties in commercial use in developed countries are likely to be protected by PVP (except for transgenic varieties protected by patents) and will give rise to voluntary payments if they incorporate SMTA-PGR.

[24] For hybrid varieties, farmers generally replace seed in every planting since the use of farm-saved seed will result in the loss of hybrid vigour and considerable decline in yields. For transgenic varieties, farmers may be precluded from the use of farm-saved seed by contractual agreements under which such seeds are sold.

Figure 2.13 Framework for assessing the potential for voluntary payments for Annex 1 crops

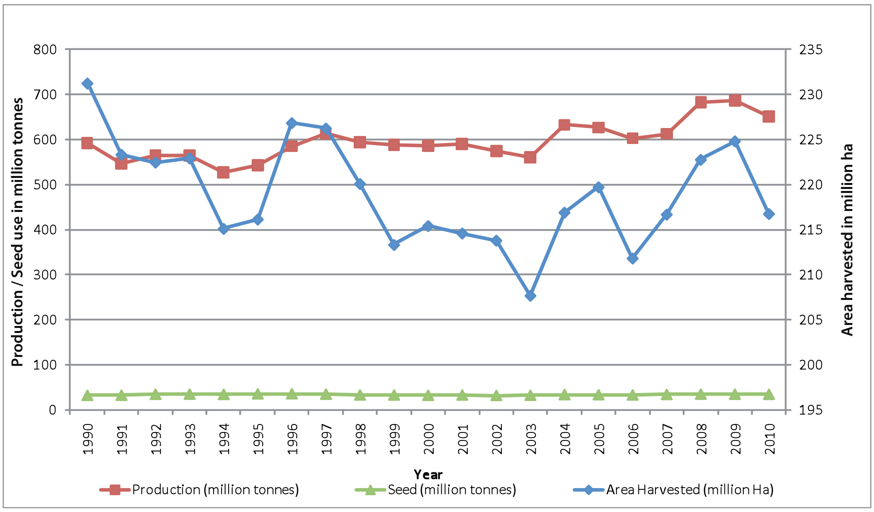


It should be clearly understood that commercial seed use of varieties incorporating SMTA-PGR *is not* the same as the commercial seed use of varieties incorporating PGR from the MLS (the latter is assessed using the method described above). Where PGR has been accessed from the MLS prior to the implementation of the Treaty/SMTAs and incorporated into a new variety, no voluntary payments are called for. An important assumption made in these assessments is that the present pattern of use of PGR from the MLS will continue and *over time* the share of varieties incorporating SMTA-PGR will be similar to the share varieties incorporating MLS-PGR. It should be noted that the incorporation of MLS-PGR in varieties is the outcome of nearly four decades of international exchange of PGR between national and international gene banks, whereas SMTA-mediated exchanges of PGR under the Treaty has occurred for only five years. Voluntary payments may take a considerable period of time – two decades or more, depending on the speed with which new varieties replace existing varieties. The assessment of voluntary payments using the method described above is discussed for the three selected crops below.

2.8.2 Wheat

Figure 2.14 shows the trends in global production, area and seed use for wheat over the last two decades. The top 20 producers of wheat and their share in world production and area are summarized in Table 2.27.

Figure 2.14 Global trends in area, production and seed use in wheat



Source: FAOSTAT.

Table 2.27 Top 20 wheat producers, 2010

Country	Share in area (%)	Share in production (%)
China	11.2	17.7
India	13.2	12.4
USA	8.9	9.2
Russian Federation	10.0	6.4
France	2.5	5.9
Germany	1.5	3.7
Pakistan	4.2	3.6
Canada	3.8	3.6
Australia	6.2	3.4
Turkey	3.7	3.0
Ukraine	2.9	2.6
Iran	3.2	2.3
Argentina	2.0	2.3
United Kingdom	0.9	2.3
Kazakhstan	6.1	1.5
Poland	1.1	1.5
Egypt	0.6	1.1
Italy	0.9	1.1
Uzbekistan	0.7	1.0
Brazil	1.0	0.9
Total	**84.6**	**85.3**

Source: FAOSTAT.

In 2010, global wheat acreage stood at 216 million ha, with production estimated at 651 million tonnes. The corresponding seed use was 34 million tonnes. The top 20 wheat producers accounted for nearly 85 percent of the wheat area and production. Developed countries accounted for 58.7 million ha of wheat area and 7 million tonnes of production in 2010, while developing countries accounted for 157 million ha of wheat area and 27 million tonnes of seed use.

Developed countries

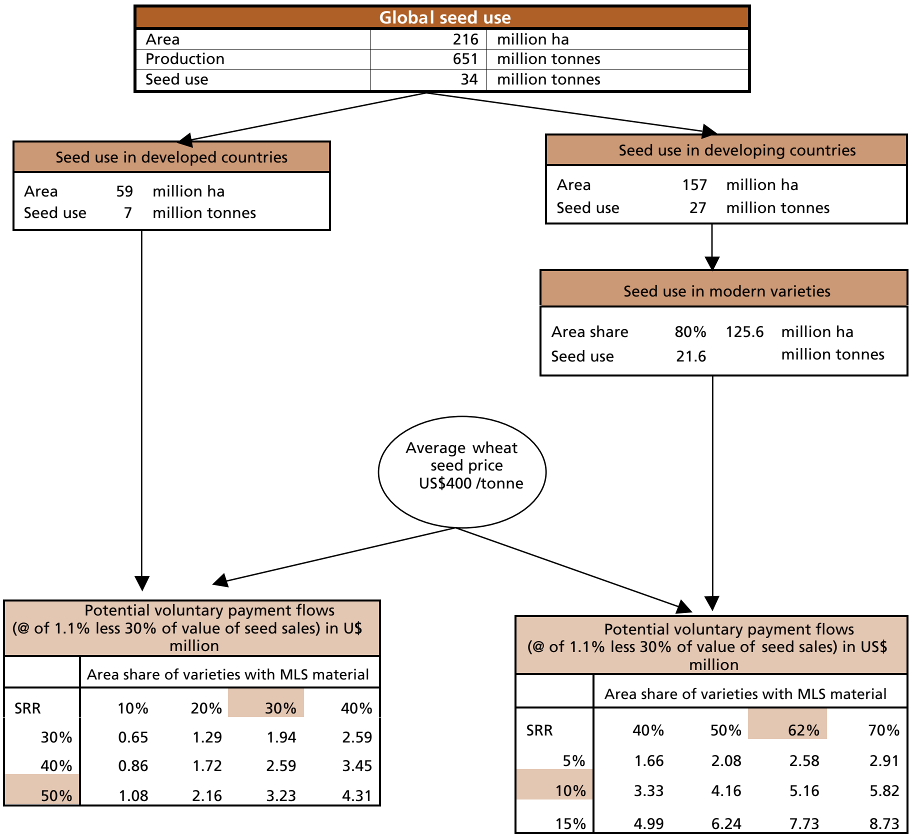
We propose to use the share of varieties having CIMMYT ancestry as a proxy for the share of varieties incorporating CIMMYT material. There are no recent assessments of the area share of varieties with CIMMYT ancestry in developed countries. As discussed in Section 2.5, an earlier assessment in the early 1990s suggested that nearly 40 percent of the area of wheat planted in developed countries had CIMMYT ancestry and the proportion was rising. However, the increasing role of the private sector in wheat breeding in developed countries over the last two decades may imply that the share of varieties with CIMMYT ancestry in total area may be lower at present. For the purpose of our simulations, it is therefore proposed to adopt a range of 20–40 percent as the share of area of varieties incorporating CIMMYT material. Information from the ISF (Buanec, 2005) suggests that, in general, the SRR varies considerably in developed countries except for wheat, which only varies from 30–50 percent. Many EU countries have witnessed an increase in the use of farm-saved seed for cereal crops – for instance, in the United Kingdom, the share of farm-saved seed in wheat increased from a low of 20 percent in the early 1990s to around 50 percent at time of writing (2012). It must also be noted that wheat is a self-pollinated crop and there has been almost no introduction of commercial hybrids in wheat.

Developing countries

As discussed in Section 2.5, it has been estimated that nearly 80 percent of the wheat area in developing countries is covered with improved (semi-dwarf) varieties and that 62 percent of the area is devoted to varieties with CIMMYT germplasm. SRRs in developing countries are much lower than in developed countries. Data from India, which has a large commercial wheat seed production programme, suggest that SRRs range from 8–16 percent in different states. Five to ten percent SRR for wheat appears to be a reasonable estimate for developing countries, given available data. SRRs are likely to increase as many developing countries have sought to increase SRRs to increase agricultural productivity (e.g. India).

The simulation of potential voluntary payments under different scenarios (parameter values of SRR and area shares of varieties with CIMMYT ancestry) is presented in Figure 2.15. We assume that seed use in different categories will be proportional to the area share of those categories. We further assume that voluntary payments would be made at the same rate as mandatory payments (were they to apply) and that they are made by all participants in SMTAs. The average price of wheat seed has been estimated based on the average value of wheat seed imported into the United States in 2010 and the estimate of wheat prices in different countries estimated by CIMMYT.

Figure 2.15 Simulations of voluntary payments for wheat



Potential voluntary payment flows (@ of 1.1% less 30% of value of seed sales) in U$ million

	Area share of varieties with MLS material			
SRR	10%	20%	30%	40%
30%	0.65	1.29	1.94	2.59
40%	0.86	1.72	2.59	3.45
50%	1.08	2.16	3.23	4.31

Potential voluntary payment flows (@ of 1.1% less 30% of value of seed sales) in US$ million

	Area share of varieties with MLS material			
SRR	40%	50%	62%	70%
5%	1.66	2.08	2.58	2.91
10%	3.33	4.16	5.16	5.82
15%	4.99	6.24	7.73	8.73

The simulation results show that the potential for voluntary payments in developed countries ranges from $0.65–4.31 million; in developing countries, the potential ranges from $1.66–8.73 million. Although the share of varieties using CIMMYT material is very high in developing countries, the potential for voluntary payments is constrained by the persistence of low SRRs. The build-up of voluntary payments to the levels estimated above will depend on the policies adopted by public and private sector recipients of SMTA-PGR and on the time taken by post-Treaty varieties to become dominant in the market. The average survival duration of cereal varieties has been declining in developed countries with the average survival duration of cereal varieties in Europe being 6–8 years (ISF). However, the average age of varieties (weighted by area shares) in developing countries has been estimated at 10–15 years (Pingali, 1999). This implies that post-Treaty variety innovations will become dominant in seed use only over period of two decades or more.

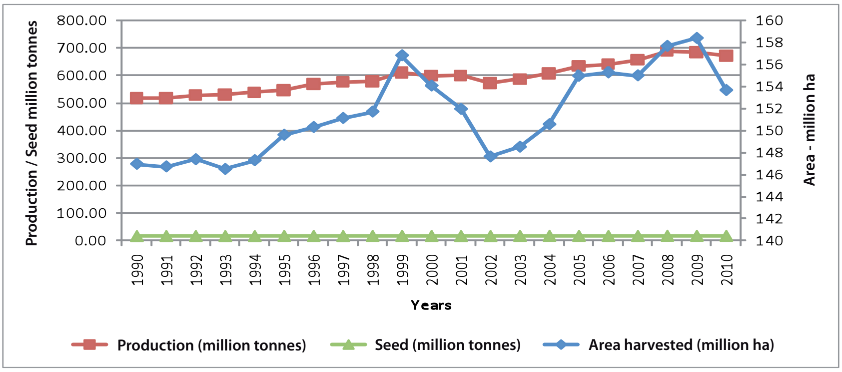
Potential voluntary payment flows (@ of 1.1% less 30% of value of seed sales) in US$ million				
	Area share of varieties with MLS material			
SRR	10%	20%	30%	40%
30%	0.65	1.29	1.94	2.59
40%	0.86	1.72	2.59	3.45
50%	1.08	2.16	3.23	4.31

This suggests that voluntary payments will build up to the levels estimated above only over an extended period of time.

2.8.3 Rice

Figure 2.16 shows the trends in global area, production and seed use for rice over the last two decades and Table 2.28 summarizes the share of the top 20 producers of rice in area and production for 2010.

Figure 2.16 Global trends in area, production and seed use in rice



Source: FAOSTAT.

Table 2.28 Top 20 rice producers, 2010 (share in area and production)

Country	Share in area (%)	Share in production (%)
China	19.6	29.3
India	24.0	17.9
Indonesia	8.6	9.9
Bangladesh	7.7	7.3
Viet Nam	4.9	6.0
Myanmar	5.2	4.9
Thailand	7.2	4.7
Philippines	2.8	2.3
Brazil	1.8	1.7
United States of America	1.0	1.6
Japan	1.1	1.6
Cambodia	1.8	1.2
Pakistan	1.5	1.1
Republic of Korea	0.6	0.9
Madagascar	0.9	0.7
Egypt	0.3	0.6
Sri Lanka	0.7	0.6
Nepal	1.0	0.6
Nigeria	1.2	0.5
Lao PDR	0.6	0.4
Total	**92.3**	**94.0**

Source: FAOSTAT.

In 2010, global rice area stood at 153 million ha and production at 672 million tonnes; the corresponding seed use was estimated at 17 million tonnes. The top 20 producers accounted for 94 percent of global production. Only two developed countries, the United States and Japan, are among the major rice producers – all other major rice producers are developing countries.

Developing countries

For rice, we propose to use the area share of varieties having IRRI lines in their ancestry as a proxy for the share of varieties incorporating MLS material. The data for rice examined in Section 2.5 suggest that nearly 75 percent of the area in developing countries is planted to modern or improved varieties. The data also suggest that IRRI's contribution to the rice varieties in South and Southeast Asia was approximately 70–80 percent, but has now declined to around 35–40 percent. This decline has been attributed to the increasing maturity of national plant breeding programmes in these countries as they become more competent in making their own crosses from IRRI material. However, the increasing generational distance between IRRI material and the final products (varieties) makes no difference to the magnitude of voluntary/mandatory payments called for, as these are related to the use of SMTA material (no matter how far back in the breeding cycle) in the new varieties developed. Therefore, the estimate of 50 percent of the area being devoted to IRRI-linked varieties in countries such as Viet Nam, Philippines and Indonesia appears to be a plausible estimate of the area share of varieties incorporating MLS material. Another important development has been the emergence of hybrid rice varieties, which has also been supported by IRRI and has seen the private sector play an important role in many countries.[25] It is estimated that there are nearly 20 million ha under hybrid rice in China and less than 10 million ha in all other countries. Hybrid rice varieties have a 100 percent SRR and seed prices may be up to eight times the price of conventional seed in rice. However, we have excluded hybrid rice from the analysis because there is no information available on the area share of IRRI linked hybrid rice varieties. China is reported to have used little of IRRI germplasm in its hybrid rice programme, and in other south and southeast Asian countries (where IRRI's contribution is likely to have been substantial), the total area under hybrids is relatively limited.[26]

SRRs for rice are generally believed to be low because of the feasibility and well-established practice of using farm-saved seed. However, some studies have suggested that SRRs average 25 percent in India with the rates going up to 50 percent in some rice producing states (Rao, 2010). SRRs for rice have been estimated at 10 percent (SAT, 2007) and around 15 percent for Viet Nam (Giao, 2009),although the rates are said to be increasing. Therefore, we use a range of 10–25 percent for SRRs in our simulations.

Developed countries

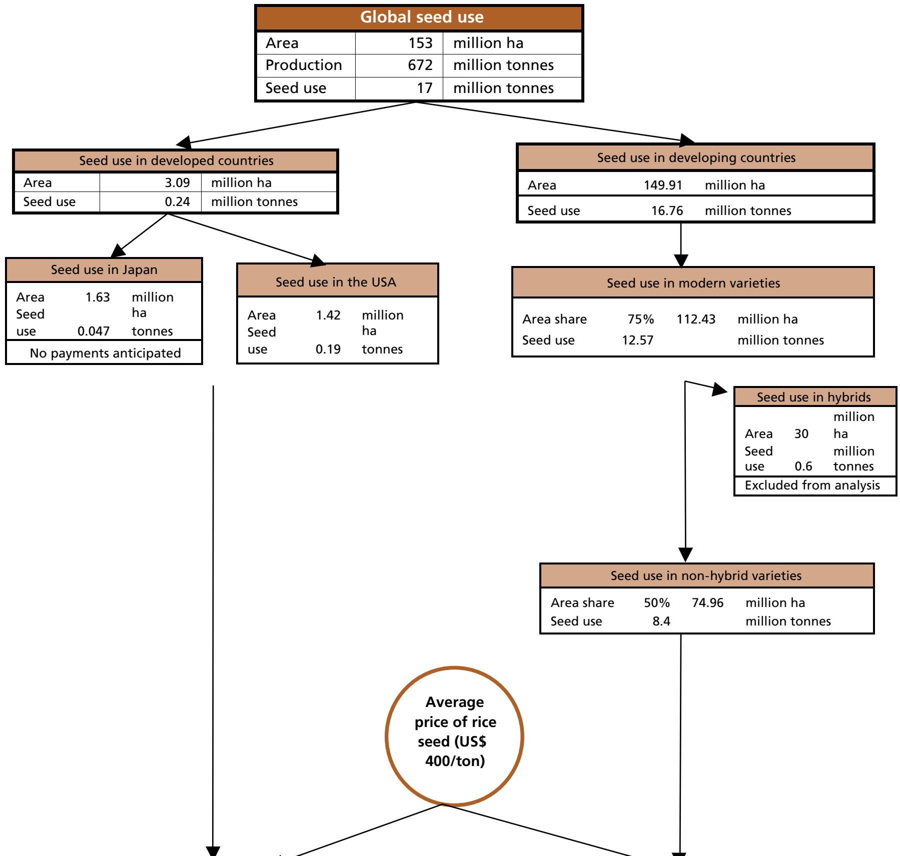
Among developed countries, Japan is a centre of diversity for rice and also has a long tradition of rice research. Although Japan has been the main source of financial support for IRRI and has contributed its scientific expertise for IRRI programmes, there appears to be no evidence of significant use of MLS material in the development of Japanese rice varieties. The United State, on the other hand, is not a centre of diversity for rice. The cultivation of rice in the United States is mainly geared towards exports with nearly half of the output being exported (Childs and Burdett, 2000). Rice breeding in the United States has been confined mainly to the private sector, but the private sector's reliance on foreign germplasm is likely to have been substantial, with the MLS being the main source of PGR. Given the export orientation of the United States rice industry, we assume that the share of area devoted to varieties with MLS linkages in the United States will be similar to that in developing countries.

[25] Although the private sector appears to be playing a significant role in the development of hybrid varieties in many countries, it relies mainly on the MLS as a source of PGR.

[26] Available at: www.irri.org/partnerships/country-relations/asia-oceania/china/rice-research-and-capacity-building-in-china

The simulation of potential voluntary payments under different scenarios is presented in Figure 2.17. We assume that seed use in different categories will be proportional to the area share of those categories. The value of seed has been derived using the average seed rice seed prices in Viet Nam and Thailand.[27] Again, we assume that voluntary payments

Figure 2.17 Simulations of voluntary payments for rice



Potential voluntary payment flows (@ of 1.1% less 30% of value of seed sales) in US$ million

	Area share of varieties with MLS material			
SRR	30%	40%	50%	60%
30%	0.05	0.07	0.09	0.11
40%	0.07	0.09	0.12	0.14
50%	0.09	0.12	0.15	0.18

Potential voluntary payment flows (@ of 1.1% less 30% of value of seed sales) in US$ million

	Area share of varieties with MLS material			
SRR	30%	40%	50%	60%
10%	1.55	2.06	2.58	3.10
15%	2.32	3.10	3.87	4.65
25%	3.87	5.16	6.45	7.74

27 Available at: www.oryza.com/content/oryza-rice-recap-vampire-squid-gets-downgraded-rice-and-other-markets-rally-central-bank

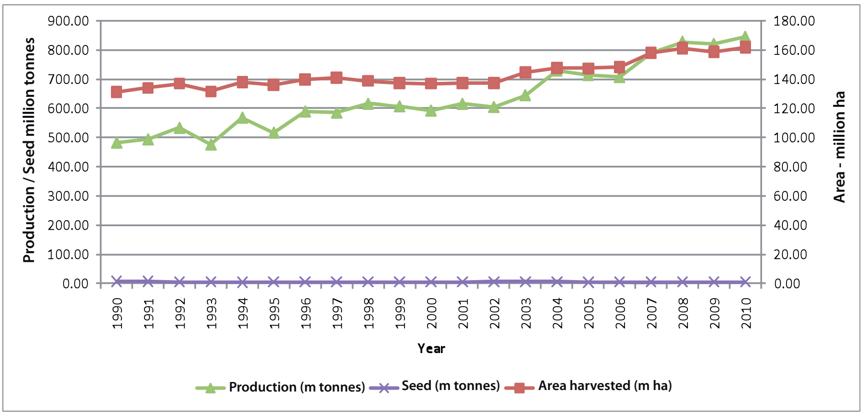
will be made at the same rate as mandatory payments, should they apply, by all recipients of SMTA-PGR.

The potential for voluntary payments from developed country rice varieties appears to be insignificant. In developing countries, the potential for voluntary payments ranges from $1.55–7.74 million for non-hybrid rice varieties incorporating material from the MLS. The expansion of hybrid rice in countries outside China through varieties developed with the use of MLS material appears to be the most promising avenue for voluntary payments in rice, although it must be noted that the expansion of hybrid rice in both China and South and Southeast Asian countries has slowed down over the last decade.

2.8.4 Maize

Figure 2.18 shows the trends in global area, production and seed use for maize over the last two decades. The top 20 producers of maize and their share in area and production are presented in Table 2.29.

Figure 2.18 Global trends in area, production and seed use in maize



Source: FAOSTAT.

Table 2.29 Top 20 maize producers, 2010

Country	Share in area (%)	Share in production (%)
USA	20.4	37.4
China	20.1	21.0
Brazil	7.9	6.6
Mexico	4.4	2.8
Argentina	1.8	2.7
Indonesia	2.6	2.2
India	4.4	1.7
France	1.0	1.7
South Africa	1.7	1.5
Ukraine	1.6	1.4
Canada	0.7	1.4
Romania	1.3	1.1
Italy	0.6	1.0
Nigeria	2.1	0.9
Serbia	0.8	0.9
Egypt	0.6	0.8
Hungary	0.7	0.8
Philippines	1.5	0.8
Viet Nam	0.7	0.5
Tanzania	1.9	0.5
Total	**76.7**	**87.7**

Source: FAOSTAT

In 2010, the global maize area stood at 162 million ha and production at 844 million tonnes. The corresponding seed use was estimated at 5.71 million tonnes. The United States is the largest producer of maize, accounting for 37 percent of global production with 20 percent of the area. Developed countries account for only 23 percent of the global area but produce 43 percent of the output, while developing countries with 77 percent of the total area account for 57 percent of the total output.

For maize, we propose to use the share of varieties having CIMMYT lines in their ancestry as a proxy for the share of varieties incorporating MLS material. An important factor influencing the assessment of potential voluntary payments in maize is the significant share (26 percent) of transgenic maize in the global maize area. As already discussed, transgenic (GM) varieties are invariably protected by patents rather than PVP. Consequently, transgenic varieties are likely to give rise to mandatory payments and are therefore excluded from this analysis of voluntary payments. Out of the 162 million ha of the total area under maize, nearly 42 million ha is estimated to be under GM maize, of which 31 million ha is estimated to be in developed countries with the rest spread over developing countries.

Developed countries

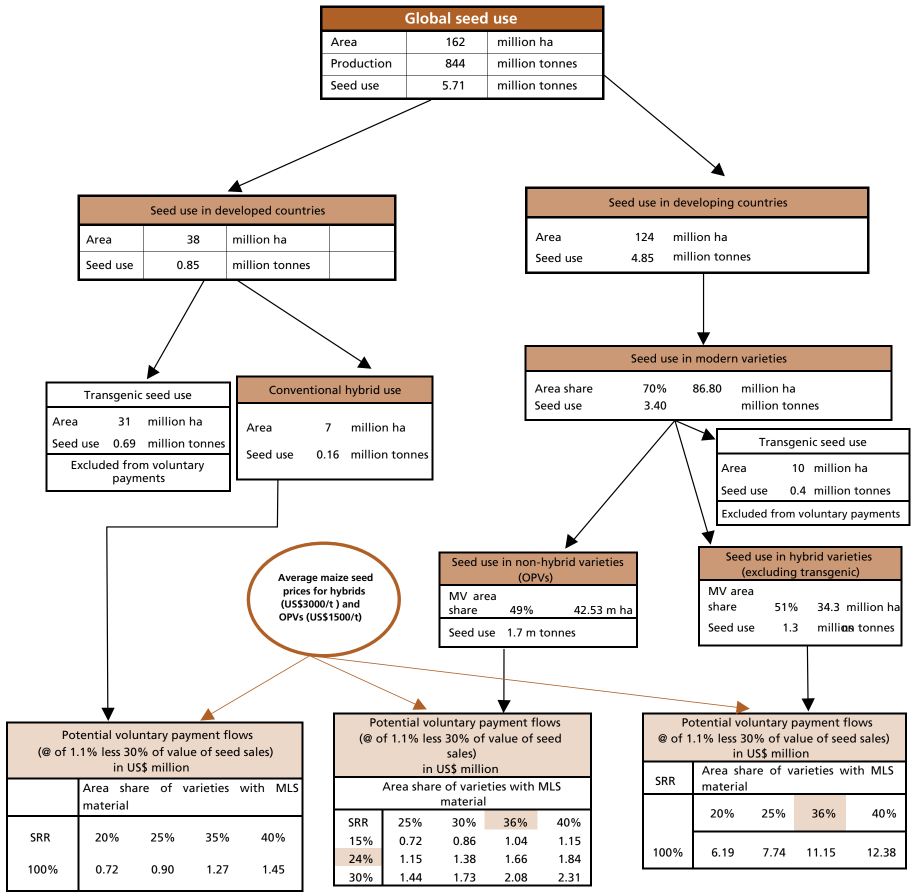
Once GM varieties are excluded, the rest of the area in developed countries is dominated by hybrid varieties, especially in the United States, where hybrids account for 90 percent or more of the non-GM area. We do not have data on the relative shares of hybrids and OPVs, and for the purpose of this simulation assume that the entire non-GM maize area in developed countries is accounted for by hybrids, necessitating an SRR of 100. Based on the data examined in Section 2.5, it is estimated that the total area planted to CIMMYT varieties is approximately 36 percent. Due to CIMMYT's mandate to serve developing countries, it has focused on non-temperate maize growing regions rather than on the temperate maize growing area predominant in the developed world. We therefore expect the share of varieties with CIMMYT germplasm to be lower in developed countries, although there is evidence of fairly extensive use of CIMMYT germplasm in the United States by private breeding programmes (Pardey, 1996).

Developing countries

In developing countries, the share of area under improved varieties was estimated at 62 percent in the late 1990s (Evenson and Gollin, 2002) and has been steadily increasing. However, OPVs are still in extensive use in developing countries. Based on previous assessments by the CGIAR (CIMMYT), we assume that the share of hybrids in the modern variety (MV) area to be 51 percent and the share of OPVs to be 49 percent. For OPVs, SRRs are estimated on average to be 24 percent (Evenson and Gollin, 2002). For developing countries, we use CIMMYT's estimate of 36 percent of the area planted to varieties with CIMMYT germplasm in the late 1990s as a reasonably conservative estimate of the present position.

The simulation of potential voluntary payments under different scenarios is presented in Figure 2.19. We assume that seed use in different categories will be proportional to the area share of those categories. We make similar assumptions about voluntary payments by recipients of SMTA-PGR as were made in the case of wheat and rice. To derive the value of maize seed, we have used the average prices of maize seed exported by the United States in 2010 – $3 000/tonne for hybrids with OPV prices estimated at 50 percent of the cost of hybrids.

Figure 2.19 Simulations of voluntary payments for maize



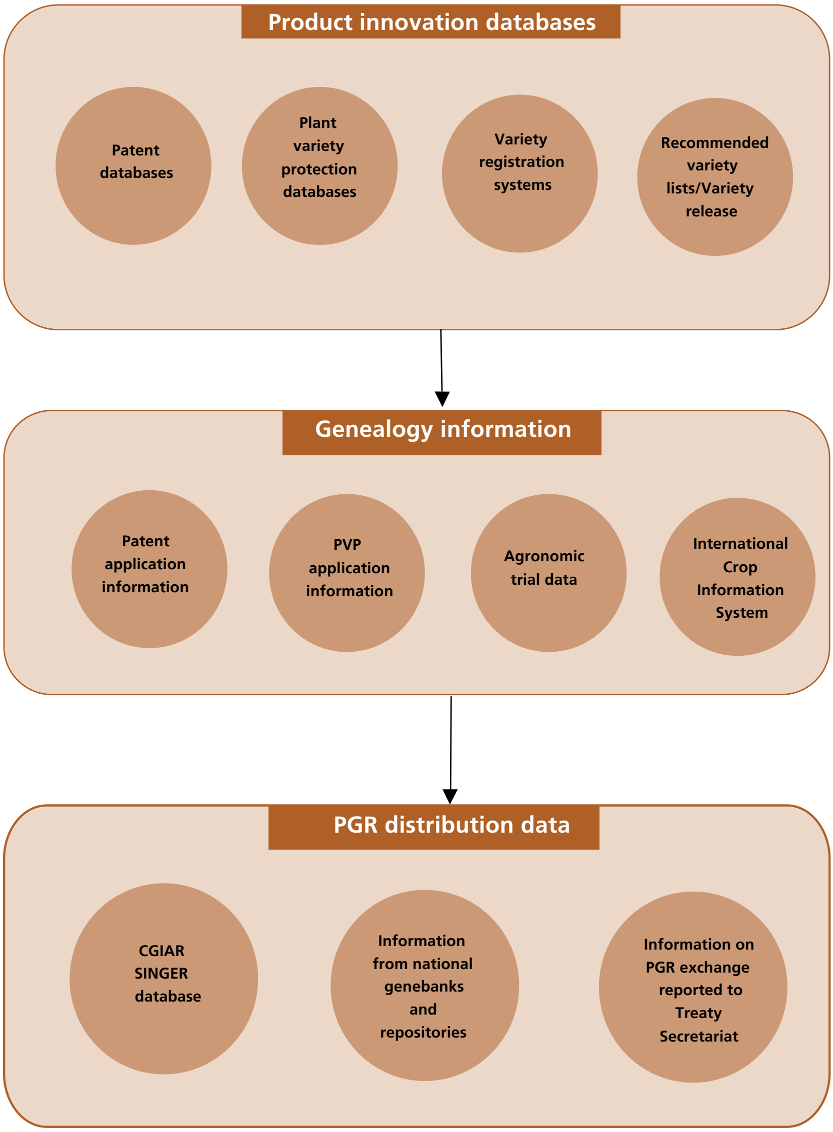
The simulation shows that potential voluntary payments in developed countries range from $0.72–1.45 million. The low magnitude of these payments is mainly due to the increasing area share of transgenic varieties and the lower contribution of CIMMYT germplasm to temperate zone maize. In developing countries, the potential for voluntary payments from OPVs (non-hybrids) ranges from $0.72–2.31 million. The magnitude of potential payments is constrained by the low SRRs and the lower price of OPV seeds. The potential for voluntary payments in respect of hybrids ($6.19 –12.38 million) is much greater in relation to OPVs and also in relation to other crops because of the large share of hybrids (which call for 100 percent SRR) and the much higher price of maize hybrids compared to seeds of other crops.

2.9 Methodologies for assessing MLS-PGR use in product innovations

The methodology adopted in the previous sections to assess the potential for benefit-sharing payments is useful only for estimating the broad orders of magnitude of these payments based on historical patterns of PGR usage under 'open-access' free-exchange regimes. An accurate assessment of the use of SMTA-PGR in product innovations requires linking individual PGR exchanges to specific final product innovations. Such an exercise would be incredibly complex and would pose formidable data challenges. This is because PGR exchanges involve a complex chain of transactions as materials move across institutions and countries. The eventual use of SMTA-PGR in the development of a new variety may take place at a point in the chain that is quite distant from the original recipient of PGR. The provisions of SMTAs require that the transfer of PGR beyond the first recipient also be subject to SMTAs and to be reported to the Treaty Secretariat. It may, therefore, be theoretically feasible to build up a picture of the transaction chains of PGR over time, if reporting requirements are complied with by all parties involved in such exchanges. However, the lead times from the initial distribution of PGR under SMTAs and their incorporation in a product innovation may be very long. More importantly, SMTA-PGR will be subject to extensive transformation since it is used in the breeding process by different institutions. Tracking the movement and use of SMTA-PGR is much more difficult when it occurs through the exchange of improved material *derived from* SMTA-PGR (rather than the exchange of the SMTA-PGR). In practice, tracing the use of SMTA-PGR by following the trail of exchanges may be unfeasible. A more pragmatic approach to assessing the use of SMTA-PGR may be to start with the identification product innovations (that may potentially involve the use of SMTA-PGR), identify the source of PGR used in these innovations, and link them through breeding histories and genealogy information to PGR exchanged under SMTAs. Such an approach would require bringing together product innovation databases, genealogy databases (and breeding histories) and information on SMTA-PGR exchanges, and linking them through suitably designed search algorithms to identify the use of SMTA-PGR in product innovations. This could be labelled as an informatics approach because it involves the coordinated use and mining of multiple databases.

Figure 2.20 describes the principal components of an informatics-based approach for the identification of the use of SMTA-PGR in product innovations. For the purpose of benefit-sharing payments under SMTAs, the relevant product innovations (i.e. innovations that are themselves in the nature of PGR) are principally new varieties of plants of Annex 1 crops with potential for commercialization. Intermediate innovations (e.g. improved breeding lines) would not generally give rise to any payments except where they are subject to protection and commercially exploited. In developed countries, the application of some form of IPRs to plant variety innovations is almost universal. IPR databases can serve as authentic sources of information on plant variety innovations intended for commercialization. In developing countries, the application of IPRs to plant variety innovations is still limited in spite of the extension of PVP regimes to these countries following the provisions of the TRIPs Agreement. The identification of product innovations in developing countries may require reliance on other types of data sources. Building a picture of product innovations at the global level would require the use of different types of data sources; the principal ones are discussed below.

Figure 2.20 Informatics-based approaches for identifying the use of SMTA-PGR in product innovations



1. *Patent databases:* At present, patents can be applied to plant variety innovations only in a limited number of countries (which include the United States, Australia, Japan and Republic of Korea). Even in these countries, patents are applied mainly to plant variety innovations developed through the application of biotechnology (e.g. GM varieties) since only these varieties can meet the patentability criteria, which are more stringent than the distinctness, uniformity and stability (DUS) criteria required for PVP (see below). Although the number of patent-protected innovations is small in relation to the total number of plant variety innovations, they are commercially important because of the rapid growth of the global area under GM varieties and their share of global commercial seed market. It is only patented varieties that give rise to mandatory payments into the Benefit-sharing Fund. The application of patents to new plant varieties generally precludes the use of farm-saved seed by farmers. Therefore, patent protected varieties are likely to give rise to higher volumes of seed sales and consequently higher flows of mandatory payments compared to varieties protected by PVP. Since patents are mostly national[28] in scope, patents have to be applied for and obtained separately in each country where protection is sought. International Patent Conventions (e.g. the Paris Convention) and the TRIPs Agreement have sought to harmonize patent legislation across countries through uniform standards of protection. They have also sought to facilitate multi-country protection of innovations, through provisions such as 'national treatment'[29] and 'right of priority'.[30] Uniform systems for the classification of patents (e.g. the International Patent Classification, or IPC) have also been developed to facilitate comparisons of patenting activity and data across countries. There are now a number of global patent databases that bring together patent information from a large number of countries. These databases provide information on millions of patents granted in different countries. The main challenge in using global patent databases to identify patent-protected plant variety innovations is that these innovations have to be located within specific patent classification categories that include other (non-PGR-related) innovations. Existing patent classification categories are not adapted or designed for the identification of plant variety innovations relevant to the Treaty. The identification of plant variety innovations within global patent databases requires complex algorithms (or rules for searching) to first identify patent classes and sub-classes within which such innovations may be found, and then to search within these classes to locate innovations of interest.

2. *Plant Variety Protection (PVP) databases*: PVP is a system of intellectual property rights applied to plant variety innovations that is distinct from the patent system with its criteria of 'novelty, inventiveness and industrial application' and instead is based on the criteria of 'distinctness, uniformity and stability'. In most developed countries, PVP

28 Europe-wide patents are issued by the European Patent Office under the European Patent Convention.

29 'National treatment' requires countries to provide foreign applicants for protection the same treatment as is afforded to nationals.

30 When an application is made for patent protection of an innovation in one country, the applicant is afforded the priority for seeking protection in other countries for a certain length of time.

systems have been in existence for the last three to four decades, and the protection of new plant varieties through PVP is almost universal. The TRIPs Agreement requires all member-countries of the WTO to put in place some form of IPRs for plant variety innovations. While many developing countries have introduced/implemented PVP legislation or are in the process of doing so, the application of PVP to plant variety innovations is still quite limited in developing countries. UPOV seeks to harmonize protection by providing uniform standards of protection and has currently more than 60 countries as members. UPOV also facilitates the multi-country protection of plant variety innovations through 'national treatment' and 'right of priority' provisions. Moreover, it also provides for rules relating to variety denominations that require a new plant variety to be protected under the same denomination in all UPOV member countries and for this denomination to be maintained even after expiry of protection. Information on PVP applications and grants is published by national PVP authorities. UPOV has also developed a plant variety database that brings together information on PVP applications and grants in all member-countries. PVP databases are authentic sources of information on plant variety innovations with potential for commercialization.[31]

3. *Variety registration systems*: Many countries in the developed and developing world use variety registration systems to regulate the marketing of plant varieties. Registration of a variety in a national register (or 'inscription' in a national list) may be a prerequisite for commercial marketing of a variety. Registration of a variety may require testing of a variety for 'distinctness, uniformity and stability' or for 'value in cultivation and use' (VCU) or may require information to be furnished on the characteristics and claimed performance of a variety. Registration may also serve to bring a variety within the purview of quality control regulations. In the EU, only varieties that are inscripted in the EU Common Catalogue of Varieties[32] (for cereal and vegetable crops) can be commercially marketed. Registration of varieties may be mandatory or optional. However, registration systems do provide authentic information on plant varieties that are eligible to be marketed commercially. An advantage of using variety registration systems as source of information on product innovations is that they include both protected and non-protected varieties.

4. *Variety release systems or lists of recommended varieties*: Most developing countries (including those that do not have a variety registration system) have variety release procedures under which new varieties developed by public or private research institutions are evaluated for their performance and recommended to farmers for adoption. Variety recommendations may be tailored to different agro-climatic environments or use of final product (e.g. use of wheat for bread making or animal feed). Recommended lists of varieties are developed on the basis of several rounds of

[31] Some PVP systems permit protection of parental lines that could be used in the development of 'final' product innovations.

[32] The EU Common Catalogue is based on the national lists of member countries of the EU.

agronomic trials of candidate varieties. Recommended lists of varieties are also used in many developing countries. These recommended lists are again an authentic source of information on new varieties with commercial potential.

Obtaining an overview of plant variety innovation at the global level will require the systematic exploration of a range of databases and sources information that vary considerably in terms of their design, content and coverage of plant variety innovations of interest.

Once product innovations with possible linkages to SMTA-PGR are identified, the second step would be to identify the source of PGR used in the development of these innovations and their breeding histories. Information on the sources of PGR and genealogy varies considerably across the product innovation databases discussed above. In the case of patent applications, the kind of information and the level of detail provided in patent applications are different in different jurisdictions. However, patent applications generally need to comply with a 'disclosure' requirement, that is, they are expected to acknowledge the 'prior art' (or previous inventions) on which the invention/innovation relies and provide a sufficiently detailed description of the innovation for a 'person skilled in the art' to reproduce the invention. In the case of plant variety innovations, this generally implies that the patent application needs to provide details of how the new variety was bred and the parental material that was used in its development, although there is no obligation to reveal the source of the parental material. For plant variety innovations, the requirement for disclosure of parental material can be met by depositing a sample of the seeds of the parental material in a designated national depository. Since there are no regulations governing the nomenclature to be used for descriptions of parental material, it is possible for applicants to comply with the disclosure requirement (through a deposit) without revealing much information on the parental material used and the sources from which they were obtained. The information provided in the patent application may be only a starting point for exploring the type of PGR used in the final product. To understand the nature and sources of parental material used in a product innovation, it may be necessary to link the information in the patent application with references to the same material in other patent applications, going back over time. As SMTA-PGR are not assigned any standard codes or descriptions, it may not be feasible to identify their use in protected plant variety innovations through data mining of patent databases, except through the use of highly complex search algorithms.

The disclosure of the pedigree of a variety and the source of parental material is generally not obligatory for PVP; however, PVP applications in many countries require information to be furnished on the parentage of the variety. In some countries, such as the United States), fairly detailed breeding histories are provided together with PVP applications that may allow identification of the ancestral material used in the breeding process over several cycles. However, it must be noted that even in the case of PVP, the disclosure requirement can be met by a deposit of the seeds of the variety (and/or its parental varieties). Data mining of PVP databases may also not provide much information regarding the use of SMTA-PGR in plant variety innovations.

Variety registration systems are oriented to regulating the commercial marketing of varieties. Although variety registration may be preceded by testing for 'distinctness, uniformity and stability' and for 'value in cultivation and use', they may provide little or no information on the pedigree of the registered varieties. Recommended lists of varieties that are based on agronomic trials of candidate varieties against benchmark or control varieties provide information on the immediate parents of the recommended varieties. However, information on immediate parents alone is unlikely to be adequate for assessing the use of SMTA-PGR in the development of a new variety. Product innovation databases, therefore, provide very limited information on the pedigree of new varieties. Information on the immediate parents used in the development of a variety, even if available, will generally be insufficient to assess the use of SMTA-PGR in the development of innovations.

Linking product innovations to the exchanges of SMTA-PGR requires extensive information on breeding histories and pedigrees of new plant varieties going back several generations. Pedigrees of new varieties developed by private sector institutions are often 'closed'–i.e. they are not disclosed on account of commercial sensitivity of the information. Pedigree information on varieties developed by public research institutions may be more accessible, but much of the information may be available within individual plant breeding programmes or institutions, and may not be organized in systematic databases. The International Crop Information System (ICIS) developed by CGIAR institutions is one of the few PGR databases in the public domain that provides pedigree information on varieties going back several generations. The crops currently covered by ICIS include wheat, rice, maize, sorghum, groundnuts, cassava, beans, cowpeas and chickpeas, and although it is not exclusively confined to them, ICIS focuses on varieties in developing countries where CGIAR has undertaken collaborative work. It is a germplasm management system with information on the characteristics and source (country) of origin of PGR, whose genealogy module allows pedigrees of varieties to be traced back to as many generations as the available data will allow. The coverage of varieties is extensive for wheat, rice and maize, and pedigrees can be expanded to ten or more generations. It has a flexible structure that allows individual countries or plant breeding programmes to add pedigree information on local varieties in local databases to supplement the variety data contained in the core central databases for each crop. While the coverage of material produced by CGIAR breeding programmes is very good, its main limitations are that the coverage of varieties varies across developing countries due to data availability constraints, and that the coverage of private sector varieties is limited. Pedigree information on private sector varieties is often not available in the ICIS or is very limited. If systematic effort is made by the CGIAR in collaboration with the NARS and the private seed industry to provide comprehensive coverage of both public and private sector varieties, then the ICIS could serve as a very powerful instrument to understand the use of SMTA-PGR in the development of new varieties. Modern varieties have complex pedigrees, and it is only when their pedigrees are expanded to ten or more generations that it will be possible to identify possible uses of SMTA-PGR. As a result of the comprehensive coverage of varieties in the ICIS, the genealogy of plant variety innovations identified from the product innovation databases can be examined in detail to assess the extent of use of PGR from different sources, including PGR exchanged under SMTAs.

The third step in the assessment of the use of SMTA-PGR in product innovations would be to link the PGR identified as constituents of new varieties to specific exchanges of

PGRs under SMTAs. The distribution of PGR under SMTAs from CGIAR gene banks is well documented under the System-wide Information Network for Genetic Resources (SINGER). However, distribution of PGR from national gene banks and repositories is generally not well documented, especially in developing countries. PGR exchanges subject to SMTAs have to be reported to the Treaty Secretariat, and this obligation extends beyond the original recipient of the material to all recipients of the material in a chain of transactions. If reporting requirements are complied with by all recipients of SMTA-PGR, then over time the Treaty Secretariat will have the information required to obtain an accurate overview of SMTA-PGR flows across different institutions and countries. Information provided to the Treaty Secretariat by transacting parties is confidential and is not made available in the public domain. It will therefore be necessary to examine whether transaction information (suitably anonymized and aggregated) could be made available for analytical purposes, i.e. for understanding the use of SMTA-PGR in product innovations. The analysis would attempt to relate the volume of PGR exchanges under SMTAs to the frequency of their occurrence in genealogy of product innovations, and would not be intended to assess how PGR exchanged in individual transactions has been used.

The coordinated use of product innovation, genealogy and PGR distribution databases to assess the use of SMTA-PGR in the development of product innovations requires the building up of technical expertise and institutional capacity in the Treaty Secretariat. This would require significant informatics capabilities to search and mine very large, complex databases using complex algorithms. It would require substantial investment in creating an institutional mechanism for assembling and updating data from highly diverse sources with the cooperation of member countries. International effort to update and expand the coverage of public domain genealogy databases such as the ICIS would be a critical pre-requisite for the successful application of informatics-based approaches. The feasibility of applying the informatics-based approaches would dramatically improve if: (i) IPR applications for plant variety innovations (whether for patents or PVP) are required to provide information on the source of parental material used in an innovation, or if IPR regulations are amended to make it mandatory for applicants to acknowledge the use of SMTA-PGR in IPR applications for product innovations; and (ii) a standardized system of nomenclature or coding is developed and applied for all MLS-PGR exchanged via both international and national gene banks and repositories. The experimental application of the above-described approach to patent databases (for identification of plant variety innovations of interest) is developed in Chapter 4. This chapter illustrates the scale and complexity of the application of informatics based approaches for assessing the use of PGR exchanged under SMTAs in product innovations.

2.10 Summary and conclusions

This Chapter has developed a framework for the empirical assessment of the potential flow of mandatory and voluntary payments arising from the SMTA-mediated exchange of PGR under the Treaty's Multilateral System. The conceptual framework used for this assessment principally views PGR in the MLS as a resource for innovation in plant breeding. It is the utilization of this resource in the innovation process that generates the flow of payments into the Benefit-sharing Fund. Factors influencing the demand for PGR from the MLS for any crop in the innovation process include the research intensity of the crop, the importance of PGR in the MLS in relation to the overall agro-biodiversity of that crop, and the commercial potential of the new plant varieties that may emerge from the innovation process. The utilization of PGR from the MLS in the innovation process is influenced by the institutional arrangements governing access and exchange of material, and the appropriation of value from innovations. The magnitude of potential benefit-sharing payments, therefore, depends on the commercial value of innovations supported by exchange of PGR in the MLS and the efficacy of the institutional mechanisms put in place by the Treaty for appropriating a portion of the commercial value of innovations to the Benefit-sharing Fund.

An accurate empirical assessment of the utilization of PGR from the MLS in the development of product innovations would be an exercise of considerable complexity as PGR exchanges proceed through a complex maze of transactions across institutions and countries. The eventual use of PGR exchanged under SMTAs in a final product innovation may occur at a point far removed from the first recipient of the material. Further, PGR exchanged under SMTAs may be subject to transformation through several rounds of breeding before they are incorporated in a final product. Information on PGR flows within and across national boundaries and their use in long breeding cycles of crop improvement are extremely limited. Empirical assessment of the contribution of PGR exchanged under SMTAs requires identification of product innovations taking place in different parts of the world and linking them to the exchange of PGR through the use of genealogy information or detailed breeding histories. An outline is provided below of the informatics-based approaches that could be used to bring together product innovation databases, genealogy databases and information on the distribution/exchanges for such an empirical assessment. These approaches are tested in Chapter 4. The development and application of these informatics-based approaches may be feasible only over the long term. Given that PGR has been exchanged under SMTAs for only six years and given the length of the breeding cycle for modern plant varieties, it may be early to make the linkage between the exchange of PGR and the commercialization of product innovations using the informatics-based approaches.

Keeping in view the information and data-related constraints, and the infeasibility of applying informatics-based approaches described above, an alternative methodology has been used to assess the potential magnitude of benefit-sharing payments that does not rely on the linkages between individual exchange transactions of PGR and product development. This methodology has been applied to three major food crops, wheat, rice and maize, which account for nearly 40 percent of the global commercial seed market value. This approach attempts to estimate the proportion of the value of the global seed market that could be attributed to product innovations incorporating PGR exchanged under SMTAs. The proxy measure used to estimate the proportion is the value share in the commercial seed market of varieties incorporating material developed by CGIAR institutions. Value shares are derived from estimates of area shares of varieties incorporating CGIAR-linked germplasm. Over the last four decades, PGR stored in CGIAR gene banks and materials developed by CGIAR breeding programmes have been freely exchanged and made available to public and private sector breeding programmes under arrangements that are substantially similar to those envisaged under the MLS. The use of material developed and distributed by the CGIAR in varietal development for different crops can, therefore, provide a reasonable indicator of the potential use of PGR exchanged under SMTAs over time. The critical assumption in this approach is that the patterns of use of PGR exchanged under SMTAs in the future will be similar to patterns of use of PGR from 'open-access' systems observed in the past. This assumption may hold only if: (i) plant breeding programmes, especially those in the private sector, do not resort to the use of strategies avoiding the use of MLS material in their programmes, deterred by the prospect of benefit-sharing payments; (ii) the need for plant breeding programmes to access the MLS has not been significantly reduced by the exchanges over the last four decades; and (iii) the MLS remains the principal sources of PGR and associated information for dealing with the emerging challenges faced by plant breeding programmes for Annex 1 crops and is not supplanted by alternative sources of access to PGR.[33]

Our analysis shows that the potential for mandatory and voluntary payments arising from the exchange of PGR under SMTAs is influenced by certain key factors, which include the following:

(a) *The coverage of crops under Annex 1 of the Treaty*: The share of Annex 1 crops in PGR-related innovation has been declining over time. This is reflected in the declining relative research intensity of Annex 1 crops over the last three decades. Non-Annex 1 crops are attracting an increasing share of the total research effort. But innovation in these crops and growth in their seed market value will not translate into any payments into the Benefit-sharing Fund. Crops such as soybean and cotton, which are excluded from Annex 1, are making a significant contribution to the value of the global commercial seed market and its growth. The exclusion of these high-growth segments from the purview of the Treaty constrains the potential growth of benefit-sharing payments.

(b) *Biotechnology-based innovations*: GM varieties are the fastest growing segments of the global commercial seed market. GM varieties are also predominantly protected by patents and would give rise to mandatory payments if they were

[33] Alternative avenues of access (e.g. through bilateral arrangements or contracts) will be increasingly constrained by high transaction costs and the emergence of CBD-compliant biodiversity legislation in many countries, highlighting the advantages of facilitated access provided by the MLS.

to incorporate PGR exchanged under SMTAs. However, maize and canola are the only two Annex 1 crops that have been subject to significant genetic modification activity. Two crops, soybean and cotton, where GM varieties have seen spectacular growth in adoption and area are not included in Annex 1. The present coverage of crops in Annex 1 restricts the potential for payments from innovations involving genetic modification or application of biotechnology.

(c) *The application of IPRs to plant variety innovations*: Mandatory payments into the Benefit-sharing Fund arise only when innovations incorporating PGR exchanged under SMTAs are protected by patents. Patents for plant variety innovations are currently available only in a limited number of countries and are mostly applied only to GM varieties. Plant variety innovations in most developed countries are predominantly protected by PVP (and not by patents), while most innovations in developing countries may not be subject to any form of protection. The vast majority of plant variety innovations at the global level do not attract any mandatory payment obligations. Thus, the potential for mandatory payments is severely constrained by the fact that only a very small proportion of global plant variety innovations attract such payments. The potential for mandatory payments will remain unaffected by the extension of PVP systems to developing countries under the provisions of the TRIPS Agreement.

(d) *Seed replacement rates*: Seed replacement rates continue to be low in developing countries with commercial seed use on average accounting for less than 15–20 percent of total seed use. Low SRRs constrain the growth potential of benefit-sharing payments since they are related to the value of the *commercial* seed market. The use of farm-saved seed of varieties incorporating PGR exchanged under SMTAs gives rise to no benefit-sharing payment flows.

Taking into account the key factors that constrain the potential for benefit-sharing payments, the application of the methodology outlined above yields 'upper-bound' estimates of mandatory and voluntary payments of around $100 million per year. It must be clearly understood that this figure is not an estimate of the level of payments that can be expected in the immediate future; the figure of $100 million is the estimated level of annual payments that could be reached over the next two to three decades. It should also be emphasized that this estimate is based on the assumption that voluntary payments are made by all recipients of PGR exchanged under SMTAs (as per the Treaty) at the *same rate* as prescribed for mandatory payments. This estimate is therefore based on 100 percent compliance with voluntary payment stipulations, which is why it is called an 'upper-bound' estimate. A high degree of compliance with voluntary payment stipulations would need to be supported by improved information on international PGR flows and their use in plant breeding programmes in different countries. The estimate further assumes that institutional plant breeding programmes do not resort to breeding strategies deliberately avoiding the use of MLS material. The anticipated payments of $100 million include mandatory payments of $3.85–9.7 million from GM varieties of maize (mandatory payments being anticipated only from GM varieties of maize and canola). Voluntary payments for wheat varieties range from \$2.31–13.04 million; for rice, from \$1.55–7.74 million; and for maize, from \$7.63–16.14 million. There are significant differences between the potential for benefit-sharing payments between developed and developing countries mainly due to the differences in the adoption of modern varieties and in seed replacement rates. This analysis has assumed that the PGR resource base in the MLS is largely static. Expansion of the resource base through improved PGR collection, conservation and characterization efforts, and effective participation in the MLS by member countries and of more countries in the Treaty – especially those with major PGR holdings such as China and the United States – may substantially enhance the anticipated level of benefit-sharing flows.

Chapter 3

MODELLING PAYMENTS TO THE BENEFIT-SHARING FUND

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"Essentially, all models are wrong, but some are useful."
– George E.P. Box, FRS (1919–2013)[1]

3.1 Introduction to the model

To date, no methodology has been proposed to provide a projection – even preliminary – of what monies are likely to result from the exchange of PGR for food and agriculture under the SMTA of the Multilateral System of Access of the Treaty, and when these monies may become available. The broader picture of possible income for the Benefit-sharing Fund under the SMTA is therefore still very unclear. This chapter will address the challenge an algorithm and model in this chapter.

3.1.1 Objectives of the model

The first objective is to provide the best possible immediate estimate of income to the Treaty, over time, from the workings of the SMTA, despite the extremely deficient information currently available. In this first iteration of the model, the chief aims are to propose a framework methodology and proof of concept, and evaluate data sources. The model is of necessity schematic, and capable of considerable further refinement.

The second objective is to describe the process of producing commercial products from materials accessed under an SMTA, in terms of an algorithm, the factors of which can be varied, so as to test a number of possible scenarios. Given data uncertainties, parsimony in the number of factors used is a deliberate aim of the model. A minimum set of factors that appear to have a substantial influence on this process may then be manipulated mathematically, in particular by varying a single factor, the other factors being held constant. In this way, the model serves as a 'tool to think with'.

The objectives of the scenarios are twofold: to investigate the effects of different sets of assumptions on possible income to the Treaty, and to evaluate the sensitivity and importance of the individual factors within the algorithm. The relationship of the estimates under different sets of assumptions is more significant than the actual numbers.

3.1.2 Initial caveats

It is necessary to make a number of strong initial caveats. It must be stressed that this is only a model, that is, a theoretical construct that produces hypothetical estimates, with a wide range of uncertainty. It is not a calculation of real values, with a strong degree of certainty. The results of implementing the model must at best be seen as indicative.

Some imprecisions derives from the weaknesses of the currently available data. Much

[1] Cited in Box and Draper (1987, 424).

of the data manipulated is 'best guess' estimates, and the lack of directly pertinent information means that a number of proxies have had to be used. Moreover, some of the data needed are by their nature unlikely ever to be of very great certainty, because they are not systematically collected, because great variation within individual factors makes averaging hazardous, and because some key data are of a proprietary nature.

In addition, the structure of the model and the assumptions on which it is based reflect current conditions and practices within plant breeding and the seed and planting material industry, but recent scientific progress in plant breeding has been rapid, suggesting that technological progress will accelerate. Changes in industrial strategy and intellectual property law are also likely to have very major implications for the working of the SMTA. As will be seen, the model suggests that the time-scale for the build-up of income to the Treaty will be long, and the further in time one projects from the present day, the more likely it is that the conditions and practices that the model seeks to reflect will have changed. The probability of accuracy declines with distance in time, and no methodology can remedy this intrinsic uncertainty.

The model is also crucially dependent on the strategic decisions of breeders and breeding companies, who are under no legal obligation to the Treaty in two crucial ways. First, they are not obliged to use materials from the Multilateral System, and there are, in most cases, alternative sources of supply outside the jurisdiction of the Treaty. Second, the bulk of payments foreseen by the SMTA are voluntary, and there are strong theoretical reasons for assuming that the level of voluntary payments will be low. Nonetheless, the model assumes, in most scenarios, a consistent relatively high use of the Multilateral System, and of voluntary payment. This is in order to ensure comparability between the various scenarios, and is not a statement of likelihood. Two specific scenarios test the importance of avoidance of material under an SMTA and of varying levels of voluntary payment. As will be seen, the importance of these factors is very high.

3.1.3 Relevant provisions of the Treaty and of the SMTA

The model does not seek to propose changes to the provisions of the Treaty and the SMTA, or suggest alternative benefit-sharing systems; this is not its purpose. Changes to the Treaty or the SMTA are the prerogative of Contracting Parties, and there are no indications from the Governing Body on which such speculation could be based. The model therefore strictly reflects the actual provisions of the Treaty and the SMTA.

Contracting Parties to the Treaty agree to treat the PGR for food and agriculture of the crops listed in Annex 1 of the Treaty that are under their management and control, and in the public domain as a pooled good, and invite all other holders of such PGR for food and agriculture – i.e. private persons, institutions and companies – to include them in the Multilateral System.[2]

International Institutions bring their *ex situ* collections of PGR for food and agriculture of

[2] Treaty Article 11.2.

the crops listed in *Annex 1* to the Treaty into the Multilateral System.[3] They also distribute their non-Annex 1 holdings, at the time of the entry into force of the Treaty, under the terms and conditions of the SMTA.[4]

The SMTA, which is a contract in private law between the Provider and the Recipient, creates a beneficial interest for the Treaty such that payments are due to the Treaty's Benefit-sharing Fund on commercialization of "a product that is a plant genetic resource for food and agriculture and that incorporates material accessed from the Multilateral System".[5]

The payment provisions are stipulated in the SMTA itself:[6]

1. Under Article 6.7, a mandatory annual payment is due of 1.1, less 30, of the total annual sales of any product or products that *are not* "available without restriction to others for further research and breeding".[7]

2. Under Article 6.8, a voluntary payment is due in the case of any product or products that *are* "available without restriction to others for further research and breeding". The Treaty does not explicitly state what the expected level of such payments is.

3. Under Article 6.11, a recipient may opt for an alternative payment scheme, at the time of receiving an SMTA, for a specific crop or crops, whereby an annual payment is due for any of his/her Product or Products of this crop, independent of whether or not the Product is available without restriction, and whether or not they incorporate materials accessed through an SMTA. The rate of payment is 0.5 of sales.[8]

If an SMTA material is crossed with a non-SMTA material, the result of the cross may only be transferred to a third party under an SMTA, thus creating a chain of SMTAs from initial access to commercialized product,[9] and binding all recipients in this chain to the terms and conditions of the SMTA.

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3 Treaty Article 15.1a.

4 Treaty Article 15.1b and IT/GB-2/07/Report, Paras. 67 and 68.

5 Treaty Article 13.2d (ii).

6 The Treaty foresees that the Governing Body may vary payment conditions, including the levels of payment, and whether payments are mandatory or voluntary: "The Governing Body may, from time to time, review the levels of payment with a view to achieving fair and equitable sharing of benefits, and it may also assess, within a period of five years from the entry into force of this Treaty, whether the mandatory payment requirement in the MTA shall apply also in cases where such commercialized products are available without restriction for further research and breeding" (Article 13.2d(ii)). The Governing Body has postponed the deadline for the review, currently until its Fifth Session in 2013.

7 SMTA Annex 2, 1a.

8 SMTA Annex 3, 1.

9 SMTA, Article 6.5.

3.1.4 Cumulative and distributive models

There are two basic methodologies by which this process could be modelled:

- by identifying the number and kind of materials that have been accessed under SMTAs since the adoption of the SMTA, projecting forward the likely releases of further materials under the SMTA, and then attempting to estimate the products derived from them over time, and their likely value. This can be characterized as a *cumulative approach*;
- by valuing the part of the international seed and planting materials market of crops for which SMTAs have been issued, and within this part, the proportion of products of these crops that are likely, at a given date, to contain material derived from the Multilateral System. This can be characterized as a *distributive approach*.

A cumulative model is likely to have a wider range of error than a distributive model due to the uncertainty and imprecision of the data available, which accumulate with each step. The distributive model, on the other hand, starts from observed empirical values and applies a number of functions to them in order to estimate that part of the international seed and planting materials market, to which the terms and conditions of the SMTA will apply at a particular time because the products incorporate material accessed under an SMTA. The absolute margin of error therefore lies within the bounds of these observed values, and is likely to be less subject to cumulative error than in the case of the cumulative model. This study has therefore used a distributive model.

3.1.5 Basic assumptions and structure of the model

The basic assumptions on which the model is based are as follows:

1. Individual crops/crop groups are modelled separately, since different factors are in play during product development and commercialization.
2. The model begins with information on world holdings of PGR for food and agriculture in *ex situ* collections for these crops and crop groups. The holdings of all countries and major international institutions are included, whether or not they are members of the Treaty.
3. It then establishes the PGR for food and agriculture that are known to be currently available under an SMTA ('SMTA material'). This is achieved by applying a 'performance' factor to the holdings of members[10] of the Treaty.
4. Due to a lack of data, no attempt is made to include information on materials held by natural and legal persons in the model.[11]

[10] Here, 'member' is used to denote both Contracting Parties and International Institutions with Article 15 Agreements.

[11] For the currently known inclusions of natural and legal persons, see www.planttreaty.org/inclusions. In

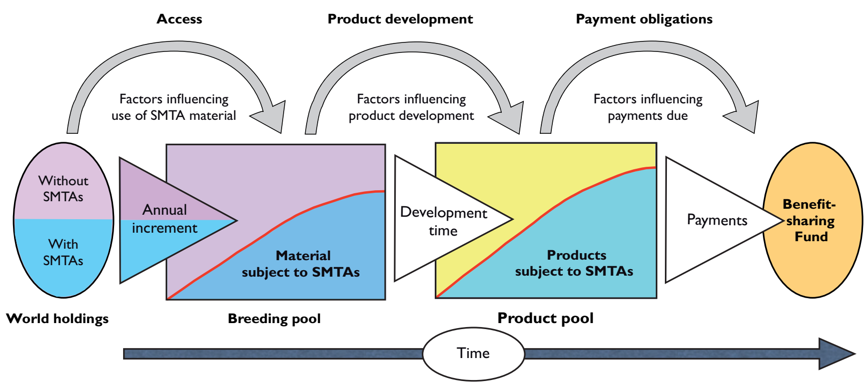
5. It is assumed that the ratio of materials that enter plant breeding annually (the sum of materials in plant breeding at any time is characterized as the 'breeding pool') reflects the ratio of SMTA materials/non-SMTA materials available to breeders, subject to various factors that influence the use of material under an SMTA.
6. No attempt is made to measure or estimate the actual number of units of PGR in the breeding pool at any time.
7. Crossing between SMTA materials and non-SMTA materials in the breeding pool ('diffusion') will over time increase the proportion of SMTA materials, and a function is implemented to model this.
8. An average time between a material entering the breeding pool and a commercial product incorporating this material is evaluated ('development time'), and a specific factor applied for this purpose.
9. It is assumed that the ratio of products subject to an SMTA/products not subject to the SMTA, at the distance of the development time from any point in time within the breeding pool, will reflect the ratio of SMTA materials/non-SMTA materials, subject to a number of factors that influence product development. The products at any one time together make up the 'product pool'.
10. As with the breeding pool, no attempt is made to measure or estimate the actual number of products in the product pool at any time.
11. The ratio of *products subject to an SMTA/products not subject to an SMTA* is assumed to be proportionally reflected in the market value of the international seed trade.
12. Income to the Benefit-sharing Fund is estimated on the basis of the provisions of SMTA Articles 6.7 and 6.8. Since payments under Article 6.8 are voluntary, a performance factor is in this case applied to simulate the 'effective rate of payment'.
13. No attempt is made to consider the probable income under SMTA Article 6.11 within the model. Article 6.11 is considered separately in section 3.3 below.[12]
14. The model assumes that values of the international seed market are stable and unvarying over time. All values are expressed in constant 2011 US dollars.

The major structural elements of the model, as constructed on the basis of these assumptions, are shown schematically in *Figure 3.1*.

its Third Session, the Governing Body "expresses its concern that information on the inclusion of plant genetic resource for food and agriculture in the Multilateral System by natural and legal persons within the jurisdiction of Contracting Parties on which to base its assessment of the progress in including these plant genetic resources for food and agriculture in the Multilateral System, is not yet available".

[12] At the time of writing, no valid acceptance of the alternative payment scheme of Article 6.11 has yet been received.

Figure 3.1 Structural elements of the model



3.1.6 Use of terminology and symbols

As is usual in a mathematical model of this nature, we express the elements of the model in scientific notation, using a set of symbols, and in *Appendix 3.2* we describe the mathematical algorithm that implements the model in scientific notation. The format used is as follows:

Indices

- **c** Crop/crop group
- **h** Holders of materials
- **t** Time.

Given data

- **C(c)** World holdings of crop/crop group *c*, measured in terms of accessions in *ex situ* collections
- **H(h)** Holdings of crop/crop group *c*, measured in terms of accessions in *ex situ* collections, by holder (country and by international institution), *h*
- **V(c)** The commercial value of crop/crop group *c*, in the world seed and planting material market, *v*.

Outcome

- **$Q(c)_t$** Monies due to the Treaty at time *t* for crop *c*.

The terminology used in mathematical modelling differs greatly between the social sciences and economics. For example, economists may use the terms 'exogenous variable' and 'endogenous variable', while social scientists would probably use 'given data' and 'outcome', respectively.

In the present chapter, the terminology adopted is as follows: indices are called *sets*, given data are called *factors*, outcomes are called *computational objects*, and the variables in the equations modelling given data in order to calculate outcomes are called *functions*.

3.1.7 Factors used in the model and definitions

Table 3.1 lists in algorithm order the factors that are used in the model. These are then defined, and their role in the model is described.

Table 3.1 Factors used in the model

C(c)	World crop holdings, by crop	**C1**	Wheat
		C2	Rice
		C3	Maize
		C4	Other Annex 1 crops, taken together
		C5	Non-Annex 1 food and agriculture crops
H(h)	World crop holdings, by holder	**H1**	States that *are* Contracting Parties
		H2	International institutions that *have signed* Article 15 Agreements
		H3	States that *are not* Contracting Parties
		H4	International institutions that *have not signed* Article 15 Agreements
π	Availability		A performance factor, defined as the part of **H1**–**H5** that is effectively available from the holder under a SMTA
t	Time		All events (such as adherence of a Contracting Party, or a change in π) enters the model at a date, and all projections evolve along **t**
B	Breeding Pool		A conceptual object (the total breeding stock per crop in breeding at any time), used for evaluating the ratio of **A/B**
A	SMTA material in the breeding pool		A conceptual object (that part of a crop's breeding stock containing SMTA material at any time), used for evaluating the ratio of **A/B**
α	Introduction of material into the breeding pool	α**1**	The annual rate at which accessions *without SMTAs* enter **B**
		α**2**	The annual rate at which accessions *with SMTAs from national collections* enter **B**
		α**3**	The annual rate at which accessions *with SMTAs from international institutions* enter **B**
υ	Avoidance		Deliberate avoidance of material under SMTAs
λ	Diffusion		The effect of crossing of SMTA materials and non-SMTA materials within **B**
P	Product pool		A conceptual object: the total number of products commercialized at any time

T	Products subject to SMTAs		A conceptual object: that part of a crop/crop group's product pool incorporating SMTA material at any one time
κ	Development time		Average time, per crop/crop group, from access to product
β	Research intensity		Investment in research and development, in a crop/crop group, relative to other crops
γ	Improved materials		The proportion of improved materials in α
δ	Consequences of γ	δ**1**	The speed of uptake of materials
		δ**2**	The proportion of materials leading to products
V(c)	Commercial value of the world seed and planting material market	**V1**	Wheat
		V2	Rice
		V3	Maize
		V4	Other Annex 1 crops
		V5	Non-Annex 1 food and agriculture crops
ι	IP status		The ratio, per crop/crop group, of products under patents
Q	Moniess due to the Treaty	**Q1**	In accordance with SMTA Article 6.7
		Q2	In accordance with SMTA Article 6.8
μ	Payment rate		For both **Q1** and **Q2**, 'one point-one percent (1.1) of the sales of the product or products less thirty percent (30)'
ρ	Real payment		A performance factor: the fraction of **Q2** that is actually paid.

3.1.8 Materials that may be accessed under SMTAs

C: World crop holdings, by crop

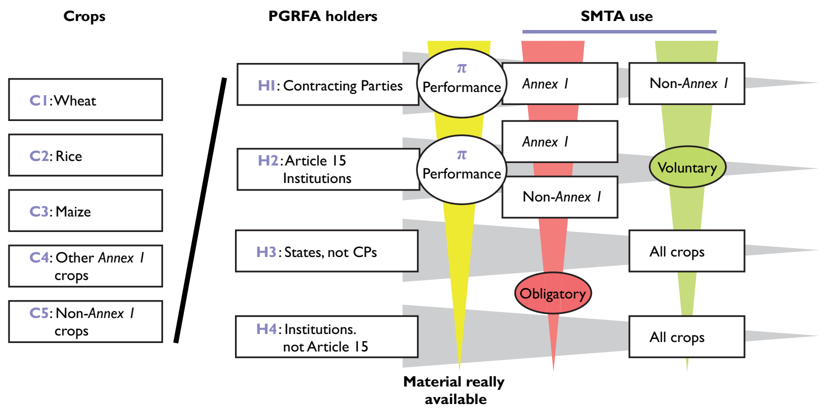
C represents the total *ex situ* world holdings of PGR for food and agriculture, quantified in terms of number of accessions. In this first iteration of the model, only the holdings of national PGR systems and of international institutions are listed. No attempt is made to model the holdings of natural and legal persons.

In this first conceptualization, five crops/crop groups are modelled:[13]

- **C1**: Wheat
- **C2**: Rice
- **C3**: Maize
- **C4**: Other *Annex 1* crops
- **C5**: Non-*Annex 1* food and agriculture crops.

[13] Due to time and resource constrictions, it was necessary to limit its focus on a few important crops for which information was available and easily accessible. Wheat, maize and rice were chosen as objects of study with these characteristics, as large crops expected to contribute a substantial part of the overall income to the Treaty, and as mandate crops of the CIMMYT, IRRI and the Africa Rice Centre. Despite this limitation, the two general categories – other Annex 1 crops and non-Annex 1 *crops – make it possible to investigate the values of all PGR for food and agriculture.*

Figure 3.2 Crops, holders and use of the SMTA



C1–**C4** are *Annex 1* crops, to which the provisions of the Multilateral System apply. International Institutions are also obliged to make certain **C5**, non-*Annex 1*, holdings available, in accordance with Treaty Article 15.1b. Both these sets of material are to be distributed under an SMTA.
C5 groups all non-Annex 1 PGR for food and agriculture.

H: World crop holdings, by holder

H represents the number of accessions of all five crops/crop groups held in *ex situ* collections by countries and international institutions, both by members of the Treaty, and non-members. The model distinguishes four categories of holders, which have different obligations towards the Treaty regarding the use of SMTAs:

1. States that are Contracting Parties, which must use SMTAs for their *Annex 1* materials;
2. International Institutions that have signed Treaty Article 15 Agreements, which must use SMTAs for their *Annex 1* materials, and distribute their non-*Annex 1* materials under the terms and conditions of the SMTA;
3. States that are not Contracting Parties; and
4. International institutions that have not signed Treaty Article 15 Agreements.

Neither point (3) nor point (4) is under any obligation to use the SMTA in distributing materials, and there is no information suggesting that any of them are doing so. In addition, a number of Contracting Parties have decided, as an independent sovereign decision, to make non-*Annex 1* materials available under the terms and conditions of the SMTA; the term 'SMTA' is used for all of them.

π: availability of materials

For members of the Treaty, **H** constitutes the set of materials potentially available under SMTAs, both from the Multilateral System (**C1**–**C4**), and outside the Multilateral System (**C5**, in the case of international institutions only). A performance factor, *π*, is applied to materials that the Treaty obliges members to make available, to specify the part of the full potential set that is actually being made available. It is not applied to materials that a Treaty member is not obliged to make available.

3.1.9 Build-up of SMTA materials in the breeding pool

t: time

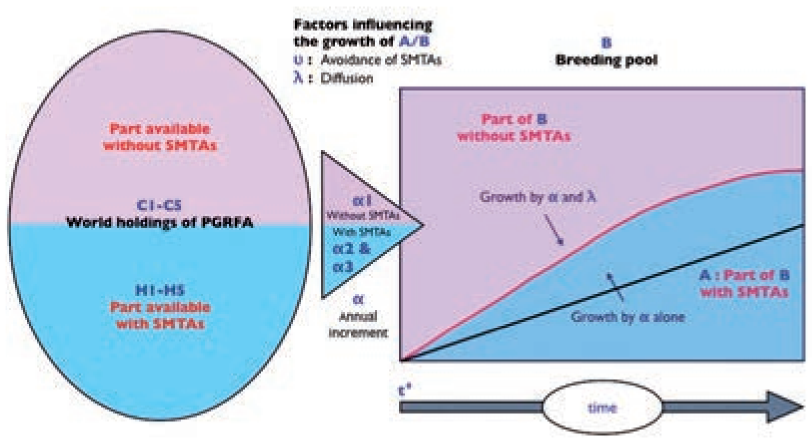
The model is diachronic, that is, all events (such as the adherence of a new Contracting Party) enter the model at a specified point in the time. All projections (e.g. of products subject to the terms and conditions of the SMTA, and payments due to the Benefit-sharing Fund) evolve along the time-line.

B: Breeding pool

A: SMTA materials in the breeding pool

B represents the fraction of world crop holdings deployed in all breeding programmes, at any one time. For the purposes of the model, it is assumed to be of stable volume over time. **A** represents that fraction of **B** that consists of SMTA materials. One of the outcomes of the model is the evaluation over time of the evolving ratio of **A** to **B**. **A** and **B** are therefore conceptual objects without absolute numerical dimension.

Figure 3.3 Build-up of SMTA materials in the breeding pool



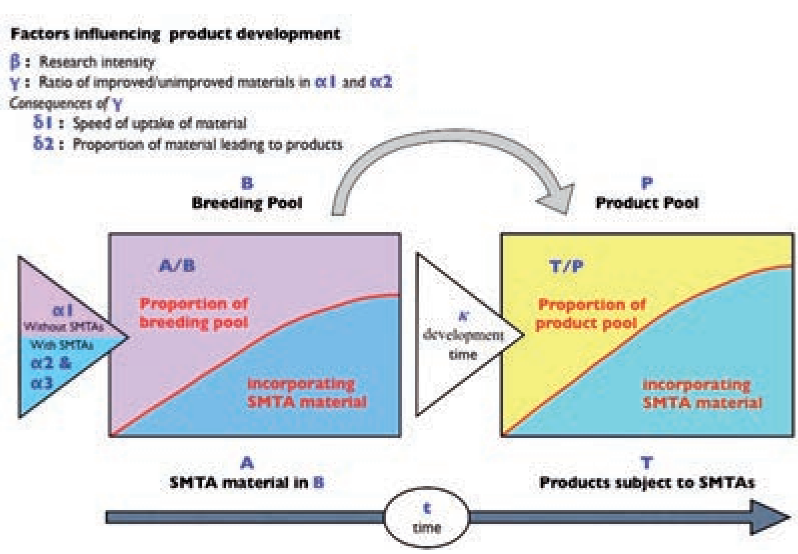
α: Introduction of materials into the breeding pool

α represents an annual rate of introduction of materials into **B**, and comprises three parts: non-SMTA materials (α**1**); SMTA materials from national collections (α**2**); and SMTA materials from international institutions (α**3**). α is estimated empirically, and expressed as a fraction of **B**.

υ: Avoidance of materials under an SMTA

There is evidence that some commercial entities have adopted a strategy of avoiding the use of materials that require acceptance of an SMTA, either in the belief that doing so will maximize their profits, or that the transaction costs involved are excessive, due to technical difficulties in tracking individual genetic contributions in plant variety development.[14] There is reason to believe that this behaviour varies according to crop, and relates largely to crops where a substantial proportion of products are commercialized under patent protection. υ therefore represents avoidance of material that must be accessed under an SMTA. It is a stochastic factor, where empirical evidence is hard to find. It is included in the model in order to be able to investigate its theoretical importance through the scenarios.

Figure 3.4 Relationship of the breeding pool to the product pool



[14] See also Chapter 2 above and the Annex.

λ: Diffusion in B of SMTA materials

Once SMTA materials enter the product pool, they will be crossed with other breeding materials. Since the terms and conditions of the SMTA extend to any material that contains genetic parts and components introduced from a material accessed under an SMTA, diffusion (λ) occurs, at a rate that depends on assumptions regarding the rate at which SMTA material is crossed with non-SMTA materials in the breeding pool.

3.1.10 Build-up of SMTA materials in the product pool

P: Product pool
T: Commercial products subject to SMTAs
κ: Development time

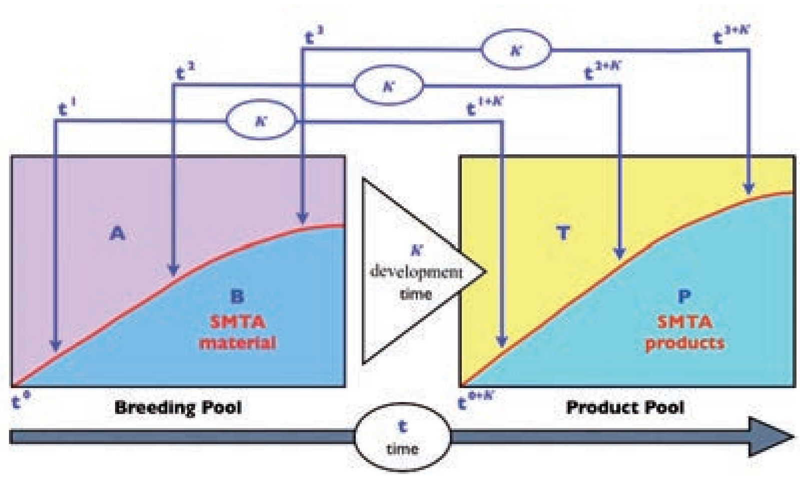
The model evaluates how the ratio of **T/P** evolves over time. **T** and **P** are conceptual objects without absolute numerical dimension. **P** represents the pool of products being commercialized at any one time. For the purposes of the model, it is assumed to be of stable volume over time. **T** represents that fraction of **P** that is made up of products that incorporate SMTA materials.

κ represents the average time, per crop, between access to a breeding material and commercialization of a product that has been incorporates that material. It may be estimated on the basis of empirical evidence.

T/P is derived directly from **A/B**, conditioned by a number of factors influencing product development (β, γ, δ**1** and δ**2**).

The relationship of **A/B** to **T/P**, over time, is shown schematically in Figure 3.5.

Figure 3.5 Build-up of SMTA materials and SMTA products over time



β: Research intensity

β represents research intensity per crop/crop group: this variable is a function of variation from an average research intensity for all crops generally. It is assessed on the basis of empirical evidence. It has a specific function varying the ratio the products derived from the different crops/crop groups in **T/P**.

γ: Proportion of improved materials released by international institutions
δ1: Speed of uptake of materials
δ2: Proportion of materials leading to products

γ represents the ratio in annual introductions into the breeding pool of improved to unimproved materials in SMTA materials/improved to unimproved materials in non-SMTA materials.

No easy estimate of this ratio is currently available, and the ratio of materials of improved/unimproved materials accessed from International Institutions under SMTAs[15] is used as the basis of a proxy, and applied to their releases only (α**3)**. These are a large part of improved materials entering the breeding pool, and are greater than average contributors to products developed from materials accessed under SMTAs.

The effect of γ on **T/P** is expressed through two separate functions, δ**1** and δ**2**. According to the dimension of γ:

> δ**1**, 'speed of uptake of materials', varies the length of the breeding period (κ), in that improved materials are assumed to be incorporated in products faster than unimproved materials;
>
> δ**2**, 'proportion of materials leading to products', varies the ratio of **T/P**, in that a greater number of improved materials than unimproved materials are assumed to be incorporated in products.

3.1.11 Monetary benefit-sharing

V: Commercial value

T may be expressed in monetary terms, by applying the variable **T/P** as a fraction of the total commercial market for a crop **C**, **V(c)**.

V represents the monetary value of **P**, that is, the total value of the world seed and planting material market, per crop/crop group (**V1–V5**), evaluated from empirical observed data. **V** is fractioned according to the ratio of **T/P**, and $\mathbf{V^T = V^*(T/P)}$ is assumed to be the monetary value of that fraction of the world market that is subject to the terms and conditions of the SMTA.

15 This figure is high because a considerable part of annual releases from the CGIAR under SMTAs is of improved materials deriving from the Centres' breeding programmes. Cf. tables 2 (p. 13) and table 3 (p. 14) of IT/GB-4/11/12, *Report on the implementation of the multilateral system of access and benefit-sharing*.

ι: Intellectual property status

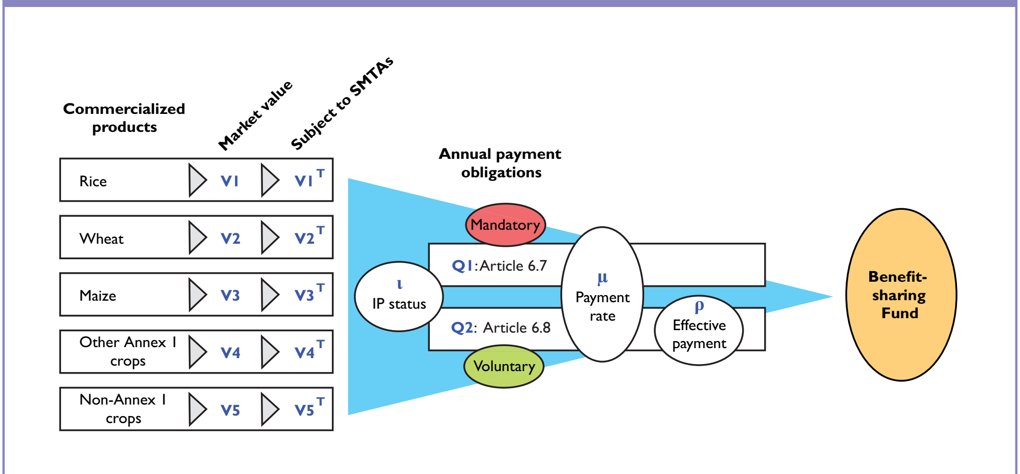
ι represents the proportion of **V**, per crop/crop group that is commercialized under intellectual property rights such that the product is not freely available without restriction to others for further research and breeding. It can be estimated empirically.

Q: Payments due

Q is a direct derivation of the monies due to the Benefit-sharing Fund from commercial products that incorporate materials subject to the terms and conditions of the SMTA (**VT**), after application of ι:

> **Q1** represents payments due for products derived from SMTA material, per crop/crop group, expressed in terms of value, where these *are protected* by intellectual property rights, and subject to mandatory annual payment, in accordance with Article 6.7 of the SMTA.
>
> **Q2** represents payments due for products derived from SMTA material, per crop/crop group, expressed in terms of value, where the products *are not protected* by intellectual property rights, and subject to voluntary annual payment, in accordance with Article 6.8 of the SMTA.

Figure 3.6 Projected products and monetary benefit-sharing



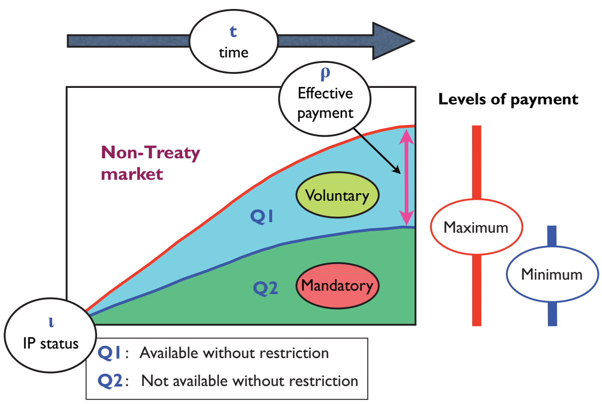
μ: Payment rate

For both **QI** and **Q2**, the payment rate is set at 1.1, less 30, of total annual product sales, which is the rate established in the SMTA, under Article 6.7.

ρ: The effective rate of payment

ρ is a performance factor, and represents that fraction of **Q2** that is actually paid. In the case of **Q1**, this is assumed to be 100. In the case of **Q2**, this is a factor that cannot currently be predicted, since there is still no empirical evidence in this regard. It is included, however, in order to be able to test its importance through the scenarios, since the effective level of payments to the Benefit-sharing Fund will substantially depend on it.

Figure 3.7 Payments under SMTA Articles 6.7 and 6.8



3.2 Scenarios

3.2.1 Methodology

The scenarios each consist of one or more 'runs' of the model (Table 3.2). Each takes the form of a projection of income to the Treaty until the various projections approach saturation, at about 2081. A specific set of assumptions governs each run, as listed in Table 3.2. For each run, two graphs are generated: a stacked area graph, summing income from all five crops/crop groups; and a line graph showing the values of each crop/crop group separately. The reference run is Run 1, which models the current situation: the data on which it is based are given in Appendix 3.1. The algorithm that implements the model is described in Appendix 3.2.[16]

[16] The raw data generated by the model is available at www.planttreaty.org/sites/default/files/Results%20of%20the%20runs%20of%20the%20model.pdf.

3.2.2 Scenarios analysed

The following scenarios were analysed using the information generated by these runs. For the discussion in this section, other graphs were also generated, and are shown in the text, in order to compare the results of relevant runs.

Scenario 1 valuates potential income with the current membership of the Treaty, and the material that current Treaty members are making available, and compares this with the effects of members making available more of their holdings.

Scenario 2 tests the effects of the Treaty's membership growing.

Scenario 3 quantifies the potential benefits deriving from the respective holdings of developing countries, and of developed countries.

Scenario 4 quantifies the potential benefits deriving from the respective holdings of countries, and of international institutions.

Scenario 5 tests the relative importance of mandatory and voluntary payments, and of differing effective levels of voluntary payment.

Scenario 6 tests the effect of avoidance of the use of material under SMTA conditions.

Scenario 7 quantifies and compares the total potential value deriving from *Annex 1* material, with the values that could be derived from non-*Annex 1* materials, should the Governing Body of the Treaty decide to increase the list of crops in *Annex 1*.

Scenario 8 summarizes and quantifies potential income to the Treaty, under optimal assumptions.

Scenario 9 tests the importance of the rate of crossing, in the breeding pool.

Scenario 10 tests the importance of the increased likelihood of a product being produced, where improved materials have been accessed for use in a breeding programme.

Scenario 11 tests the effect of varying values of α, the annual rate of incorporation of new materials in breeding programmes.

Table 3.2 Runs performed and assumptions

	Membership			Material			Other factors				
Run	**Developing countries**	**Developed countries**	**International institutions**	**Annex 1**	π **Availability**	**Non-Annex 1**	α **Introduction**	υ **Avoidance**	λ **Diffusion**	$\delta 2$ **Products**	ρ **Voluntary payment**
1	Current	Current	Current	All	Current	Known	4.2	Standard	2	Standard	50
2	Current	Current	Current	All	100	Known	4.2	Standard	2	Standard	50
3	Current	Current	Current	All	33	Known	4.2	Standard	2	Standard	50
4	Current	Current	Current	All	66	Known	4.2	Standard	2	Standard	50
5	+ China Japan, USA	Current	Current	All	100	Known	4.2	Standard	2	Standard	50
6	All	All	All	All	100	Known	4.2	Standard	2	Standard	50
7	Current	No	No	All	Current	Known	4.2	Standard	2	Standard	50
8	No	Current	No	All	Current	Known	4.2	Standard	2	Standard	50
9	Current	No	No	All	100	Known	4.2	Standard	2	Standard	50
10	No	Current	No	All	100	Known	4.2	Standard	2	Standard	50
11	Current	Current	No	All	Current	Known	4.2	Standard	2	Standard	50
12	No	No	Current	All	Current	Known	4.2	Standard	2	Standard	50
13	Current	Current	No	All	100	Known	4.2	Standard	2	Standard	50
14	Current	Current	Current	All	100	Known	4.2	Standard	2	Standard	0
15	Current	Current	Current	All	100	Known	4.2	Standard	2	Standard	33
16	Current	Current	Current	All	100	Known	4.2	Standard	2	Standard	66
17	Current	Current	Current	All	100	Known	4.2	Standard	2	Standard	100
18	Current	Current	Current	All	100	Known	4.2	High	2	Standard	50
19	Current	Current	Current	All	100	Known	4.2	Value-Based	2	Standard	50
20	Current	Current	Current	All	100	No	4.2	Standard	2	Standard	50
21	Current	Current	Current	No	100	All	4.2	Standard	2	Standard	50

22	All	All	All	All	100	All	4.2	Standard	2	Standard	50
23	Current	Current	Current	All	100	No	4.2	Standard	2	Standard	100
24	All	All	No	All	100	No	4.2	Standard	2	Standard	100
25	Current	Current	Current	All	100	All	4.2	Standard	2	Standard	100
26	All	All	All	All	100	All	4.2	Standard	2	Standard	100
27	Current	Current	Current	All	100	Known	4.2	Standard	1	Standard	50
28	Current	Current	Current	All	100	Known	4.2	Standard	3	Standard	50
29	Current	Current	Current	All	100	Known	4.2	Standard	5	Standard	50
30	Current	Current	Current	All	100	Known	4.2	Standard	2	Variant 1	50
31	Current	Current	Current	All	100	Known	4.2	Standard	2	Variant 2	50
32	Current	Current	Current	All	100	Known	4.2	Standard	2	Variant 3	50
33	Current	Current	Current	All	100	Known	2	Standard	2	Standard	50
34	Current	Current	Current	All	100	Known	6	Standard	2	Standard	50

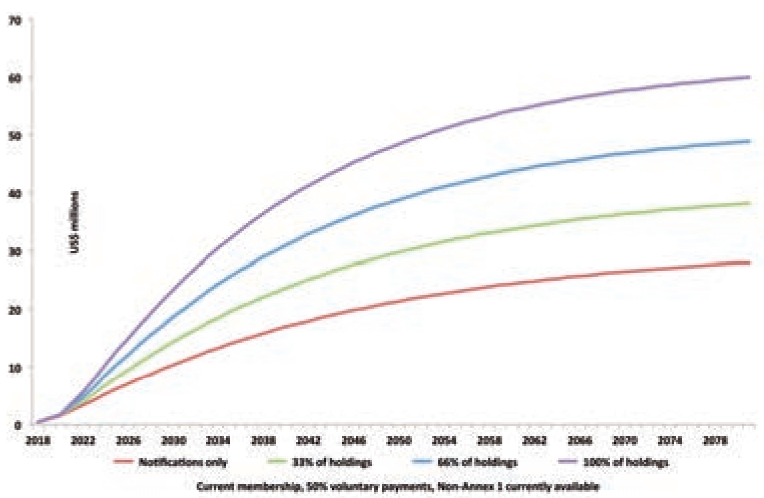
Membership: 'Current' means the membership in December 2011. 'All' means all possible members.
Material: 'Known' means all material notified to the Secretariat, thus known to be available. 'All' means all the crops in that group. Except where noted, the only non-*Annex 1* material covered is that held by international institutions, under Article 15.1b of the Treaty, or known to be made available by countries under SMTAs, as their sovereign decision. π is not applied to non-*Annex 1* material.

υ, **Avoidance:**	**C1 Wheat (%)**	**C2 Rice (%)**	**C3 Maize (%)**	**C4 Other Annex 1 (%)**	**C5 Non-Annex 1 (%)**
'Standard'	5	5	18	5	0
'High'	10	10	36	10	0
'Value-based'	10	10	67	10	0
$\delta 2$, **Products** 'Standard'	217	296	180	197	204
'Variant 1'	0	0	0	0	0
'Variant 2'	435	591	360	394	408
'Variant 3'	659	896	545	597	618

Scenario 1: The current situation

Scenario 1 (runs 1, 2, 3 and 4) tests the effects of varying the percentage of members' holdings that are effectively available through the Multilateral System. It projects potential income, with the current membership of the Treaty, on the basis of only the materials that have been notified to the Secretariat as available under SMTAs; at least 33 percent, 66 percent, or 100 percent of their holdings. The values of 't', as far as possible, have been established empirically. The rate of effective voluntary payment is assumed to be 50.

Figure 3.8 Potential income, based on holdings made available under SMTAs



As is self-evident, income flow into the Benefit-sharing Fund is crucially dependent on members effectively making their materials available under SMTAs. In this scenario, the annual income predicted by 2081, which is near peak income, is approximately $28 million on the basis of current holdings, $38 million at 33 percent availability, $49 million at 66 availability, and $60 million at 100 percent availability.

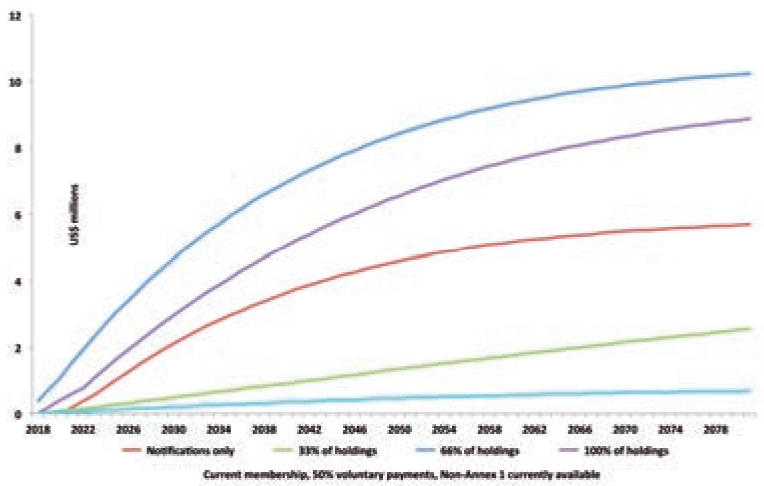
The Governing Body has established a current fund-raising target of $116 million, for the period between July 2009 and December 2014;[17] this translates to an annual target of $21 million. Under this scenario, based on currently available holdings, the equivalent of the annual fund-raising target would be achieved in 2049, and half of

[17] From voluntary contributions by donors, rather than from benefit-sharing payments due on the commercialization of products incorporating plant genetic resources accessed under an SMTA.

the full potential income would be available by 2035. For comparison, if 100 percent of current members' holdings were immediately available, the current fund-raising target could be reached by 2029, and 50 percent of the full potential income by 2034.

Using the same set of values, Figure 3.9 models income by crop for the current situation. The lower line estimates income from non-Annex 1 material from members who are already releasing such material under SMTA terms and conditions. By far the largest income is projected to derive from maize. Both wheat and other Annex 1 crops, taken as a group, also make substantial contributions, with rice providing a smaller income. It should be borne in mind that the figure for maize reflects the fact that about 26 percent of the world's area planted to maize of transgenic varieties,[18] and such materials, being marketed under patents, are subject to full mandatory payments. For this reason, an avoidance rate of 13 percent (equivalent to half this area) has accordingly been applied to maize, and a background avoidance rate of 5 percent to other crops, except for non-Annex 1, where 0 percent is applied.[19] The effective payment rate of 50 percent is optimistic, and a lower voluntary payment rate would lower the relative contribution of all crops, from products that are not subject to patents, where only voluntary payments are foreseen. Scenario 5 specifically tests the importance of voluntary payments.

Figure 3.9 Crop-specific income, based on holdings made available under SMTAs

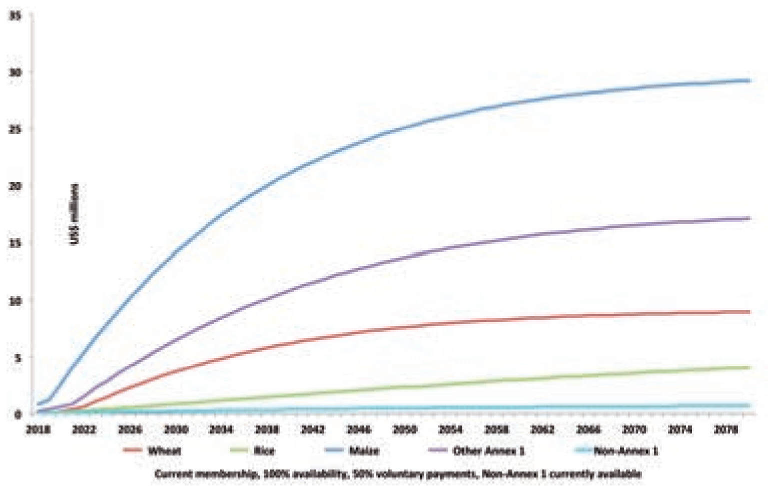


[18] Chapter 2, Figure 2.10.

[19] Except where otherwise mentioned, these avoidance assumptions are applied as standard in other scenarios.

Figure 3.10 shows, for comparison, the income that might be expected from the different crops and crop groups, on the assumption that members make 100 percent of their holdings immediately available. The importance of maize is even greater.

Figure 3.10 Crop-specific income, if all holdings were made immediately available



Scenario 2: Expanding membership

A further critical factor in projecting income is the membership of the Treaty. Scenario 2 (runs 1, 5 and 6) tests the effects of the Treaty's membership growing, to include: the three largest missing holders of material (China, Japan and the United States) and all potential members.

Figure 3.11 Membership and income

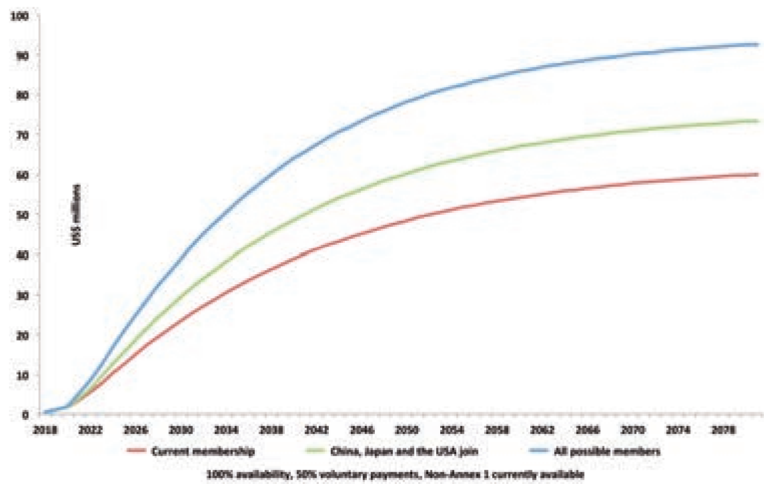


Figure 3.11 assumes that members make 100 percent of their holdings available, and applies the standard avoidance rates and an effective voluntary payment rate of 50 percent. While income with current membership is estimated at about $60 million by 2081 under these assumptions, it is estimated at about $73 million, if the three non-member countries holding the largest *ex situ* collections (China, Japan and the United States) join, and at $93 million if all potential members join.

In this context, it should be borne in mind that the largest *ex situ* collections held by international institutions, which account for by far the largest part of international holdings – those of the CGIAR – have already been brought into the Multilateral System. They account for a good part of the current projection. The part of international institutions cannot therefore be expected to grow substantially.

Scenario 3: The relative contribution of developing and developed countries' collections

The model also makes it possible to evaluate the relative contribution of materials held by developing and developed country Contracting Parties. In this scenario (runs 7, 8, 9 and 10), effective voluntary payment is set at 50, avoidance at the standard rate, and the non-Annex 1 material includes only that certain members have already been made available under the terms and conditions of the SMTA. Two projections at 2081 have been made, the first at current availability, and the second at 100 percent availability; they are presented in Table 3.3.

Table 3.3 The relative contribution of developing and developed countries' collections

	Developing countries	Developed countries
Current availability	$0.55 million	$7.67 million
100% availability	$3.53 million	$43.37 million

It should be borne in mind that developing countries may require a longer period to make the necessary arrangements to provide their materials to the Multilateral System, in accordance with the Treaty. Moreover, while developing countries, as a group, maintain proportionally fewer and smaller *ex situ* collections, they are as a group rich in *in situ* material of interest to food and agriculture, which does not feature in this analysis, and is difficult to quantify.

Figure 3.12 Crops in developing and developed countries releases

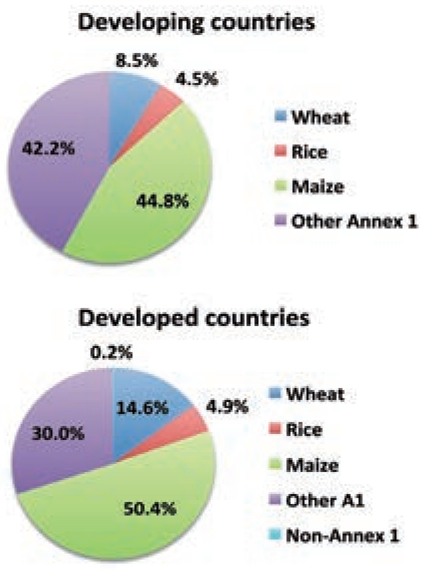


Figure 3.12 illustrates the differing value by crop of developing and developed country releases, projected at 2081.

Scenario 4: The relative contribution of countries' and international institutions' collections

The model also makes it possible to assess the relative contribution of materials held by international institutions and by countries that are currently members. In this scenario (runs 11, 12 and 13), effective voluntary payment is set at 50 percent. Two projections until 2081 have been made, the first at current availability, and the second at 100 percent availability. The standard avoidance rate and 50 percent voluntary payment are assumed.

Figure 3.13 Relative contribution of countries' and international institutions' collections

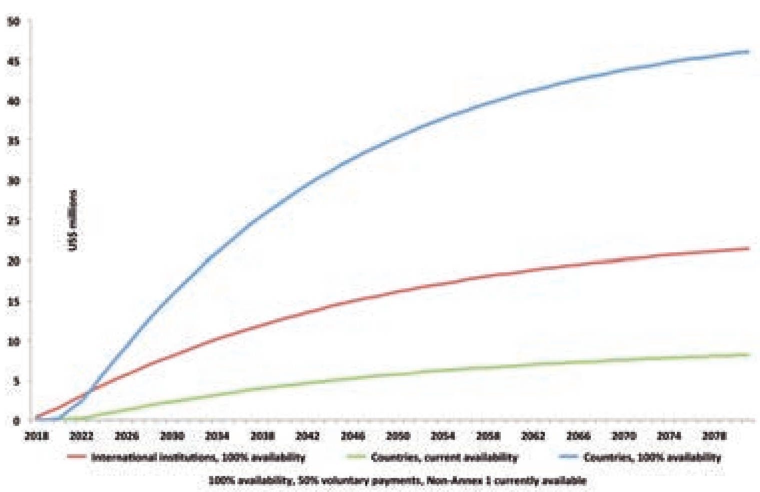
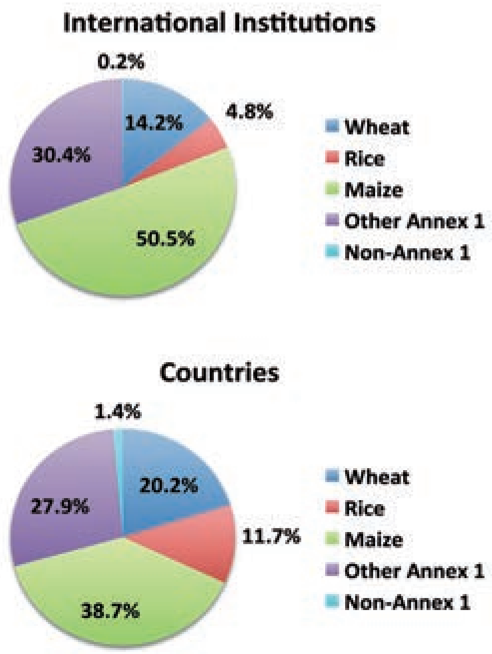


Figure 3.13 shows the evolution of the contributions to income of these two sources, collections of countries and international institutions, over time. In the early days of the Treaty, and until Contracting Parties have substantially increased the availability of their materials, the ex situ collections of international institutions, which are already making available all of their collections, are the major source of income to the Benefit-sharing Fund of the Treaty. Since the great bulk of the international institutions materials have already been included in the Multilateral System, the projection for these materials does not change, but the contribution of international institutions is underrepresented in Figure 3.13. Only releases from their *ex situ* collections are covered, and as noted above, the CGIAR Centres reported in 2011 that, for Annex 1, 71 percent of their distributions were of improved materials from their breeding programmes, rather than

from their *ex situ* collections, and for non-Annex 1, 31 percent.[20] This means that a large part of their releases under SMTAs are of improved materials, with a high multiplier effect on the development of commercial products, which this projection does not fully account for.

Figure 3.14 illustrates the differing composition by crop of international institutions and countries country releases, projected at 2081.

Figure 3.14 Crops in international institutions' and countries' releases

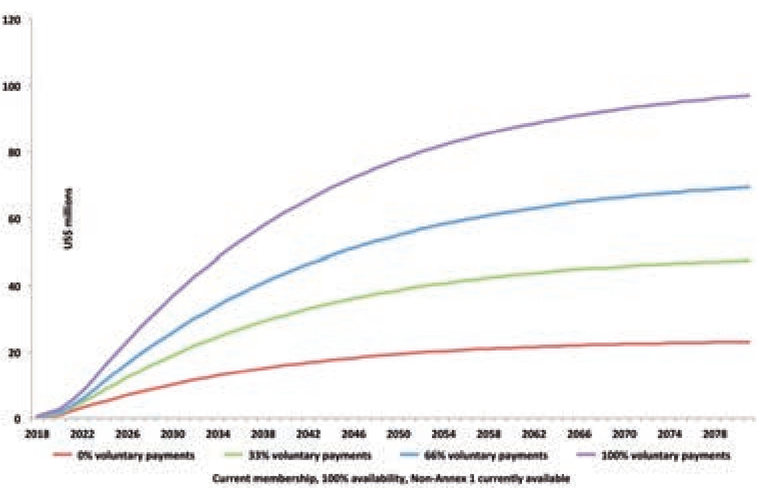


[20] IT/GB-4/11/Inf.5, Experience of the International Agricultural Research Centres of the Consultative Group on International Agricultural Research with the Implementation of the Agreements with the Governing Body, with Particular Reference to the Use of the Standard Material Transfer Agreement for Annex 1 and non-Annex 1 Crops, p. 5.

Scenario 5: The relative importance of mandatory and voluntary payments

Scenario 5 (runs 14, 15, 16 and 17) deals with a matter of particular importance in estimating likely income for the Benefit-sharing Fund, namely, the level of voluntary payments in accordance with Article 6.7 of the SMTA. The scenario tests the effects of various levels of such payments: at 0 percent, 33 percent, 66 percent, and 100 percent, assuming that the same rate of payment (1.1 percent, less 30 percent, of the annual commercial sales of a product) applies to both mandatory and voluntary payments. Avoidance is set at the standard rate.

Figure 3.15 The relative importance of mandatory and voluntary payments



The scenario presented in Figure 3.15, shows clearly the great dependence of the Treaty on substantial voluntary payments. At 2081, the projected annual income under this scenario is as follows.

Table 3.4 Projections at 2081, at varying degrees of voluntary payment

0%	33%	66%	100%
$23 million	$47 million	$69 million	$97 million

In Chapter 2, it is estimated that the upper levels of potential mandatory and voluntary payments, on the basis of the historical use of past CGIAR material, at $10 million and $37 million, respectively, for a total income of US$47 million annually, which would be reached by 2030, at a 100 percent voluntary payment rate. The methodology used in Chapter 2 is separate and different than that used in the model, and the build-up of the projected income is not articulated over time.

The initial survey of plant-breeding experts (see Annex to this volume) suggests that, at least in the private sector, it is believed that voluntary payments are in practice likely to be minimal.

The scenario points out the critical importance for the Treaty of the mandatory payments that potentially flow from maize varieties, if these are commercialized under patents. Figure 3.16 shows the break-down, by crops and crop groups, of the income projection at 0 percent voluntary payment, in which case income to the Treaty would flow almost exclusively from maize.

Box 3.1 Games theory analysis

	Company 2 cooperates	Company 2 defects
Company 1 cooperates	0,0	-,+
Company 1 defects	+,-	0,0

If one company makes a voluntary payment (cooperates), and the other does not (defects), the company that defects has a strategic advantage over the company that cooperates. This advantage can:

1. be taken as increased profit;
2. provide an research and development advantage; or
3. be used to lower the sales price of a competitor product.

The advantage is always to the company that defects, and represents a substantial part of profits.

Profit in plant breeding is low. If we assume a profit range of 4 to 6 percent, 0.77 percent of sales equals 19.25 to 12.83 percent of profits.

No company can therefore make the first move and cooperate because of the risk that other companies defect.

A games theory analysis (Box 3.1) suggests that no company can afford to make voluntary payments that its competitors avoid, because this would result in uneven competition, and a substantial market disadvantage for the company paying. The lack of certainty about competitors' intentions therefore results in a situation where a company hesitates to be the first to make substantial voluntary payments, which this creates a vicious circle.

Figure 3.16 Income by crop and crop group at 0% voluntary payment

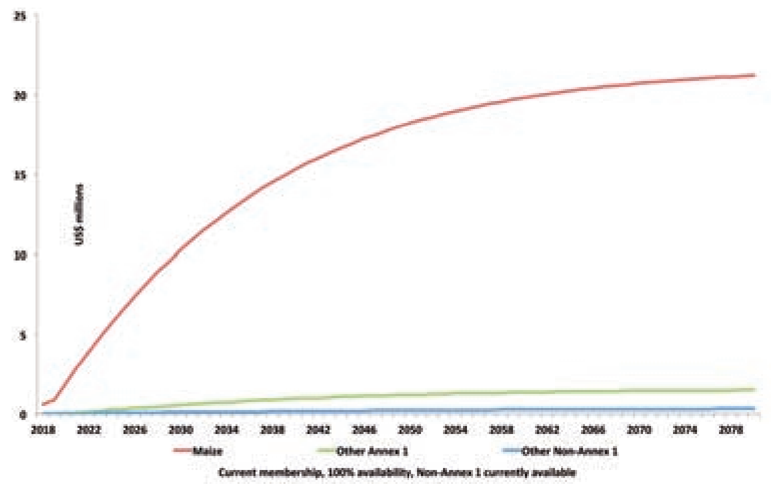
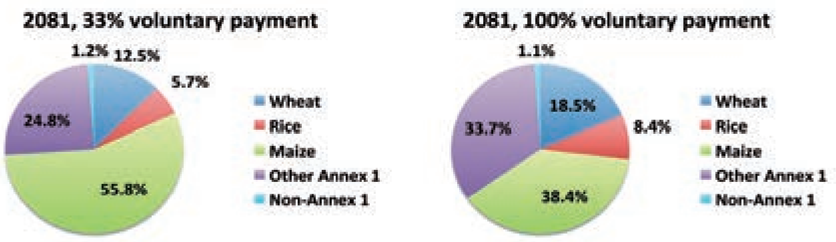


Figure 3.17 shows income by crop at 2081, at 33 percent and 100 percent voluntary payment. Even at 100 percent voluntary payment, maize remains the single most important crop currently in the Multilateral System.

Figure 3.17 Income by crop group, at 33% and 100% voluntary payment



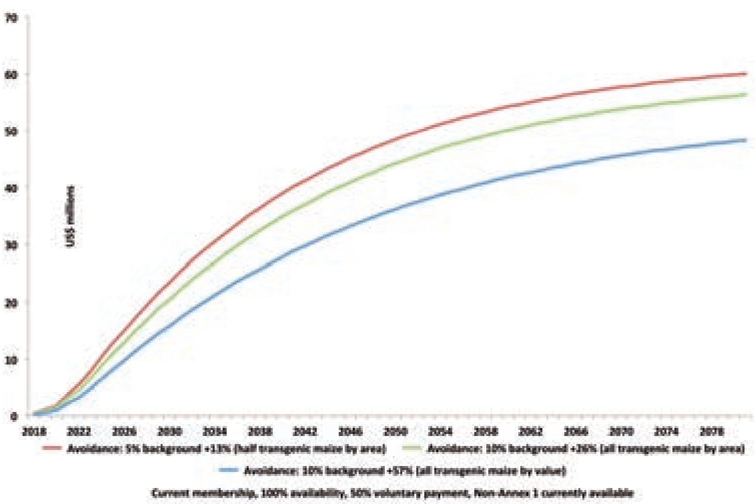
Scenario 6: Avoidance of the use of material under SMTA conditions

Scenario 6 (runs 2, 18 and 19) tests the effect of avoidance of material under SMTA conditions. This is a further crucial factor in evaluating the likely income for the Treaty, and very little hard evidence is available on which to base an estimate.

In most developing countries, the public sector has been and remains the dominant player in plant breeding research, although the private sector is playing an increasing role in several crops. In developed countries, the role of the public sector in 'near-market' plant breeding research has declined over the last two decades, with the private sector playing a dominant role in the breeding of new varieties of key crops, such as maize in the United States, particularly those involving the application of biotechnology.

The emergence of the CBD, the extended negotiation process leading to the Treaty, and the uncertainties surrounding the nature of the plant genetic resource exchange regime that would eventually emerge may have created strong incentives for private sector breeding programmes to stockpile materials before the Treaty came into force, to adopt breeding strategies that avoid the use of materials accessed under SMTA conditions, and, if necessary, to acquire the same genetic material from collections that do not form part of the Multilateral System. The preliminary survey of plant breeders (see the Annex) found some indication of explicit avoidance in private sector breeding.[21]

Figure 3.18 Avoidance of SMTA material



Such avoidance is most likely to occur in cases where the volume of sales is large, and the overall profits are high. Moreover, since voluntary payments cannot be enforced, avoidance is most likely where the product is to be commercialized under patent protection. These factors all point to avoidance being most likely in the case of maize.

As a general rule in the scenarios, a background rate of avoidance is assumed: 5 for Annex 1 crops, and 0 for non-Annex 1 crops. In addition, in the case of maize, an additional

[21] See Annex, section A.4.

avoidance of one half of the percentage of the area of maize planted to transgenics (i.e. half of 26,[22] or 13) is added. Scenario 6 compares a projection at these levels with a projection that doubles the background rate to 10, and assumes 100 avoidance for the full market share of transgenic maize (i.e. adds the full 26).

However, the use of areas planted to maize as the basis of the assumptions is conservative, because while transgenic varieties represent 26 percent of the *area* planted to maize, they represent fully 57 percent of the *value* of the international maize seed market.[23] A third projection is therefore made on the basis of a background rate of 10 precent, and 100 percent avoidance of the full market share of transgenic maize (i.e. adds a full 57 percent). The difference between the projections under these three sets of projections is shown in Table 3.5, in US dollar terms, and as a percentage decline from the higher rate.

Table 3.5 Projections at varying degrees of avoidance, at 2081

Avoidance	US$ million	Percentage
5% +13% for maize	55.99	
10% +26% for maize	56.33	-6
10% +57% for maize	48.31	-19.5

While these projections show the importance of mandatory payments for potential income to the Treaty, this factor must be viewed in conjunction with the rate of voluntary payment, which is analysed in scenario 5, because the whole area of Figure 3.18 under the lower line derives from voluntary payments, here at 50 percent.

Scenario 7: The value of Annex 1 and the potential value of non-Annex 1 material

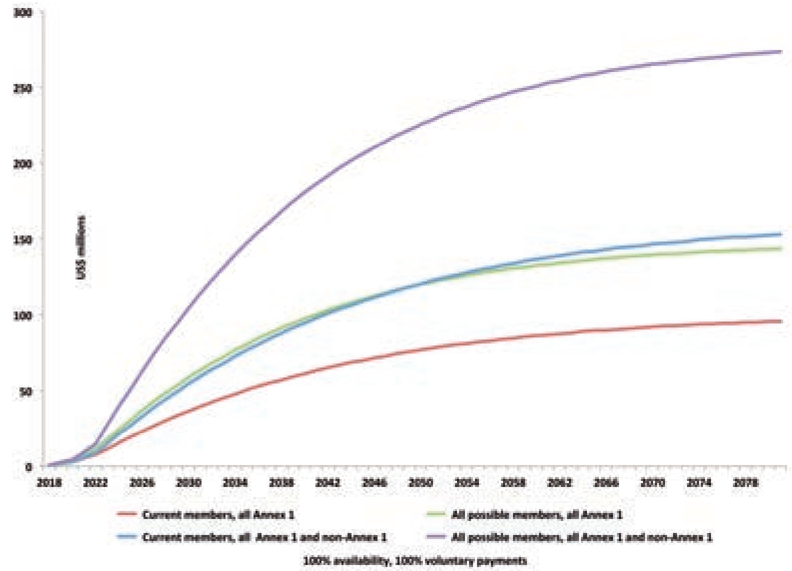
The Multilateral System covers only those crops currently in Annex 1 to the Treaty. In all the other scenarios, only those non-Annex 1 materials that are already being made available under the terms and conditions of the SMTA as a sovereign decision of the countries involved are valued. This scenario (runs 2, 21, 22 and 23), however, projects and compares the values that derive from Annex 1 materials, and the values that might derive from non-Annex 1 materials, should the Governing Body decide to expand the list of crops in Annex 1. Four projections are made, on the basis of membership, and of whether non-Annex 1 materials are included. In each projection, the assumptions are that the materials in question (Annex 1 and non-Annex 1 materials) are made fully available, that voluntary payments are made at 100 percent, and the standard avoidance rate is assumed.

Figure 3.19 shows nearly the full potential of the Treaty, under each of these sets of assumptions. Projected total income at 2081 for each of these is summarized in Figure 3.20. The growth of membership from the current situation to all possible members would increase the potential annual income by 59.5 percent. The expansion of the list to non-Annex 1 material would increase the potential annual income by 47.5 percent.

22 Chapter 2, Figure 2.10.

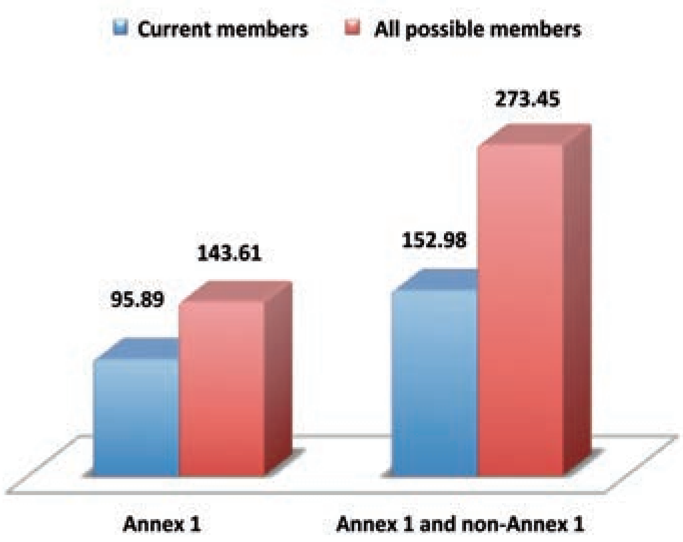
23 Calculated from Appendix 3.1, Table 5.

Figure 3.19 The potential of increased membership and the possible expansion of Annex 1



Source: FAOSTAT

Figure 3.20 Increased membership and the possible expansion of Annex 1 projected annual income, at 2081 (US$ million)

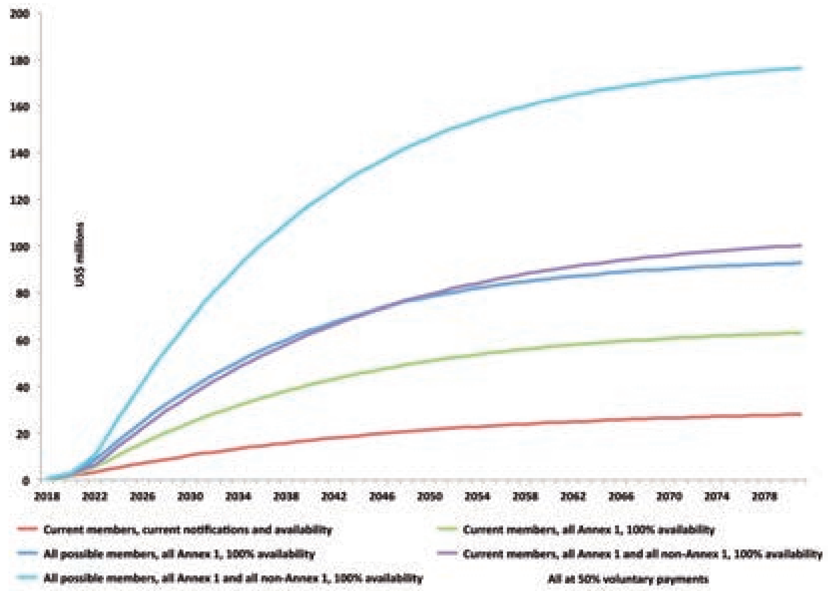


Scenario 8: Levels and speed of income under various scenarios

Scenario 8: Levels and speed of income under various scenarios

Figure 3.21 (runs 2, 23, 24, 25 and 26) provides a summarized overview of the relative levels of potential income to the Treaty, under different sets of assumptions. A 50 percent voluntary payment rate is assumed in all cases, as is the standard avoidance rate.

Figure 3.21 Levels and speed of income under various scenarios



The variables in Figure 3.21 and projected annual values may be tabulated as follows (Table 3.6):

Table 3.6 Projections by membership, and Annex 1 and non-Annex 1 material, at 2081

Members	Availability	Annex 1	Non-Annex 1	US$ million
Current	Current	Yes	No	28
Current	100	Yes	No	60
All	100	Yes	No	93
Current	100	Yes	Yes	100
All	100	Yes	Yes	176

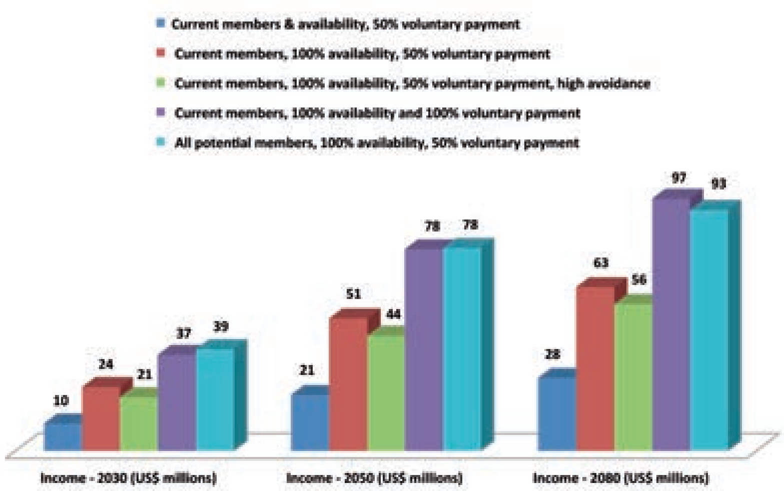
An alternative set of projections, which do not include the possibility of an expansion of the list in Annex 1 is provided in Figure 3.22, which expresses the assumptions in Table 3.7.

Table 3.7 Projections by membership, availability, voluntary payment and avoidance, at 2081

Members	Availability-(%)	Voluntary payment (%)	Avoidance (%)
Current	Current	50	5 + 13
Current	100	50	5 + 13
Current	100	50	10 + 26
Current	100	50	5 + 13
All	100	100	5 + 13

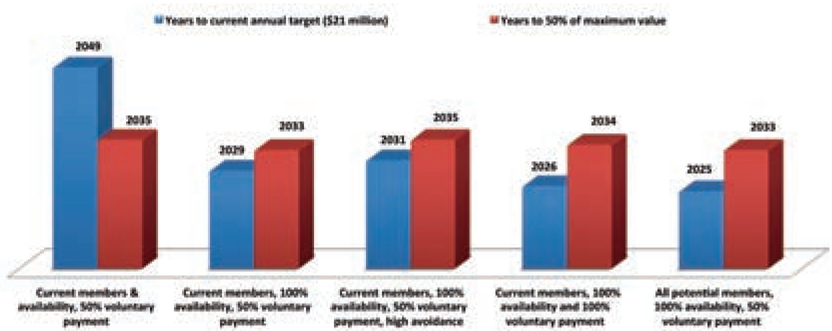
On the basis of these assumptions, Figure 3.22 displays the projected annual income at 2030, 2050 and 2080.

Figure 3.22 Income at 2081, under various scenarios



Of crucial importance for understanding the potential development of the benefit-sharing potential of the Treaty is the time factor, that is, the speed at which income is likely to build up. Two indexes that can help visualize the time factor in the these scenarios are: the number of years it would take to reach a level equal to the current annual fund raising target, which the Governing Body currently set at $21 million annually; and the time it would take to reach half the projected maximum annual income, as presented in Figure 3.23.

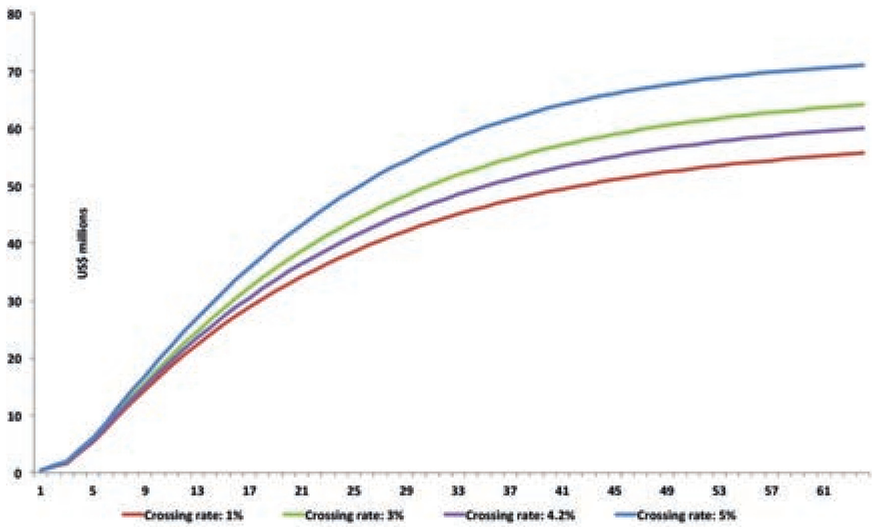
Figure 3.23 The time factor



Scenario 9: The effect of crossing in the breeding pool.

Scenario 9: The effect of crossing in the breeding pool

Figure 3.24 The effect of various rates of crossing in the breeding pool

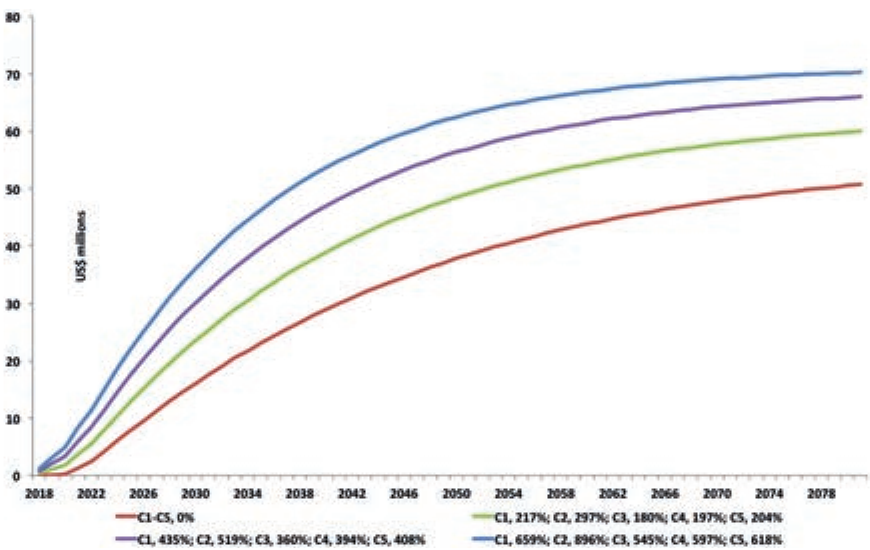


The effect of the crossing of SMTA materials with non-SMTA materials in the breeding pool, addressed in this scenario (runs 2, 26, 27 and 28), and presented in Figure 3.24, is to place all products of the cross under the terms and conditions of the SMTA, either if then transferred to a third party, or incorporated in a commercialized product. In effect, a single SMTA material in the ancestry of a commercial product renders voluntary or mandatory payment obligatory.

This factor is therefore very sensitive. Expressed in terms of an annual crossing rate, a 4 percent increase in the rate, from 1 percent to 5 percent, translates into an increase of 25 percent (from a projected $56–71 million) in income, at 2081. It therefore has a substantial multiplier effect, and in this light the accuracy in the estimate of this factor is as yet inadequate.

Scenario 10: The increased likelihood of a product being produced when improved materials have been accessed

Figure 3.25 The effects of the use of improved materials on the proportion of materials leading to products



Scenario 10 (runs 2, 30, 31 and 32) compares various rates of the factor that models the effects of the proportion of improved materials to the number of products.[24] In this iteration of the model, this factor is applied only to the materials of the CGIAR, which represent about 14 percent of total current holdings at 100 percent availability.[25] For

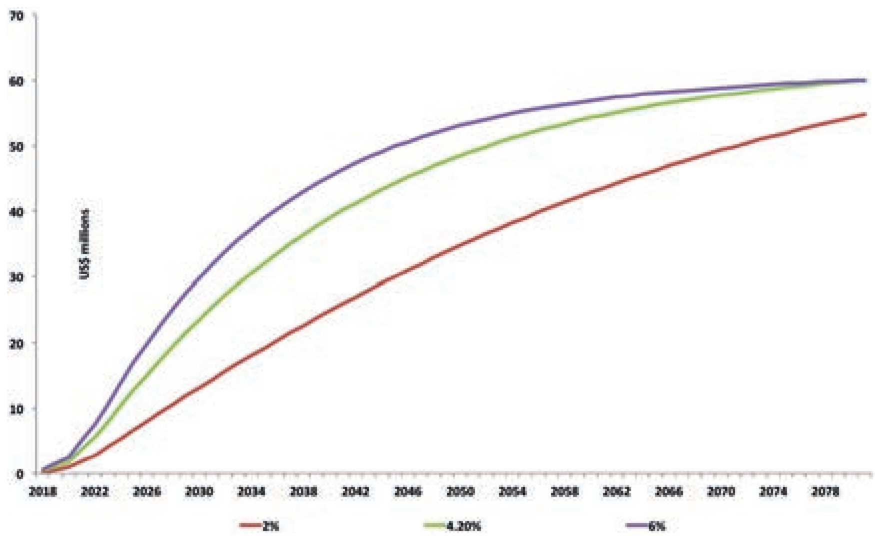
[24] δI in notations. See Appendix 3.1.

[25] See Table 3.8: 628 200 of 4 504 641 accessions.

Annex 1 materials, between about 85 percent and 95 percent of the CGIAR's releases are of improved materials.[26] Given the limited number of accessions to which this factor has been applied, the factor is sensitive, as Figure 3.25 shows. Its effects are significant, at the values assumed in the model. Moreover, unlike the effect of the annual rate of introduction of material into the breeding pool, discussed in scenario 11 below, it affects the absolute volume of products, and thus the level, rather than the speed, of income to the Treaty.

Scenario 11: The importance of the annual rate of introduction of materials into the breeding pool

Figure 3.26 The effects of differing annual rates of introduction of materials into the breeding pool



Scenario 11 (runs 2, 33 and 34) varies the speed at which material enters the breeding pool. The proportion of the constituents of the annual increment (material without SMTAs, with SMTAs from national collections, and with SMTAs from international institutions) is unchanged, so the percentages applied here do not refer only to material subject to an SMTA. As Figure 3.26 shows, the effect of increasing the rate of introduction is not to increase the absolute terminal level of income, but to increase the speed at which income builds up. To illustrate this, the percentage difference in income at various dates is given in Table 3.8.

26 γ in notations. See Appendix 3.1.

Table 3.8 Increase in speed of income with increase of the introduction rate

	2024		2034		2064	
Incorporation rate (%)	**US$ million**	**%**	**US$ million**	**%**	**US$ million**	**%**
2%	5.38	–	18.02	–	45.59	–
4.20%	10.39	48	30.53	41%	55.82	18
6%	13.92	25	37.31	18%	57.82	3

The speed of increase is greatest in the early period, and the effect tapers off after peaking at a date that is earlier, the higher the incorporation rate assumed.

3.3 The alternative payment option in SMTA Article 6.11

It has not been not possible to incorporate in the model consideration of the possible income that may derive from the alternative payment option under SMTA 6.11. Too many stochastic variables are involved. This is because the payment provisions of Article 6.11 are structurally different to those of Articles 6.7 and 6.8. Whereas the latter provide for payments, *from the time of commercialization*, for a product derived from a *specific* plant genetic resource received under an SMTA, the provisions of Article 6.11 require an *immediate mandatory yearly payment* by the subscriber for *any* of his product of the crop in question, whether or not these are available without restriction, and whether or not they incorporate materials accessed through an SMTA. There is also no basis on which one may estimate the relative number of recipients who might opt for the Article 6.11 option. To date, no recipient has accepted to accept this option, and discussion with the industry confirms that the rate of payment of 0.5 percent of sales on all one's products is seen as much more onerous than the payment of 1.1percent, less 30 percent (i.e. an effective rate of 0.77 percent) on the sales of a single product.

A totally hypothetical projection of maximum possible income at 2081 can be made, however, by running the model with the following set of assumptions: that all recipients have already agreed to accept Article 6.11, and therefore that mandatory payment applies to all products, at the rate of payment of 0.5 percent of the sales price of all products. It is then possible to test the effects of varying membership; whether Annex 1 material only, or whether both Annex 1 and non-Annex 1 material is included, and what level of availability is assumed. The relative value of the different crops/crop groups can also be projected. The results of this exercise are shown in Table 3.9.

Table 3.9 Hypothetical projection of maximum possible income from SMTA Article 6.11 (US$ million)

At a payment rate of 0.5%					
Wheat	**Rice**	**Maize**	**Other Annex 1**	**Non-Annex 1**	**Total**
Current members, Annex 1 only, and current availability					
7.53	3.41	9.82	11.34	-	32.11
Current members, Annex 1 only, and 100% availability					
11.83	5.41	26.20	21.54	-	64.97
All possible members, Annex 1 only, and 100% availability					
15.18	7.38	44.05	27.34	-	93.95
All possible members, Annex 1 and non-Annex 1, and 100% availability					
15.18	7.38	44.05	27.34	84.32	

3.4 Conclusions of the modelling exercise

The first conclusion that can be drawn concerns the overall potential of benefit-sharing under the Treaty. If other factors are favourable, the annual sums that could become available are large. Even without the possibility of an expansion of *Annex 1*, if current members make all their resources available immediately, the evaluated annual return by 2030 could reach $24 million. The projection with the material currently known to be available, however, is only $10 million. A corollary of this point is that the effective availability of materials by the current membership should be an immediate priority. Every delay in reaching full availability will reduce the amount available at any future date, and push forward the date of reaching the current annual target. A further factor that would substantially increase the flow of funds is membership. If all potential members had already joined the Treaty, $39 million annually might be available in 2030.

The model has shown the key importance of the *ex situ* collections of international institutions, as well as the substantial potential value of the non-*Annex 1* materials that a number of members are already making available under the terms and conditions of the SMTA. Further availability of non-*Annex 1* materials would increase this promising additional revenue stream. Similarly, any decision by the Governing Body to expand the list of crops in *Annex 1* has the potential to greatly expand the flow of income to the Benefit-sharing Fund.

The sums cited in these conclusions are based on the assumption that voluntary payments will be made at rate of 50 percent. This assumption is based on no evidence, and there is much to suggest – in particular, the comments made by industry peer reviewers on an initial report – that voluntary payments will never be significant. Indeed, a games theory analysis shows the impracticality of a system based on voluntary payment, when no single recipient can afford to make substantial payments, without competitors having to make similar payments. A second factor of great importance is the likely avoidance of the use of materials from the Multilateral System, which will reduce income proportionally. The scenarios have shown the key role of maize in the potential income to the Treaty, because it is currently the only crop in which a substantial proportion of seed – of transgenic varieties – is marketed under patents, and therefore attracts mandatory payments. Avoidance by breeders of transgenic varieties would proportionally reduce the only mandatory source of income. Combined with a failure to make substantial voluntary payments, the projected income to the Treaty would evaporate. While members may take actions to increase their performance, avoidance and voluntary payments are solely at the discretion of recipients of PGR, in accordance with the current provisions of the Treaty, and there is no legal obligation on them either to use materials that require agreeing to the terms and conditions of the SMTA, or to make voluntary payments.

Finally, the model suggests that, even under favourable assumptions, the initial build-up of income will be slow: with current membership and availability, it will be 38 years before the current fund-raising target is reached. Furthermore, this does not take into account possible technological developments that may change the process of plant breeding, and possibly reduce the use of plant genetic materials from the Multilateral System. Even under two highly favourable sets of assumptions – (i) that all members immediately make available all their material, and that voluntary payments in fact reach the same level as mandatory payments; or (ii) that all potential members immediately join the Treaty and make available all their materials, and voluntary payments reach a 50 level – it would take approximately 15 years before the current annual target is reached.

The potential income, then, is high, but current projections are low, and obstacles to substantial success under the current arrangements cannot be ignored.

3.5 Strengths and weaknesses of the model

The model, although rudimentary, appears to be robust and capable of providing useful policy insights.

The model provides information on the effects of the behaviour of Treaty members, simulating their effectively making available or not making available their Annex 1 materials, in accordance with the Treaty, and the impact that this will have for the time required for the build-up of substantial income to the Benefit-sharing fund. It is also useful in quantifying the potential return to the Treaty from non-Annex 1 materials that countries are, as a sovereign decision, already making available under the terms and conditions of the SMTA, as well as the total potential value of non-Annex 1 materials.

The main data sets that the model manipulates (world crop holdings, **C**; and the commercial value of the world seed and planting material market, **V**) would benefit from improvement, but already appear to be relatively sound. Of the two, **V** is the less certain, as is clear from the review of available data, and from the many proxies that were needed to develop the estimates, in Chapter 2. Further research could improve these values.

An important but opaque set of factors relates to the behaviour of users of materials available under SMTAs, and, in particular, to two factors: avoidance (υ) and the real rate of voluntary payment (ρ). Hard information on these factors is not only not available, but is unlikely to become available for a considerable period of time, and then only from analysing the data regarding accessions released and payments made. Nonetheless, the survey presented in the Annex shows that many actors in the plant breeding industry expect avoidance to be very high, and voluntary payments to be very few. The model, in scenarios 5 and 6, is able to simulate how real behaviour, with regard to these two factors, is likely to condition the Treaty. They are critical in any realistic evaluation of the benefit-sharing potential of the Treaty.

A further set of factors are related to technical issues, where improvements in the information base and in the construction of the model could greatly improve its performance. These include relatively static factors, in particular, the development time per crop/crop group (κ) and research intensity (β), although, as currently constructed, they do not have extremely large effects on the projections of the model. More important factors are: the introduction of material (α), diffusion (λ), and the ratio of improved materials/unimproved materials (γ) and its consequences for the speed of uptake of material (δ**1**) and the proportion of materials leading to products (δ**2**). These are all factors that have a high multiplier effect within the algorithm, and their more precise calibration would increase its predictive power.

In considering the time factor, it is obvious that the further the projection into the future, the more likely it is that the current dominating conditions will have changed. Given the speed at which technology is developing, the use of genetic material in plant breeding will undoubtedly be very different from what we know today, even in 20 years. Projecting ahead to 2081, the world is sure to have changed so much that the economics of plant breeding and the structure of the market will be very different, with unpredictable implications for the Treaty. No model can intelligently address such unpredictability. This is not a weakness of this particular model, but a general fact.

Major current weaknesses in the model include the lack of a methodology and data to model the value of materials that do not proceed directly from *ex situ* collections, but from breeding programmes. The volume of such materials is currently uncertain, except in the case of the CGIAR collections, and the model would benefit from covering such materials as well. Similarly, a methodology to reflect the materials that are made available by natural and legal persons would be of value, including through their release as commercial products, and as contributions both to *ex situ* collections and to further breeding programmes.

A more difficult task would be to assess the potential volumes and value of *in situ* materials, which are to be made available in accordance with Article 12.3h of the Treaty. The incorporation of such an element in the model has the potential to reflect with greater accuracy the importance of materials held by developing countries.

The expansion to other crops, in particular to a representative sample of vegetable crops, would appear to be a priority for further work. Discussions with breeders suggest that these materials are of high value, and the identification of individual crop seed market values and the calibration of the factors that describe their use would be an important next step.

This kind of model is primarily an analytical tool, rather than a predictive instrument. For this reason, we would suggest focusing any further development of the model on identifying the most important questions to be addressed, and on improving and extending the model with these questions in mind, rather than complicating the algorithm by introducing a wide range of other factors that are not of analytical value for policy development. Diminishing returns to increased effort and investment will otherwise soon set in.

The model has not attempted to simulate directly the possible income to the Treaty from the workings of Article 6.11, because the factors involved are very different. We suggest not attempting to introduce it directly into the logarithm.

Finally, the initial survey of plant breeders (see Annex) that sought values, however approximate, with which to populate the model, has shown the willingness of breeders in both the public and private sectors to contribute their knowledge and experience. Any further development of the model should seek to draw plant breeders more closely into its design, and into the generation of the data necessary to make it function effectively.

Chapter 4

INTELLECTUAL PROPERTY, INFORMATICS AND PLANT GENETIC RESOURCES

Paul Oldham and Stephen Hall

4.1 Introductory note

This chapter focuses on the intellectual property issues around PGR under the Treaty. Specifically, it focuses on the use of informatics techniques to identify PGR for food and agriculture within the international patent system.

The extension of intellectual property protection to agricultural crops and forages has been a significant focus of debate, in particular, the extension of patent protection to plants and their components; an extensive literature exists that considers the implications of property protection for food and agriculture. However, intense interest in patent protection in the field of food and agriculture has not been accompanied by equally intense interest in generating empirical data on what is actually happening with respect to patent activity for food and agriculture. This is a common pattern in international debates on genetic resources in general. This chapter aims to contribute to resolving this problem in the case of the world's major food crops and forages by providing a statistical baseline for the analysis and interrogation of trends in patent activity. As such, this chapter focuses on methodological issues in establishing baseline data and explores potential ways forward in addressing more complex questions such as the relationship between public germplasm collections, research and development, and intellectual property.

The main focus of this chapter is on patent activity. We divided our empirical work on patent activity into two segments:

- the elucidation of patent statistics for PGR for food and agriculture in general;
- the elucidation of patent statistics for Annex 1 food crops and forages in particular.

The patent system is a global electronic information system consisting of in excess of 60 million documents in multiple languages. One of the primary purposes of the system is information retrieval for assessing prior art during the examination process and fulfilling the longer-term purpose of the patent system, which is to disclose new and useful inventions to the public for wider use. Considerable advances have been made in recent years to make patent information more widely accessible to the public through the development of public electronic databases such as the European Patent Office (EPO) esp@cenet worldwide database. In addition, in 2006, the EPO released the World Patent Statistical Database (PATSTAT) in order to facilitate the development of gold standard patent statistics. This initiative forms part of wider work by the OECD Patent Statistics Taskforce to advance methodological development for patent statistics and initiatives by individual agencies such as WIPO in promoting methodological development in the form of patent landscape studies. This chapter builds on these advances and applies them to PGR for food and agriculture.

In approaching the presence of food and agriculture in the patent system, researchers are immediately confronted by the problem of where and how to begin in interrogating a system consisting of millions of documents. In practice, there are two main approaches:

- use of the IPC as a system of over 70 000 alphanumeric classification codes used to describe the contents of patent documents developed by the IPC Union and administered by WIPO;

- searches by species and common names in patent texts using whole text databases.

In approaching patent activity, there is also the question of which tools to use. Thus, public databases such as EPO esp@cenet are excellent for access to individual or small numbers of records, but it is not readily possible to conduct large-scale analysis using these tools. In contrast, commercial database providers, notably Thomson Innovation, give detailed access to patent activity from the main patent jurisdictions and allow to download up to 30 000 records at a time. However, the data are limited to the main patent jurisdictions, as are opportunities for interrogating patent data using large numbers of species names. In contrast, PATSTAT provides access to over 60 million records for statistical analysis. However, PATSTAT is limited to data fields such as the titles and abstracts together with other information fields, and cannot be used for large-scale text mining.

In developing a statistical baseline for patent activity for food and agriculture in general and food crops and forages covered under Annex 1 in particular, a hybrid approach is required. This approach recognizes the strengths and weaknesses of existing tools and exploits the increasing availability of large-scale computing power to overcome obstacles in interrogating patent data.

The following section focuses on establishing the statistical context for patent activity for PGR using three main tools:

- the IPC;
- the Thomson Reuters commercial database Thomson Innovation focusing on the main patent jurisdictions;
- the EPO World Patent Statistical Database (PATSTAT) for the elaboration of global statistical trends.

The key outcome of this approach is to progressively capture and expand the statistical context of patent activity for PGR by progressively scaling up. This approach then provides the context for identifying Annex 1 species discussed in Section 4.3. We now turn to the use of the IPC as a means of defining PRG in the patent system.

4.2 Establishing the statistical context for patent activity for plant genetic resources

4.2.1 Introduction: the International Patent Classification

The international patent system uses a hierarchical alphanumeric classification system, the IPC, to describe the contents of patent documents. The IPC consists of approximately 70 000 classification codes and is regularly reviewed and updated. As demand for patent information grows, there is an increasing tendency to use classification codes to describe the contents of documents as fully as possible. This means that patent documents are frequently awarded classification codes in more than one technology area.

We initiated our research by selecting a sample of 70 969 patent documents across all years in Thomson Innovation with the classification code A01H for New Plants or Processes for producing them. By adopting this approach, we began with a known starting point for PGR. Using Vantage Point analytics and text mining software from Search Technology Inc., we then reviewed all other IPC codes that were linked to A01H in the data to identify additional areas of the classification that specifically refer to PGR. Our assumption in adopting this approach was that patent activity involving PGR in areas outside A01H would inevitably become linked to A01H over time.

In practice, agricultural PGR are confined to three main areas of the patent classification: (i) new plants or processes for producing them (A01H); (ii) peptides (C07K); and (iii) genetic engineering (C12N). Other important areas of the classification system of direct relevance to plants include biocides (A01N), biotechnology processes using microorganisms (i.e. C12P), A23L (foodstuffs) together with recombination DNA technology (C12N15/09) and measuring or testing using nucleic acids (for DNA sequencing under C12Q1/68). However, for the purposes of information retrieval to inform policy debates, it is important to note that these classification codes do not necessarily involve claims over plant genetic material or are very general (i.e. recombinant DNA technology). The inclusion of these types of codes for statistical purposes would seriously distort the resulting statistics by including data on a range of other organisms (i.e. humans, animals, etc.). We therefore focused on defining the classification as tightly as possible while seeking to ensure data capture for the majority of patents involving claims over PGR.

Table 4.1 sets out the main classification codes deployed for information retrieval for patent statistics for the period 1900 to January 2012.

Table 4.1 Primary international patent classification codes for plant genetic resources

Classification code	Description	Level
A01H	New plants or processes for obtaining them; plant reproduction by tissue culture techniques	Sub-class
C07K14/415	Peptides having more than 20 amino acids –from plants	Sub-group
C12N05/04	Undifferentiated human, animal of plant cells, e.g. cell lines; tissues, cultivation or maintenance thereof; culture media thereof – plant cells or tissues	Sub-group
C12N15/05	Mutation or genetic engineering – preparation of hybrid cells by fusion of two or more cells, e.g. protoplast fusion – plant cells	Sub-group
C12N15/29	Mutation or genetic engineering – genes encoding plant proteins, e.g. thaumatin	Sub-group
C12N15/82	Mutation or genetic engineering for plant cells	Sub-group

Our research was limited to the main jurisdictions in the Thomson Innovation commercial patent database consisting of the United States, the EPO, the Patent Cooperation Treaty, France, Germany, the United Kingdom and Japan. Wider work using PATSTAT is discussed below.

The Thomson Innovation specific query used was (A01H) OR (C07K0014415) OR (C12N000504) OR (C12N001505) OR (C12N001529) OR (C12N001582). The classification codes provided in the Table 4.1 can be adapted to meet the specific formatting requirements for querying other patent databases.

At this exploratory stage of the research using Thomson Innovation we were able to identify a total of 89 912 documents for PGR as defined by the IPC Classification Codes provided above.

4.2.2 Trends in the major patent jurisdictions

We began our analysis of the statistical context by focusing on results from Thomson Innovation using Vantage Point analytics software. This allows researchers to gain easy access to all the major patent data fields and to review thousands of documents in an efficient manner.

We would emphasize that patent data requires considerable care in interpretation. As a starting point, it is important to note that raw US patent data from Thomson Innovation includes data on US Plant Patents as a specific form of protection for plants in the United States that is distinct from utility patents. In Thomson Innovation these documents are generally labelled USPP, where the PP stands for Plant Patent, or with the kind code P (i.e. P1, P2, P3, P9). US Plant Patents typically involve only one claim over a specific plant variety and are dominated by ornamental plants.

A total of 21 795 US Plant Patent publications were identified in the data with 68 111 documents identified as patent publications. For the purposes of this study we decided to simply exclude US Plant Patents from the analysis in the interest of methodological clarity. As with PVP, it remains to be seen whether the material claimed contains contributions from plant genetic material covered under the Multilateral System. Plant Patents are not further considered in this chapter.

Patent data can be counted in three primary ways: (i) first or 'priority' filings that can be measured using INPADOC first family member identifiers; (ii) patent publications of applications and grants, and; (iii) publications of linked applications and grants in the form of family members.[1] Each of these types of counts provides an important layer of information in developing an understanding of activity for PGR. Counts by family members in Thomson Innovation are complicated by multiplier effects from combinations of records and data on family trends is therefore considered using PATSTAT. Table 4.2 illustrates the basic activity for PGR in the main jurisdictions using the INPADOC first family member (for International Patent Documentation Centre under the EPO) as the first filings.

Table 4.2 Patent activity by publication authority, 1900 – Jan 2012

Publication authority	INPADOC First Family Members	
(First filings)	Publications main jurisdictions	
EPO	6 400	13 146
EPO applications	-	10 661
EPO grants	-	2 485
France applications	1 425	1 459
Germany	2 056	2 477
Germany applications	-	840
Germany European translations	-	1 303
Germany grants	-	334
Japan	7 401	10 906
Japan Applications	-	7 964
Japan grants	-	2 942

1 First filings were calculated by combining the 68 111 publications onto their respective 23 193 INPADOC first family members, which reduces the data to the earliest known filings. EPO and PCT (WO) filings are typically secondary filings except where applicants choose to file directly with the relevant offices.

Publication authority	INPADOC First Family Members	
UK applications	301	326
US	14 349	25 690
US applications	-	12 672
US grants	-	13 018

4.2.3 Trends in first filings

First filings of patent applications are commonly used as an indicator in economic studies because they are the closest in terms of time to the date of innovation of a claimed invention and research and development expenditure. The count of first filings presented in Figure 4.1 was developed by duplicating the 68 111 patent publications identified above onto their respective INPADOC First Family Member numbers. This has the effect of reducing the data to only the first (and earliest) filing in the data set. In total, excluding plant patents, we identified 23 193 first filings in the data. Data on first filings only refers to patent applications rather than subsequent grants. Figure 4.1 shows trends in first filings displayed by the priority year (year of first filing).

Figure 4.1 Patent trends by first filings, priority year

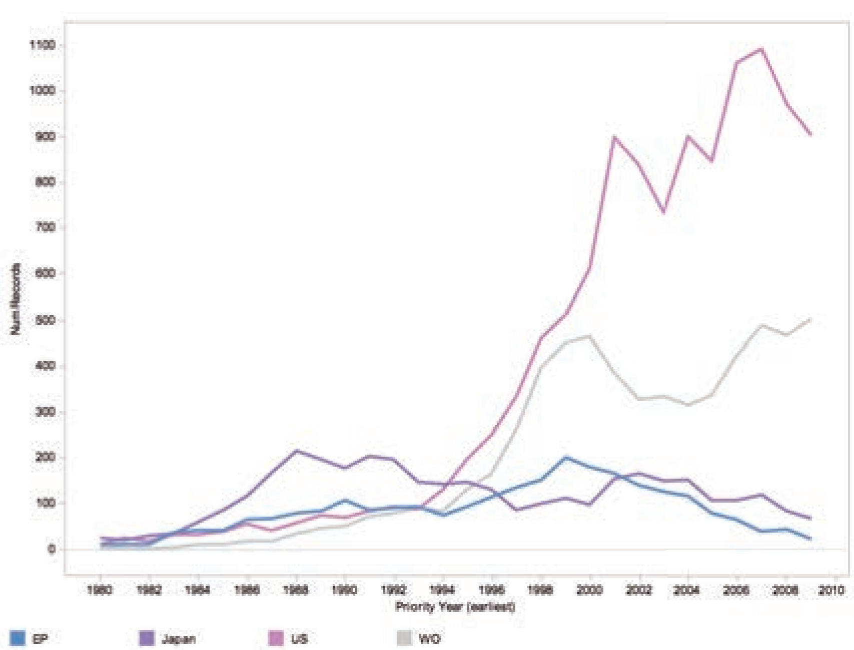


Figure 4.1 only presents data from 1980 onwards with very limited activity traceable in the data back to the first record in 1907. This will typically involve documents that have been reclassified in subsequent years as the IPC system developed. A brief review of the titles of historic documents suggested that they were mainly concerned with methods and apparatus that relate to plants and agriculture.

In considering Figure 4.1, it should be noted that activity for France, Germany and the United Kingdom is low, falling in the 100–200 filings mark and is therefore not displayed. In practice this low activity may reflect the use of regional and international instruments as the preferred route to pursuing patent rights by applicants from these countries. In the case of the Patent Cooperation Treaty (PCT), it should be noted that these applications are typically preceded by a first filing in a national office, and are shown here to demonstrate trends (measured on one publication only) in filings over time.

On balance, and consistent with previous research, we observe an increasing trend in filings into the 1990s with activity levelling off and beginning to display a declining trend from 2000/01 onwards. In the United States, following significant growth until 2000, the situation becomes unclear from 2001 onwards. In wider research, a decline in filing activity after 2000 and notably in 2001 has been interpreted as reflecting the bursting of the biotechnology bubble and the tightening of patent office rules regarding biotechnology patents (i.e. for Expressed Sequence Tags, or ESTs). Filings then staged a partial recovery before showing a decline in 2008 that is likely to reflect the financial crisis. Because of lag times in the availability of data on first filings (see below), the apparent decline into 2009 is likely to be exaggerated by a lack of data. However, a decline in filing trends is clearly visible in US filings prior to the onset of the data lag.

With respect to PGR, it should be noted that patent data may also be susceptible to decisions by applicants on whether to pursue PVP or both plant variety protection and patent protection based on considerations of cost (notably for patent protection). In future research, it would be interesting to compare trends in patent activity with trends in filings for PVP to assess whether applicants decided to concentrate on PVP filings at the expense of patent filings during the financial crisis.

With respect to the PCT (WO), patent trends are more significant than for any single patent office because they reflect demand for patent rights in more than one country. Under the PCT, an applicant submits a single patent application and then, within set time periods, makes decisions about which jurisdictions they wish to pursue protection in. This takes the form of regional/national level applications (referred to as 'entering the regional/national phase') at which point the application becomes a formal application in the member state and, if relevant fees are paid, may be examined and become a patent grant. As such, PCT documents are always applications and cannot themselves be grants. What is clear in the PCT data is that after a period of growth in the 1990s, the number of filings had entered a trough and flattened out before showing signs of pick up in the late 2000s (see below). Data for the European Patent Convention (EPC) closely match the trends for the Patent Cooperation Treaty but appears to show a more radical decline than the PCT (WO).

Considerable care is required in interpreting data on first filings as it moves closer to the present day. The reason for this is that patent applications and grants are typically published two years after they are filed. As a result, there is a time lag factor of at least two years in filing data, which creates the impression of a radical downturn the closer we move to the present. For this reason, filing data are only shown until 2009, with a reporting effect that is probably observable for data for this year. Accurate data for this year will only become apparent when more data enter the system in future years. As highlighted in wider work by the OECD, this serves to illustrate that timeliness is a major issue in using patent data to develop indicators. To address this problem, organizations such as the OECD have developed 'now casting' methods that could potentially be applied in future analysis of trends for PGR.

4.2.4 Publication trends

As an original application passes through the system en route to becoming a potential patent grant, it is republished. When viewed as a global system, the republication of patent documents introduces a radical multiplier effect into patent statistics. Thus, a single application may be published in a single country as an application, a divisional or continuation application, a grant or a grant with corrections. In the case of international and regional patent applications, the original application is typically republished with a search report. When an application moves into the regional or international system, this effect multiples in accordance with the number of countries involved and can be mapped using patent family data (see below). In the case of PGR, our 23 193 patent filings resulted in 68 111 patent publications in the main jurisdictions, suggesting that each original filing is published approximately 2.9 times.

The importance of patent publications is that they are publicly accessible and allow researchers to identify trends in applications and patent grants. Figure 4.2 sets out trends in patent publications for the individual countries and instruments. When comparing Figures 4.1 and 4.2, note that the trends will be the same, but the peaks or troughs observable in Figure 4.1 for filing trends will typically appear two to three years later in Figure 4.2 on publications trends. Figure 4.3 breaks down the data for applications and grants.

Figure 4.2 Patent publication trends by jurisdiction/instrument

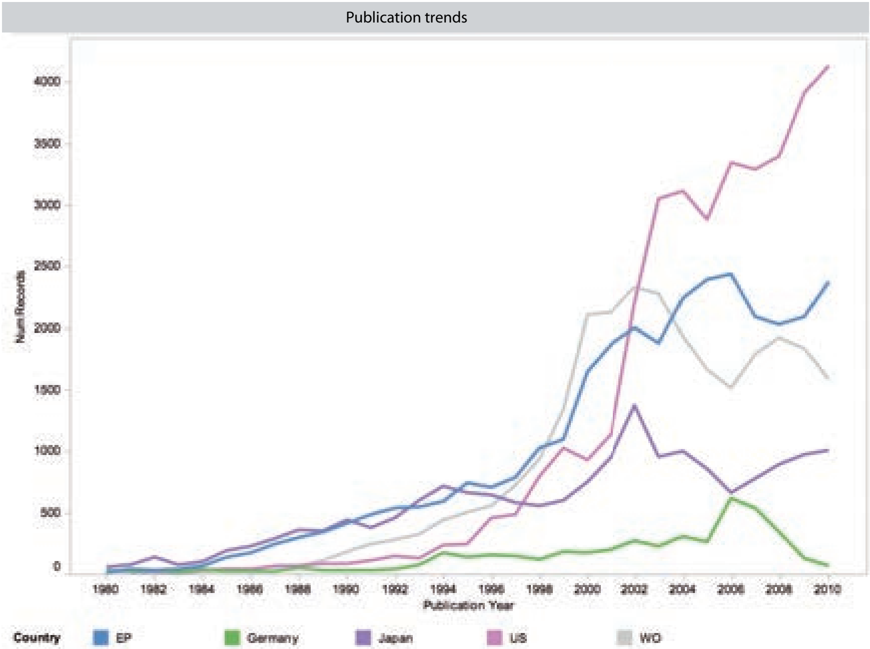
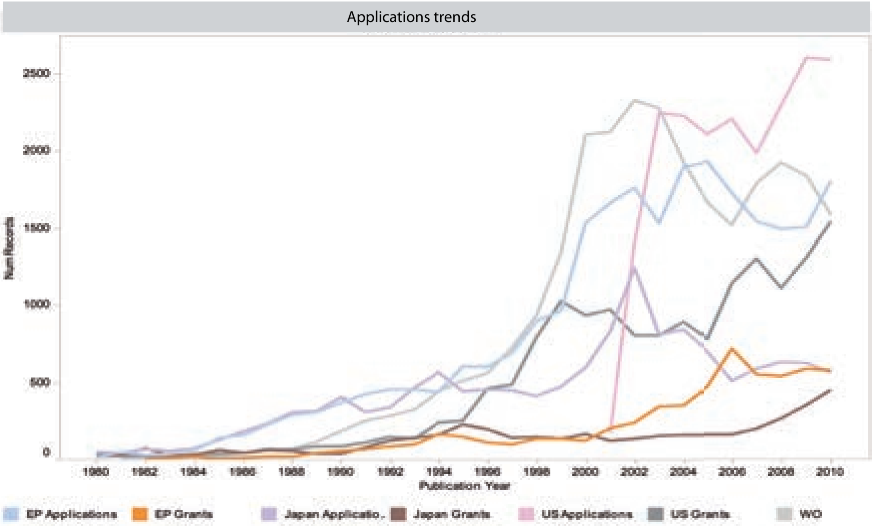


Figure 4.3 Patent trends by applications and grants



In considering Figures 4.2 and 4.3 a number of important observations need to be made.

First, prior to 2001, US Patents were only published when granted. From 2001 onwards, US patent documents were also published at the application and the grant stage in conformity with wider international practice. In order to distinguish patent applications and grants in the US data, patent publications prior to 2001 were reclassified as patent grants. The impact of the change to publishing patent applications and grants in the United States can be clearly seen in Figures 4.2 and 4.3. From 2001 onwards, there appears to be a radical spike in activity. This is, in fact, a reporting effect arising from the publication of applications rather than a dramatic increase in activity. In future work, it might be useful to 'back cast' US Patent application activity to minimize the impact of this reporting effect and to more accurately reflect US Patent activity for PGR in previous years.

Second, in Germany, a very high proportion of activity is reported as translations of EPC documents originally submitted in English or French into German. Under the EPC, applications may be granted by the EPO, and then enter into the national phase of the procedure where they are examined prior to award of a grant. What is unclear in the case of translated documents is whether they enjoy status as grants or applications. For this reason they are maintained as a separate category in the data. Future work could clarify this issue by engaging with legal status codes in the patent data to clarify if translations have become grants in Germany or other European countries under the EPC.

Third, Thomson Innovation data for certain jurisdictions, notably France and the United Kingdom, are confined to patent applications. In the case of the PCT administered by WIPO, applicants submit applications through one of the major offices or WIPO and subsequently make a decision about which countries they wish to pursue protection in. As such, and in contrast with the EPO, patent grants are not awarded under the PCT.

4.2.5 Priority filing countries

Up until now we have focused on establishing patent trends by using the patent publication authority. However, under the 1883 Paris Convention and regional and international patent instruments, patent applications may pursue protection in more than one country. Thus, in the United States, in excess of 40 percent of patent applications are filed by non-nationals of the United States. Insight into the origins of patent filings is provided by information on priority countries (countries of origin of filings) in patent data. Table 4.3 sets out the priority countries for patent activity in the main jurisdictions.

Table 4.3 Priority countries (first filings in major jurisdictions), 1980–2010

Rank	Priority country	Records	Rank	Priority country	Records
1	United States of America	15 887	21	Austria	35
2	WIPO (PCT)	9 863	22	Finland	34
3	Japan	7 500	23	Hungary	28
4	European Patent Office	6 723	24	Taiwan	25
5	Germany	1 906	25	Belgium	12
6	France	538	26	Malaysia	20
7	United Kingdom	898	27	South Africa	19
8	Australia	307	28	Brazil	19
9	Italy	90	29	Russian Federation	9
10	Republic of Korea	245	30	Iceland	7
11	China	141	31	Singapore	7
12	Denmark	101	32	German Democratic Republic (GDR)	5
13	Spain	95	33	Mexico	6
14	Canada	92	34	Poland	6
15	India	89	35	Cuba	5
16	Netherlands	73	36	Czechoslovakia	1
17	Israel	67	37	Portugal	4
18	New Zealand	59	38	Colombia	3
19	Switzerland	36	39	Czech Republic	3
20	Sweden	40	40	Luxembourg	2

In interpreting Table 4.3, it is useful to break down the data to identify the filings originating from other countries in a single jurisdiction. In total, in the period between 1980 and 2010, we identified 22 670 patent publications in the United States for PGR (excluding US plant patents). These publications originated from 12 679 first filings (INPADOC first family members).[2] To calculate the origins of the filings, we combined the data onto the INPADOC first family members to reduce the data to the original filings. We focus here on data from the United States.

Table 4.4 shows the top 20 countries/instruments of origin for patent publications for PGR in the United States.

2 Minor variance in the total number of U.S. first family members (12 685) is observed in Table 4.4 compared with the total numbers of first family members (12 679). This may potentially arise from combinations of first family numbers.

Table 4.4 Priority countries in US Patent data for plant genetic resources, 1980–2010[3]

Priority country	US filings	US grants	US applications
United States of America	12 685	8 522	7 947
WIPO (PCT)	3 260	1 502	2 630
Japan	692	453	415
European Patent Office	597	242	489
United Kingdom	410	271	210
Germany	328	201	220
France	180	115	100
Australia	172	93	127
Republic of Korea	127	58	111
Canada	59	46	32
Denmark	56	18	47
Israel	42	29	19
India	41	17	34
Italy	40	18	27
Netherlands	37	31	13
China	33	20	26
New Zealand	31	20	20
Spain	31	19	23
Switzerland	21	18	5
Sweden	20	13	14

In interpreting Table 4.4, it is important to note that references to the PCT as a priority refer to applications that enter a country through the PCT route, i.e. filed nationally or regionally and subsequently through the PCT for wider protection in multiple countries.

4.2.6 Patent applicants

Patent applicants (assignees) can be ranked using a variety of measures. However, it is important to note that patent applicant data are affected by the use of multiple variant spellings of names and subsidiaries that affects the status of the rankings. Cleaning patent applicant data is thus a significant issue in the development of statistics. Previous work to engage in large-scale assignee name cleaning has demonstrated that the effect of cleaning measures is to reinforce the position of top ranking applicants and to adjust the relative

[3] A first filing may be published more than once (i.e. as an application and grant) or subdivided into separate applications. Therefore the US grants and US applications figures will be higher than the number of filings linked to a particular country/instrument.

rankings. In future work on patent statistics for PGR, we propose that analysis should use the EEE-PPAT patent harmonized names list developed by Eurostat and the Catholic University of Leuven, and we illustrate this approach below for global PATSTAT data and Annex 1.[4]

In order to develop an indicative list to inform validation of the wider research, we engaged in basic cleaning of assignee names by using the Thomson Innovation long names approach. Thomson Innovation long names include codes that seek to identify common assignees that display multiple spellings and allow a means to exclude individuals. We excluded individuals using this approach and then grouped assignees names based on co-occurrence with an INPADOC first filing number. This approach captures and groups the majority of variant names. The top results are provided in Table 4.5.

Table 4.5 Top patent assignees (major jurisdictions, publication counts)

Rank	Assignee	1980–2010
1	Pioneer Hi-Bred Int Inc (Du Pont)	4 265
2	Monsanto Technology LLC	4 127
3	E. I. du Pont de Nemours and Company	1 941
4	Syngenta Participations AG	1 890
5	Basf Plant Sci Gmbh	1 618
6	Bayer Cropscience Gmbh	940
7	Univ California	823
8	Novartis AG	731
9	Stine Seed Farm Inc.	716
10	Calgene LLC	628
11	Zeneca Ltd.	624
12	Dokuritsu Gyosei Hojin Nogyo Seibutsu SH	586
13	Aventis Cropscience N.V.	565
14	Commonwealth Scientific and Industrial Research Organisation	483
15	Dow Agrosciences LLC	454
16	Bayer Bioscience N.V.	437
17	Cornell Research Foundation Inc.	429
18	Max Planck Society for the Advancement of Science (German: Max-Planck-Gesellschaft zur Förderung der Wissenschaften e. V)	415
19	Cropdesign N.V.	408
20	Hoechst-Schering Agrevo Gmbh	408

Table 4.5 presents the top 20 of the 5 365 patent assignees identified in the Thomson Innovation data. The top rankings in terms of activity are what would be expected within the agricultural sector. However, it is also apparent that additional work is desirable to identify

[4] See Du Plessis *et al., 2009; Magerman et al., 2009; Peeters et al., 2009.*

company and organizational ownership. Thus, Du Pont acquired Pioneer Hi-Bred in 1999 and will rise to the top of the rankings if this acquisition is taken into account.[5] In addition, the profile for the sector could shift if rankings were measured on, *inter alia*, patent grants and patents in force. Future work would ideally include analysis of company ownership and also examine institutional types (i.e. companies and universities) based on the standardized tables developed by EEE-PPAT for use with the World Patent Statistical Database.

Having demonstrated that it is possible to define PGR within the patent system and then move into the analysis of statistical trends within the main patent jurisdictions, we now move to the analysis of global level trends using the EPO World Patent Statistical Database (PATSTAT) to gain a fuller picture.

4.2.7 The global picture

The analysis of patent activity in this chapter has focused on the use of Thomson Innovation data and will be discussed in more detail below in relation to the Treaty. However, it is important to highlight that the international standard for the generation of patent statistics is the PATSTAT, which enables the generation of global statistics based on the DOCDB database of world patent data of the EPO. The limitation of PATSTAT compared with Thomson Innovation is that data are confined to the information on the front page of patent documents and text information is limited to the titles and abstracts. As we will see, this is an important limitation when seeking to identify plant genetic material under the Multilateral System with precision.

We briefly demonstrate this wider worldwide data using the October 2011 edition of PATSTAT using the same IPC criteria provided in Table 4.1.

4.2.8 Global trends

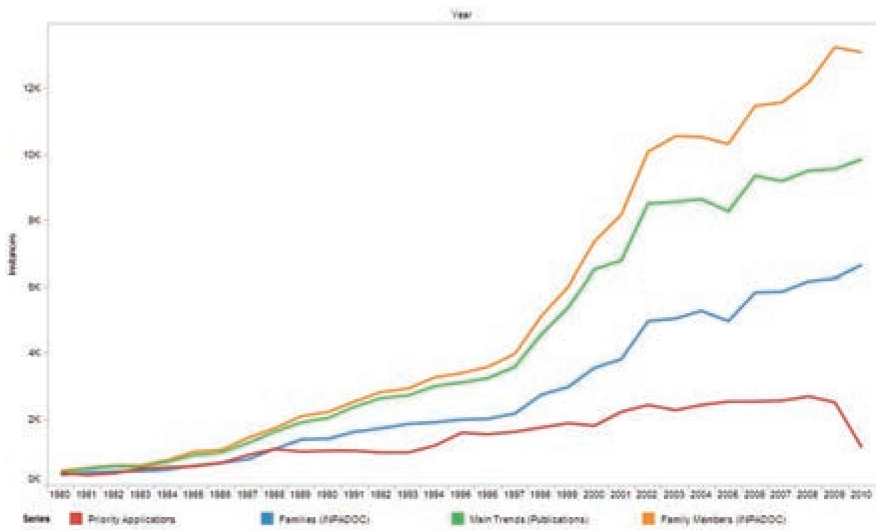
In interpreting this data, priority applications refers to the number of first filings (documents are counted only once). The availability of priority data decreases from 2008 onwards. Families refers to counts of the number of patent families based on INPADOC data. Counts of Main trends refers to counts of patent publications.

In total, across all years, we identified 43 288 priority filings, 34 830 patent families, 124 921 publications, and 136 030 family members based on the IPC definition for PGR.[6] In the period 1980–2010, we identified 40 970 first filings belonging to 32 391 patent families, 116 795 patent publications and 131 505 family members worldwide.

5 One limitation in taking into account mergers and acquisitions is that a company patent portfolio may be sold off or transferred in part to other companies. It cannot therefore simply be assumed that a patent portfolio is simply transferred wholesale to the new owners; this would require detailed analysis of data on patent reassignments.

6 The total numbers of global publications and the total number of family members should exactly match. In practice, calculation of global family members in PATSTAT is affected by 'artificial priorities'. Typically, artificial priorities arise from US provisional applications (priority filings that are not published and are thus artificial). In addition, artificial priorities arise from the loss of connection to a priority filing and year data that are grouped into the '900' identifier series in PATSTAT. For this reason, we focus only on total calculable publications.

Figure 4.4 Global trends, 1980–2010 (PATSTAT, Oct. 2011)



4.2.7.2 Priority filing countries

Table 4.6 repeats the exercise in identifying the priority countries of filing using PATSTAT across all years from 1907 as the data source. This immediately makes it clear that China, which ranks 16th as the country of priority in the main jurisdictions, rises to second place above Japan. This reflects a wider trend in which residents of China are pursuing patent protection across a range of sectors. However, patent applicants are primarily filed at the national level and do not presently have much impact on international activity compared with other countries such as Japan. The rise of Hungary in the overall rankings may require further investigation and, as with the Russian Federation, may reflect historic rather than recent patent activity.

Table 4.6 Priority countries by priority filings (PATSTAT 1907–2011)

Priority country	First filings
United States	17 656
China	6 130
Japan	5 154
European Patent Convention	1 866

Priority country	First filings
Hungary	1 616
Republic of Korea	1 381
France	1 229
Russian Federation	1 603
United Kingdom	1 038
Germany	945
Australia	878
Bulgaria	774
Romania	460
Spain	230
Italy	208
Canada	206
Belgium	200
Morocco	186
Denmark	151
Ukraine	143
United States	17 656
China	6 130
Japan	5 154

4.2.7.3 Publication countries (PATSTAT, 1907–2011)

Table 4.7 provides data on the main publication countries involved in patent activity for PGR.

Table 4.7 Publication countries (PATSTAT, 1907–2011)

Publication country	Publications
United States	24 086
PCT	13 517
European Patent Convention	12 383
China	11 605
Japan	10 942
Australia	10 364

Publication country	Publications
Canada	6 420
Hungary	5 009
Germany	4 456
Republic of Korea	2 196
France	1 882
Austria	1 861
Brazil	1 809
Spain	1 784
United Kingdom	1 147
Russian Federation	2 111
Mexico	1 119
Israel	1 069
New Zealand	1 033
United States	24 086
PCT	13 517

Table 4.8 sets out the top patent assignees in global data on PGR from PATSTAT. In contrast with Thomson Innovation data, patent names have been harmonized using EEE-PPAT. This pattern confirms the prominence of DuPont (including Pioneer), Monsanto, Syngenta and BASF Plant Science. However, it also raises the profile of universities such as the University of California and Cornell, together with companies involved in other sectors and national research organizations, such as the CSIR (Australia), the National Institute of Agrobiological Sciences, and the National Research Council of Canada.

Table 4.8 Top patent assignees for plant genetic resources (PATSTAT 1907–2011)

Assignee	Publications
Pioneer Hi-Bred International, Inc. (Du Pont)	7 063
Monsanto	5 883
E.I. Du Pont De Nemours and Company	3 087
Syngenta	2 619
Basf Plant Science Gmbh	2 326
Regents of the University Of California	1 322
Calgene Llc	975
Bayer Cropscience	941

Assignee	Publications
Commonwealth Scientific and Industrial Research Organisation	904
Cropdesign N.V.	820
Zeneca Limited	807
Stine Seed Farm, Inc.	746
Bayer Bioscience	739
Dow Agrosciences LLC	723
Cornell Research Foundation, Inc.	717
Novartis AG	676
Japan Tobacco Inc.	651
National Institute of Agrobiological Sciences	641
Ciba-Geigy	623
Rhone-Poulenc Agrochimie	582
Institut national de la recherche agronomique	553
Weyerhaeuser Company	551
Icon Genetics Gmbh	513
Seminis Vegetable Seeds, Inc.	498
BASF AG	460
Mycogen Cororation	440
Biogemma UK	434
Consejo Superior De Investigaciones Cientificas	429
Ceres, Inc.	428
Plant Bioscience Limited	417
Novozymes	410
Dekalb Genetics Coporation	377
North Carolina State University	372
Mogen International N.V.	367
Centre national de la recherche scientifique (CNRS)	350
Washington State University Research Foundation	348
Cargill, Incorporated	333
National Research Council of Canada	330
Limagrain Genetics Grandes Cultures S.A.	329
Pioneer Hi-Bred International, Inc. (Du Pont)	7 063

Assignee	Publications
Monsanto	5 883
E.I. Du Pont De Nemours and Company	3 087
Syngenta	2 619
Basf Plant Science Gmbh	2 326
Regents of the University of California	1 322
Calgene LLC	975
Bayer Cropscience	941
Commonwealth Scientific and Industrial Research Organization	904
Cropdesign N.V.	820

4.2.9 Conclusion

In this section, we have focused on elaborating the statistical context for patent activity for PGR. Any future work in this area would ideally focus on refining this approach and in particular, the analysis of the structure of corporate ownership of patent assignees.

The main outcome of this analysis is the elucidation of statistics on trends based on an IPC definition of PGR. In approaching the definition of PGR, we deliberately adopted a conservative approach that only includes the IPCs that explicitly make reference to plants. On a more advanced level, the data provided above could be expanded to include legal status data to determine the number of patents in force at a given time and the degradation curve in the maintenance of patents. Furthermore, legal status data could provide the basis for empirical analysis of patent licensing practices in this field. Specifically, patent data could be used to identify cases of the transfer of rights or issuance of a licence, which could be followed by qualitative research with companies and universities to map out the structure and dynamics of activity linked to licensing.

4.3 Patent informatics and Annex 1 species

4.3.1 Introduction

The discussion of patent statistics presented above provides an overview of the global context of patent activity for PGR. We now turn to the species and genera falling within Annex 1 of the Plant Treaty.

The main methodological challenge in identifying Annex 1 species and genera in the patent system is that the IPC does not provide further guidance on the types of species appearing in patent documents. This is a possible area where cooperation could be sought from WIPO and the EPO (as the custodian of the world's patent information) in order to meet the information needs of Contracting Parties and organizations concerned with trends in activity for PGR. Specifically, we recommend consideration of the use of 'tagging' patent documents for relevant genera under Annex 1 based on the experience of the EPO with introducing tags for nanotechnology and climate change-related technologies. This informal approach could provide an important first step towards meeting patent information needs under the Plant Treaty.

In order to examine the presence of PGR covered by Annex 1 in patent data, we used advanced text mining techniques, which will be discussed in this section, focusing on three issues:

- identification of Annex 1 species and genera;
- the problem of common names in patent data on PGR;
- experimental work in searching for CGIAR Centre names and plant variety names and codes.

4.3.2 Species and genera

Annex 1 of the Plant Treaty covers 64 basic genera and associated species, with some explicit exclusions and inclusions; however, some of the categories within Annex 1 include multiple genera. Thus, the Brassica complex consists of 13 distinct genera, which brings the total to 76 genera, while the Major aroids category (two genera) increases genera covered to 77. Wheat includes three genera (Agropyron, Elymus and Secale), which increases the genera count to 79.

In some cases, a genus covered under the Treaty covers only one representative (i.e. breadfruit is confined to Artocarpus altilis), while in other cases, i.e. the Brassica complex, many hundreds of species may be involved. In other categories under Annex 1, specific species may be excluded, e.g. Lepidium meyenii in the case of the Brassica complex and Zea perennis, in the case of wheat. The structure of the Annex 1 therefore requires careful attention in preparing for the identification of species in patent documents.

As noted above, there is growing demand for patent information on biological organisms across a spectrum of international policy instruments and debates. In response to this, in 2011, with support from the UK Economic and Social Research Council (ESRC) the authors of this chapter initiated the creation of an index of species appearing in patent data. This involved acquiring the whole texts of the United States patent collection, the European Patent collection and the PCT (WO) collection, totalling 11 million patent documents. With the kind assistance of the Global Biodiversity Information Facility (GBIF) and the Encyclopedia of Life (EOL), the authors were provided with access to the world's major taxonomic backbone consisting of 19 million records of species names, including multiple spellings that resolve to a list of six million species names.

Using computational pattern matching algorithms developed by Dr. Stephen Hall, the corpus of 11 million patent documents was searched for the six million species names using Lancaster University's High End Computing (HEC) facility. The HEC consists of 1 700 computer processing cores running in parallel and is ideal for large-scale text searching of the type described here. In order to respond to the emerging demand for patent information in the field of genetic resources, the outputs of the searches are collated into an index.

As part of the present research, all genera and species falling under Annex 1 of the Plant Treaty (taking into account explicit inclusions and exclusions) were identified. The results were then compiled into a distinct Plant Treaty Index. This approach was based exclusively on the appearance of Latin names in the texts of patent documents. Issues involving the use of common names in this sector are discussed in further detail below.

Our approach also involved distinguishing the appearance of Latin species names in either the title, abstract, description and claims sections of patent documents. This distinction is important because the appearance of a species name in the title, abstract or claims section of a patent document is a strong indicator that the patent fundamentally concerns that species or its genetic components. In contrast, a species name may appear in the description section for a variety of reasons either as a direct focus of a claimed invention, as a passing comparative reference, or in cited literature. We therefore focus primarily on the results in either the title, abstract or the claims, with a particular focus on the claims.

Figure 4.5 sets out the top results for Annex 1 species names appearing in patent documents. These data are not constrained by IPC codes and therefore refer to all areas of technology in the patent system that make reference to an Annex 1 species. Figure 4.6 breaks out the data to display the relevant sub-species captured during the search. Here, we would note that grouping is based on GBIF data and includes variant species names. For each species we have also been able to break down the data by the overall number of publications from the selected jurisdictions that contain the species name and the number of occurrences of the species names in the claims. This provides a useful indicator of the intensity of references to a particular species within the document set and, in particular, the intensity of claims around a particular species.

Figure 4.5 Top Plant Treaty species (Latin names only)

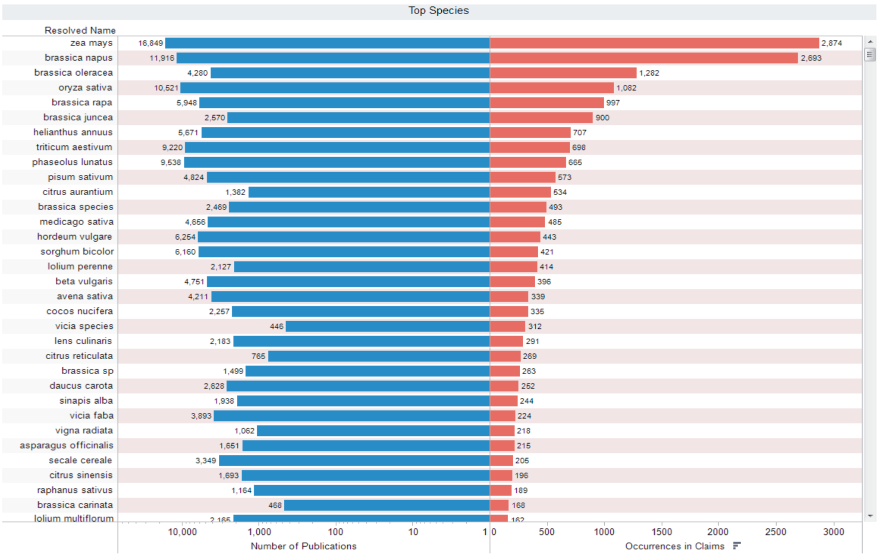
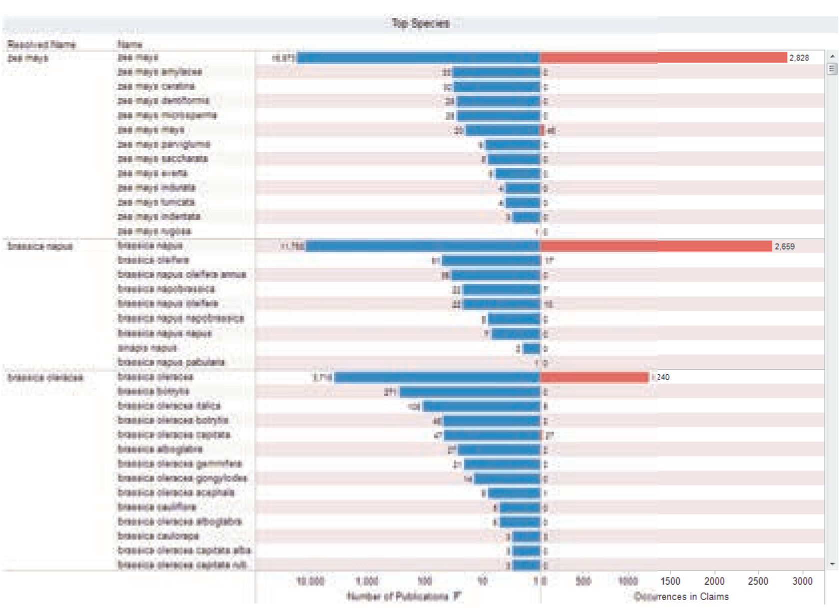
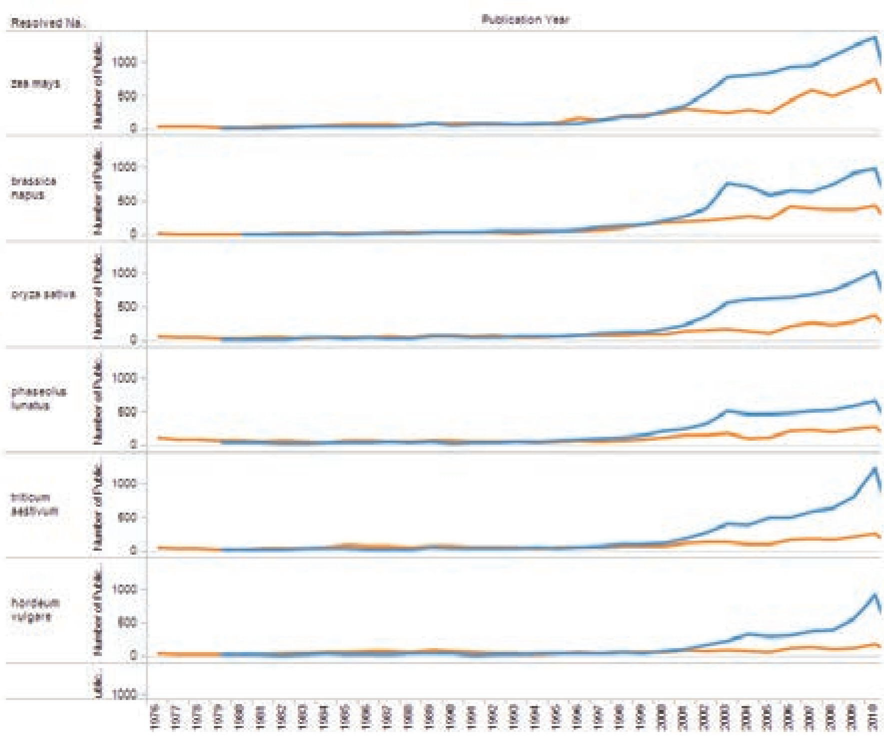


Figure 4.6 Top Plant Treaty species breakout (Latin names only)



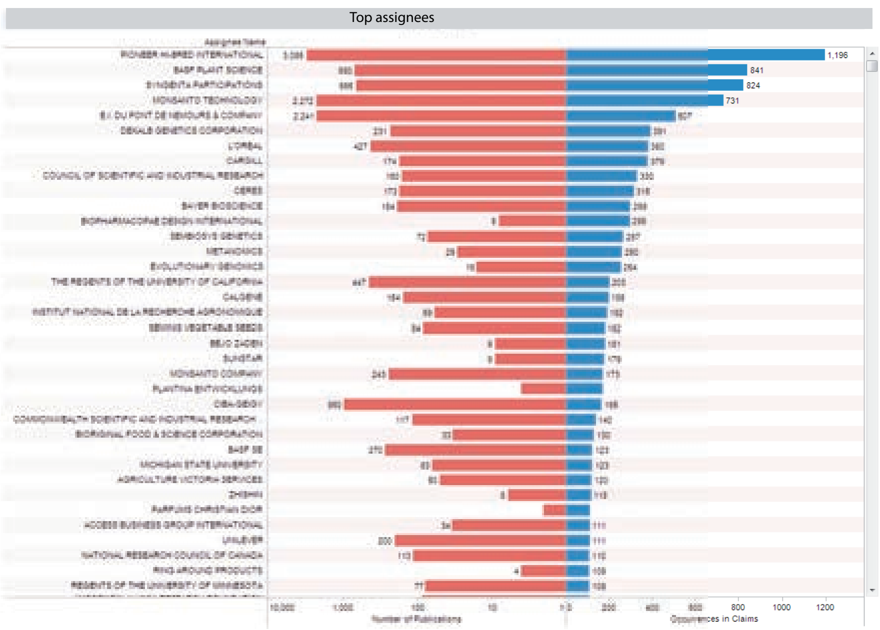
As we will see below, in practice, it is desirable to include common names in the search criteria to generate a fuller view. However, for the present, this approach demonstrates that it is possible to identify species-level activity for Annex 1 within the texts of patent documents. Figure 4.7 breaks out the data to demonstrate trends over time for applications and grants. To generate this data, patent document, kind code A has been used to indicate trends in applications (blue) and kind code B has been used for the measurement of grants. Due to the varying uses of kind codes, some further work would be desirable to clean these data. Nevertheless, they provide a useful demonstration of trends in activity by species over time.

Figure 4.7 Patent trends for top Annex 1 species (Latin names only)



The analysis of patent activity for Annex 1 species by Latin names also allows for the identification of patent assignees. This data have been harmonized using the EEE-PPAT table discussed above, but no attempt has been made to group data based on corporate ownership. Figure 4.8 shows the data for top assignees.

Figure 4.8 Top patent assignees for Annex 1 species



In considering Figure 4.8, as we might expect, the top patent assignees closely match the top assignees for the IPC-based statistics presented above. However, we would note that the index presently only includes patent data from the United States, the EPC and the PCT. While capturing the most important patent documents, the approach could usefully be extended to other collections if they are available in whole text form.

Furthermore, and in contrast with the Thomson Innovation data, the assignee list presented above has been cleaned using the harmonized patent assignee data developed by the ECOOM-Eurostat-EPO PATSTAT Person Augmented Table (EEE-PPAT) project (EEE-PPAT 2011 edition).[7] This project developed harmonization methods for millions of assignee names within patent data and provides the most complete data available for assignees. However, we would once again emphasize that no attempt has been made to harmonize patent data based on the ownership structure of the companies involved (for example, Pioneer Hi-Bred is owned by Du Pont). We would also note that additional name cleaning is likely to be desirable in this sector to improve the accuracy of data capture beyond the advances made by EEE-PPAT.

7 See Du Plessis *et al.,* 2009; Magerman *et al.,* 2009; Peeters *et al.,* 2009.

The most important constraint with the indexing approach to date is the use of Latin species names. The use of common names in patent documents for species under Annex 1 is discussed below.

4.3.3 Addressing common names in patent data

Up until now, we have elucidated statistics for plant agriculture using two approaches: the first depends on the use of IPC codes and is useful for developing statistics on overall activity; and the second used large-scale text mining for Latin species names and allows for the identification of species and trends by species falling within Annex 1 of the Plant Treaty. However, a limitation of this approach is that it only focuses on the use of Latin species names in patent documents. In the case of plant agriculture, this is a significant problem because, for common crops, patent applicants frequently use common names such as potato, corn/maize and rice, including in relation to varieties involved in a claimed invention.

Data capture could be addressed by simply introducing the common names into searches. However, this creates 'the potato problem', where patent applicants may be claiming potato chips, potato peelers or cookers, and so on. While a partial solution is provided by restricting searches to specific areas of the IPC (i.e. exclusion of kitchen equipment), the problem of precision remains for cases where an applicant makes a claim over plant genetic material using a common name rather than a species name.

In order to identify possible solutions to this problem, we returned to the original patent collection from Thomson Innovation based on the IPC definition for PGR provided above. This time, however, the focus is on the claims section of the patent documents using Vantage Point text mining and natural language processing software from Search Technology Inc. in the United States. The aim was to clarify the extent to which applicants for PGR were using common names in the claims section of patent documents compared with the use of Latin species names.

Within the dataset of 71 496 patent documents, a total of 47 183 claims were available for 67 percent of the documents within the dataset. Table 4.9 shows the results of searches of 1 328 982 words and phrases appearing in the claims by Latin genus name, and English common name for the comparison of data capture.

Table 4.9 Testing data capture for species and common names in patent claim

Term	Latin name	Common name	Variance
Zea/maize/corn	1 682	11 533	14.58% (85.42)
Triticum/wheat	596	5 917	10.07% (89.93)
Oryza/rice	991	6 904	14.35% (85.65)

Table 4.9 reveals that the variance between data capture on Latin names and common names within the claims section of the dataset is very significant in terms of the loss of

data capture. In essence, patent applicants in this area of technology more frequently use common names in the claims section of patent documents than Latin names. In our experience with patent data, this is distinctive in the agriculture sector.

To address this problem, we identified known English common names for Annex 1 species with a view to conducting additional searches using High-End Computing to improve data capture.

A major consideration in conducting these searches was a need to minimize noise. As noted above, common names such as potato or rice may appear in patent documents across a spectrum of technologies (i.e. potato fryers, potato peelers, rice cookers) or appear as part of other names (i.e. potato mosaic virus) that do not refer to or involve the target species as a plant genetic resource. In short, the use of common names poses the risk of very large numbers of irrelevant results.

To control for this problem, the searches for common names were restricted in two ways:

- We limited the searches to the IPC-based definition of PGR identified at the beginning of this chapter. The aim here was to remove the danger of including equipment and apparatus for preparing the target species and other areas of science and technology involving the species (i.e. cosmetics) except where these areas of technology are specifically linked to the IPC based definition.
- We focused on the results from the Titles, Abstracts and Claims of the patent documents. This has the effect of including only those documents that are in a fundamental sense about these species.

4.3.4 Results

The results of this exercise were then incorporated into ABSPAT. In incorporating the results of common names searches into Annex 1 we decided that the most sensible approach was to group the common names under the accepted scientific name. In one case, beans, this did not prove possible because this single common name is associated with a large number of species. This exposes some of the challenges involved in using common names. Table 4.10 shows the top results from this exercise including the grouping of common names onto their respective accepted Latin name.

What can immediately be seen is that the results for Zea mays, Oryza sativa and Brassica napus, among others, increase dramatically. Specifically, the impact of the use of common names in the claims section of patent documents becomes apparent in the data. As such, any future work on patent activity for PGR should recognize the importance of including both Latin names and common names in search criteria and adopting appropriate controls to limit the data to PGR as provided by the IPC definition in this chapter.

Figure 4.9 shows a summary of the top results for Annex 1 species including the results of common name searches aggregated on the accepted scientific name. As noted above, the category ‘beans’ is presently ambiguous and requires further work. Furthermore, we believe that while the restrictions adopted by common name are reasonable, further work may be required to remove noise in the results.

However, it is immediately clear from this analysis that the bulk of references to major

Annex 1 species such as Zea mays and Oryza sativa are in fact occupied by common names appearing in the claims section of patent documents. Figure 4.10 shows the results aggregated onto the scientific name including the unresolved name beans (undefined) and references to species within a genus (i.e. citrus spp.).

Figure 4.11 shows the trends in patent publications over time for Annex 1 species and associated common names. Figures 4.12 to 4.15 demonstrate that it is also possible to break down the data on patent assignees by their corresponding sectors using the sector allocations within EEE-PPAT. This approach has the considerable advantage of allowing policy makers to examine the different types of organization involved in research and development resulting in patent activity for PGR.

Figure 4.9 Top species including common names in titles, abstract and claims using the IPC definition of plant genetic resources

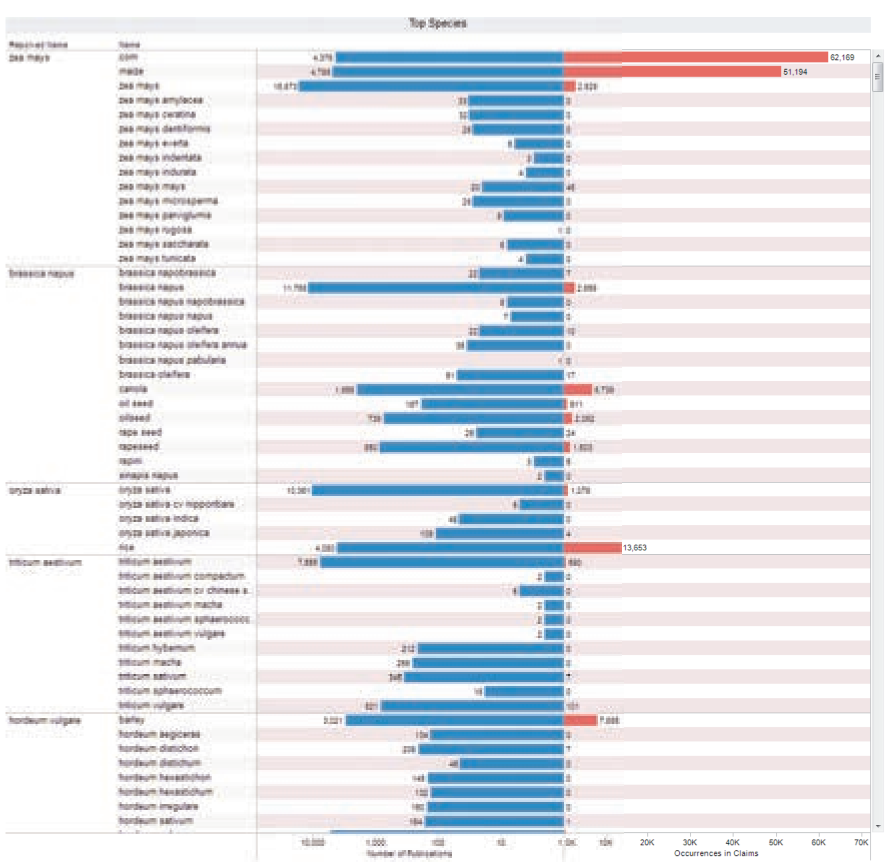


Figure 4.10 shows the top results by species grouped under the scientific name.

Figure 4.10 Top species including common names

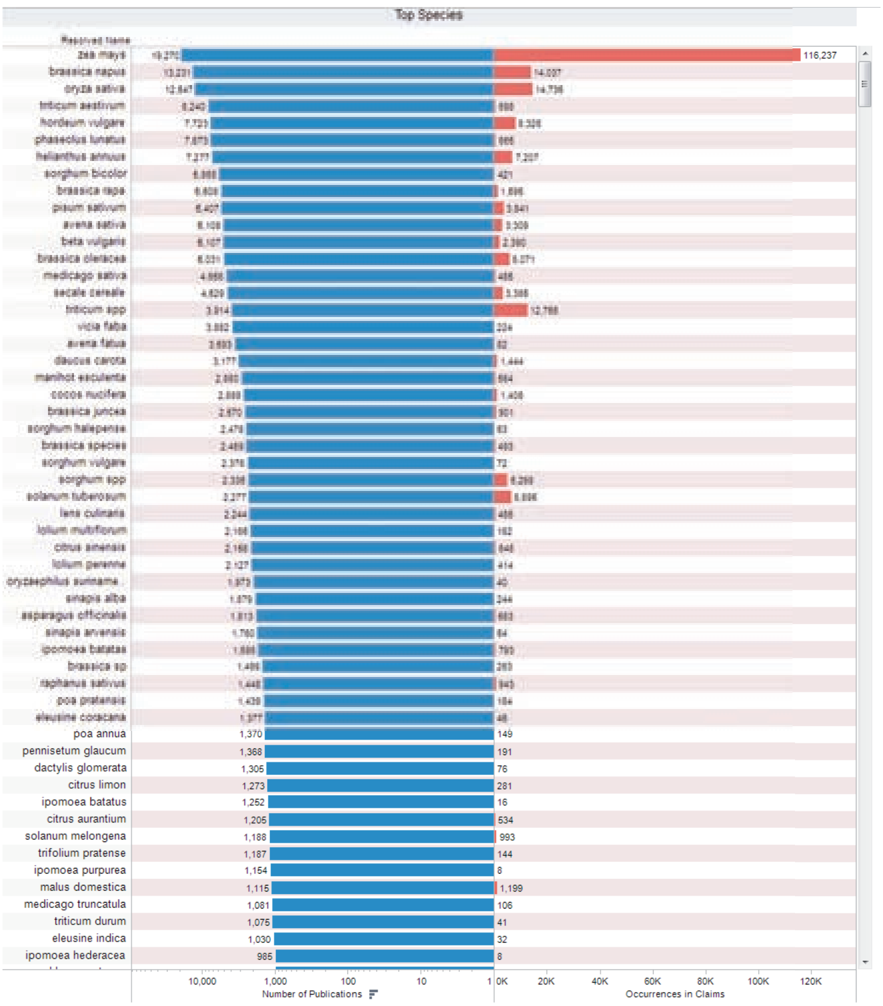


Figure 4.11 Patent publication trends by applications and grants (including common names)

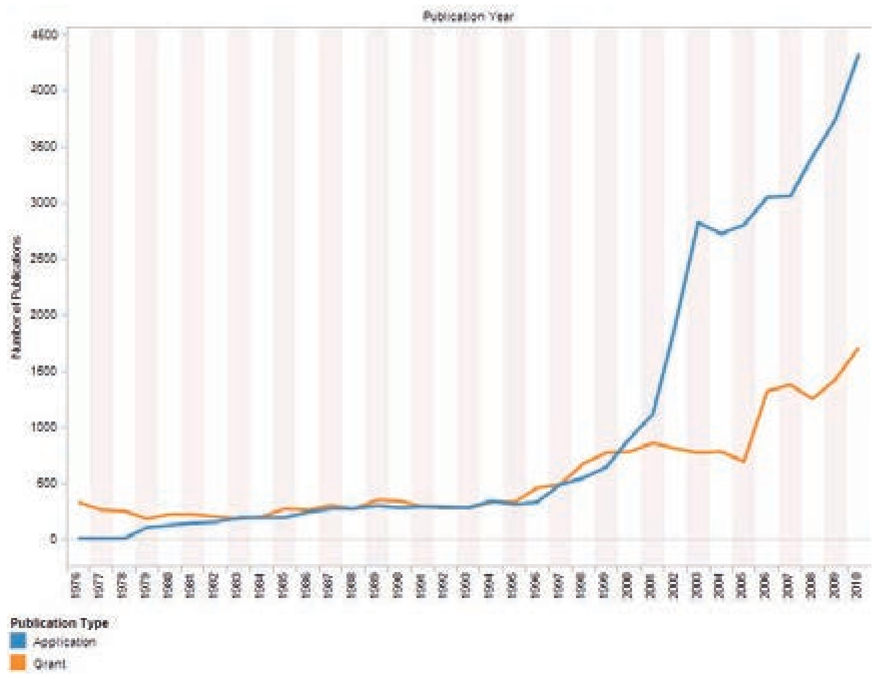


Figure 4.12 Top assignees (all) ranked by claims

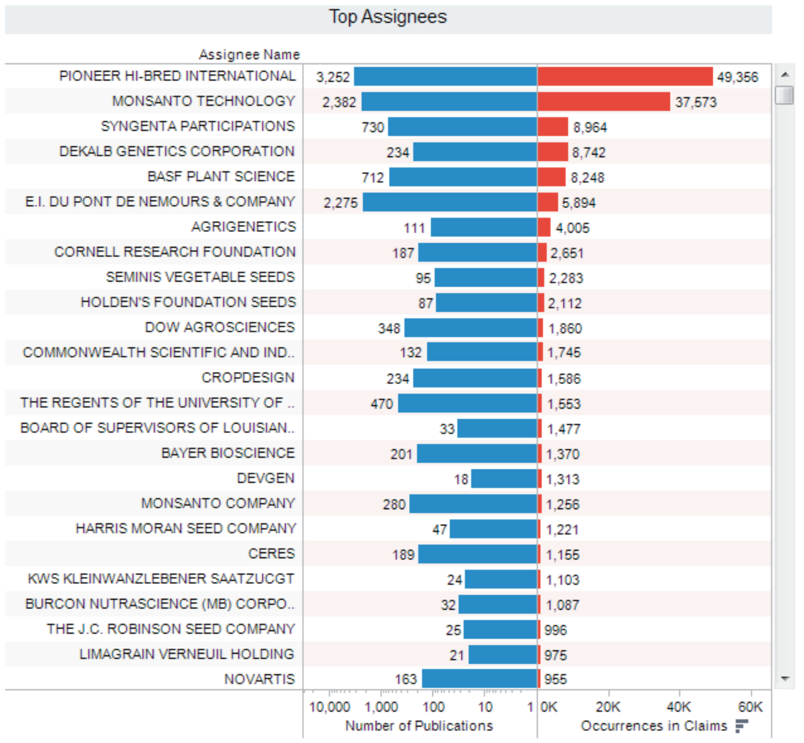


Figure 4.13 Top assignees (companies) ranked by claims

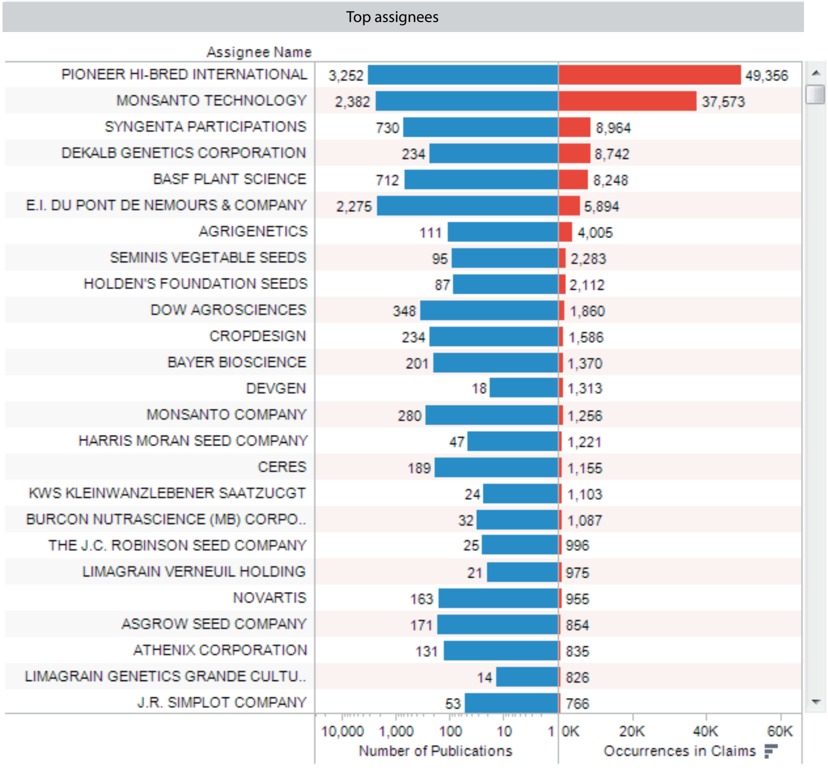


Figure 4.14 Top assignees (universities) ranked by claims

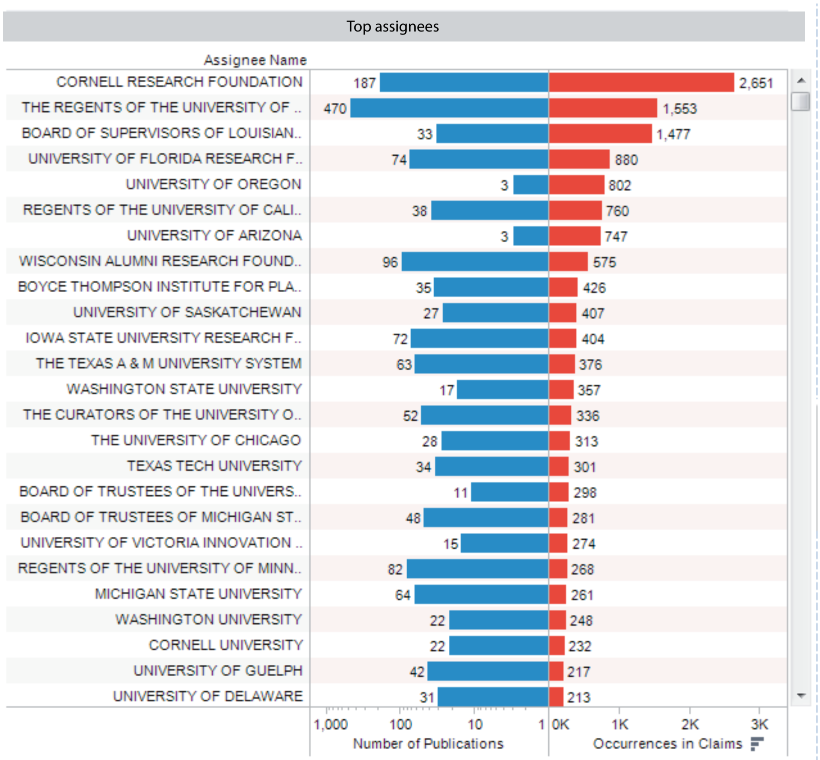
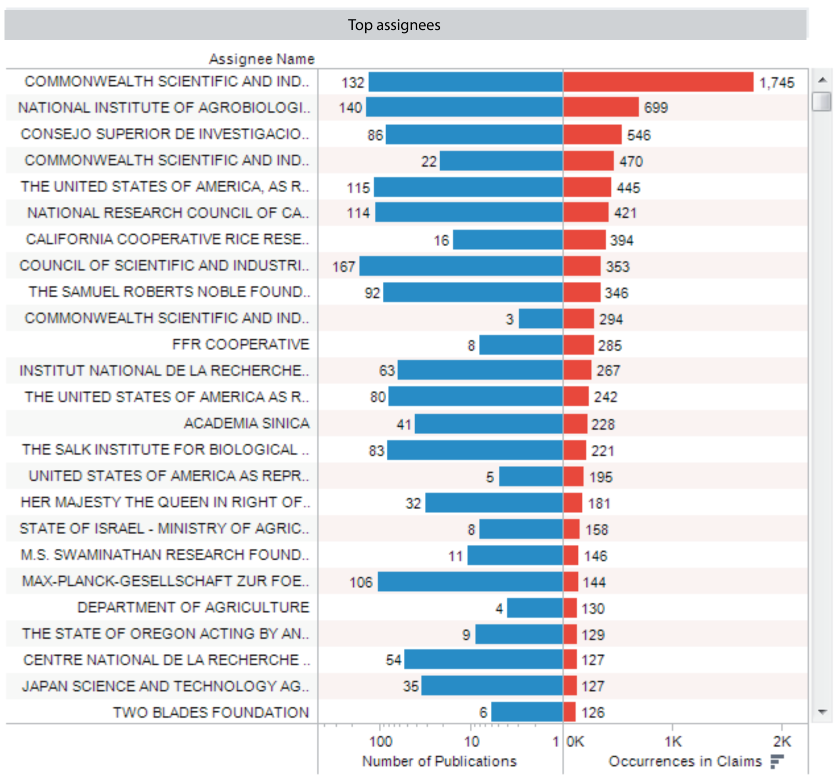


Figure 4.15 Top assignees (government non-profit) ranked by claims



4.3.5 Conclusion

In this section, we have demonstrated that it is possible to identify patent trends for PGR falling within Annex 1 of the Plant Treaty using large-scale text mining techniques. We have further demonstrated that in this particular sector, patent applicants are more likely to use common names for species than Latin names in constructing their claims. To address this problem we engaged in additional searches for common names and restricted the results to the IPC definition of PGR and the title, abstract and claims of patent documents. This combined approach takes us much closer than has previously been possible to a full picture of patent activity for Annex 1 species and genera.

In addition, in closing this discussion we have demonstrated that advances in the harmonization of patent assignee names have made it possible to arrive at a detailed breakdown of organizations by sector of activity. We believe that this is an important advance because it could allow future research to target particular sectors of activity engaged in patent activity on genetic resources such as universities. Analysis of co-patenting activity between companies and other organizations might also allow for the mapping of networks of relationships between patent applicants to provide a fuller picture of research and development for PGR. In particular, this may provide a way forward in mapping networks of linkages between organizations accessing public collections and the research and development chain. In the final section of this chapter, we provide an illustration of network mapping using the scientific literature that illustrates the feasibility of this approach.

As highlighted above, further research is desirable to refine patent analysis using common names. Taking into account the data provided above, a fruitful way forward in making patent information available to policy makers would be to explore the possibility of tagging patents of direct relevance to the Plant Treaty in patent databases using informal classification codes following the approach pioneered by the EPO. Given that Annex 1 covers very large numbers of species, this approach could focus on tagging genera while taking into account issues around common names and the specific inclusions and exclusions of species in Annex 1.

4.4 Plant genetic resource collections and informatics

4.4.1 Introduction

In this section we briefly discuss approaches to text mining patent data to scope out available information on PGR appearing in patent data that may originate from the multilateral system. We also discuss searches in relation to plant breeders' rights (PBR) in patent documents. Finally, we discuss the development of additional software tools to complement the existing International Crop Information System (ICIS) system by facilitating large-scale extraction and analysis of the parentage of plant varieties.

4.4.2 Text mining for collections and related bodies: preliminary results

To test for information on the potential contribution of CGIAR Centres and treaty bodies to innovations in the patent system, we conducted a series of searches in the main patent jurisdictions using the Thomson Innovation commercial patent database. The search terms and search results counted on the number of patent publications, and the original filings (INPADOC filings) to which they belong are show in Table 4.10.

Table 4.10 Text searches in Thomson Innovation for collections and related terms

Search query	Publications (major jurisdictions)	INPADOC families
Accession	178 805	+30 041
"Africa Rice Center" or "Africa Rice Centre"	0	0
"Bioversity International"	0	0
CIAT OR Centro Internacional de Agricultura Tropical	863	823
"CIFOR" OR "Center for International Forestry Research"	38	37
"CIMMYT" OR "Centro Internacional de Mejoramiento de Maiz y Trigo" OR "International Maize and Wheat Improvement Center" OR "International Maize and Wheat Improvement Centre"	269	131
["CIP" OR "Centro Internacional de la Papa" OR "International Potato Center" OR "International Potato Centre"]	[45 555]	[+22 312]
"Centro Internacional de la Papa" OR "International Potato Center" OR "International Potato Centre"	33	14
"ICARDA" OR "International Center for Agricultural Research in the Dry Areas" OR "International Center for Agricultural Research in Dry Areas" OR "International Centre for Agricultural Research in the Dry Areas" OR "International Centre for Agricultural Research in Dry Areas"	2	1
"ICRISAT" OR "International Crops Research Institute for the Semi-Arid Tropics" OR "International Crops Research Institute for the Semi-Arid Tropics"	41	22
IFPRI OR International Food Policy Research Institute	41	19
"IITA" OR "International Institute of Tropical Agriculture"	2 273	1 585
"ILRI" OR "International Livestock Research Institute"	279	263
"International Treaty on Plant Genetic Resources for Food and Agriculture" OR "plant treaty"	0	0
"IRRI" OR "International Rice Research Institute"	2 210	1 925
"IWMI" OR "International Water Management Institute"	58	45
"ICRAF" OR "World Agroforestry Centre" OR "World Agroforestry Center"	6	6
"Worldfish center" or "world fish center" or "worldfish centre" or "world fish centre"	0	0
"CGIAR" OR "Consultative Group on International Agricultural Research"	14	7
Other Art 15 Bodies		
"Tropical Agricultural Research and Higher Education Center" or "Tropical Agricultural Research and Higher Education Centre"	0	0

Search query	Publications (major jurisdictions)	INPADOC families
"International Coconut Genebank for African and the Indian Ocean" OR "International Coconut Genebank for African and the Indian Ocean" OR "International Coconut Gene bank for Africa and the Indian Ocean" OR "International Coconut Gene bank for Africa and the Indian Ocean"	0	0
"International Coconut Genebank for the South Pacific" or "International Coconut Gene bank for the South Pacific"	0	0
"Mutant Germplasm Repository of the FAO/IAEA Joint Division"	0	0
"International Cocoa Genebank" OR "International Cocoa Gene bank"	0	0
"CEPACT" OR "Centre for Pacific Crops and Trees"	0	0
potato park	no valid	no valid
AFSA OR Association Française des Semences de céréales à paille et autres espèces Autogames	153	69

Table 4.10 reveals that there are a limited number of references to the search terms with respect to CGIAR and related centres. With respect to the International Potato Centre, the results are very heavily affected by noise on the term 'CIP'. The results for the Potato Centre are included purely for the purpose of illustrating the problem of noisy terms, rather than as an indicator of actual activity. In the absence of carefully standardized terms such as distinctive institutional codes, this type of problem will repeatedly be encountered in research on patent activity.

To examine the data in more detail, the whole texts of the corresponding patent documents were exported for analysis in Wordsmith Corpus Linguistics software. This allows a term of interest, such as CGIAR, to be identified in a document together with the sentence of which if forms a part. The results are known as a concordance.

We tested a number of the resulting datasets to assess levels of data capture and noise. Typically, as in the case of CIP, we encountered significant numbers of irrelevant results on acronyms resulting from the presence of machine code in the texts (i.e. IRRI produced results for 'irri-tation' owing to the presence of the hyphen in the text). In other cases, an abbreviation referred to either a mechanical or chemical process that was not relevant to plant agriculture. The second largest group of results was made up of references to scientific literature either published by, or involving, researchers from a particular research centre. The frequency of references to scientific literature from CGIAR Centres or researchers at the CGIAR is a potentially important finding in revealing the contribution of these Centres to trends in research and innovation in agriculture.

In the following pages, we provide samples of concordances from some of the results to give an idea of the references.

Concordance sample for CGIAR

1 **In 1993, the Consultant Group on International Agricultural Research (CGIAR) suggested that increasing the mineral uptake of plants could be used to address the problems associated with deficiency of zinc and other nutrients (Ruel and Bouis, 1998).**

2 ...on all types of productive soils will be enormous (McCalla A (1994) Agriculture and Food Needs to 2025: why we should be concerned, **Sir John Crowford Memorial Lecture, Washington DC, Secretariat, Consultative Group on International Agricultural Research (CIGAR) c/o The World Bank**; Leach G (1995) Global land and food in the twenty-first century, Trends and issues for sustainability, SEI, Polestar 5, p

3 ....developing a transgenic potato resistant to Ralstonia. However, such a product has not yet been developed, and even if developed, public acceptance of such a product cannot be predicted. **Although the Consultative Group on International Agricultural Research has recently concluded that appropriate chemical control measures that are practical and effective do not exist, U.S. Pat. No. 6,015,830** to M

4 ...the U.S. the third largest exporter worldwide. **Approximately 99 of the rice varieties currently grown are the result of public breeding programmes, many originating from breeding programmes sponsored by CGIAR international research centres such as International Rice Research Institute (IRRI) and International Center for Tropical Agriculture (CIAT).** The majority of U.S. rice varieties are developed...

Concordance sample for the International Rice Research Institute

1 The reverse drooping flag leaf character can be introduced into the perennial female fertile male sterile seed parent by crossing with RGS20, which is publicly available from IRRI (Philippines). The reverse drooping flag leaf character is particularly suited for use with perennial female fertile male sterile rice plants which possess genetic male sterility since such trait has been found capable of being closely linked with such male sterility and is further useful as a marker during the initial establishment of such male sterile plants as discussed hereafter. pn - US5304722A pad - RING AROUND PRODUCTS INC tie - Hybrid rice production utilizing perennial male sterile rice plants

2 Biological material: **The biological material used are the two parental lines (samples IR20 and 6383) from a F2 population of Rice. The parental lines were acquired from the IRRI in the Philippines**. ad - KEYGENE NV tie - METHOD FOR GENERATING OLIGONUCLEOTIDES, IN PARTICULAR FOR THE DETECTION OF AMPLIFIED RESTRICTION FRAGMENTS OBTAINED USING AFLP

3 However, resistance breaking biotypes have developed in some localities to the extent that local rice production is threatened. **As fast as new BPH resistant varieties come out of the IRRI programme, new resistance breaking biotypes of the insect evolve**. There is thus a continuous need for novel sources of BPH resistance genes to incorporate into the breeding programme.... Genetic engineering may make

a useful contribution here since it allows genes encoding insecticidal proteins to be inserted into elite lines of crop plants in a single step irrespective of the natural source of the protein or its ability to cross-breed with the host. EP600993B1. NOVARTIS AG. tie – PROTEINS WITH INSECTICIDAL PROPERTIES AGAINST HOMOPTERAN INSECTS AND THEIR USE IN PLANT PROTECTION

4 Plant materials and growth. **The F1 hybrid seeds of 78-1-5 BC2F3 and IR24 were obtained from the International Rice Research Institute (IRRI)** (R. Nelson and G. Khush). Plants of 78-1-5 DC2F3 were derived from a cross between O. sativa cv IR31917-45-3-2 and O. minuta Acc. 10141 (Amante-Bordeos *et al.* 1992). pn - US20060143734A1 pad - TEMASEK LIFE SCIENCES LABOATOR. tie - Nucleic acids from rice conferring resistance to bacterial blight disease caused by xanthomonas spp. What is claimed is: 1. An isolated nucleic acid sequence comprising SEQ ID NO: 1 or an isolated nucleic acid comprising a polynucleotide sequence of greater than about fifty nucleotides which hybridizes under stringent conditions to SEQ ID NO:1 and provides a plant with resistance to Xanthomonas when transfected into the plant.

Concordance sample for CIMMYT and ICRISAT

1 EXAMPLE 8 Wheat Regeneration. Immature embryos were isolated from seeds of the wheat Triticum aestivium S-5704 (CIMMYT 1981) when they were 1.0-2.0 mm in length, in the same procedure as described for barley in Example 3. The embryos were plated onto callus induction medium C having 3 mg/l 2,4-D, 2 mg/l NAA and 2 mg/l IBA, and cultured in the light for 20 days.... This procedure was repeated for immature embryos isolated from Triticum aestivium S-5829 (CIMMYT 1981) and Triticum aestivium S-6006 (CIMMYT 1981). Plants were obtained in each instance. pn - US4666844A. pa - Sungene Technologies Corporation, Palo Alto, CA, US. ti - Process for regenerating cereals. What is claimed is: 1. A process for regenerating cereal plantlets from cell or tissue culture which comprises the steps of: (a) culturing tissue obtained from a cereal plant selected from the group consisting of barley, corn which is capable of being regenerated on medium containing 2,4-D, wheat, rice and sorghum on a callus induction medium comprising mineral salts, vitamins, sucrose and a hormone selected from the group consisting of (A) 2,4-D, (B) a mixture of 2,4-D and IAA, (C) a mixture of 2,4-D, NAA and IBA, and (D) a mixture of 2,4-D, IAA and NAA, in an amount sufficient to insure callus formation; (b) culturing said callus on a series of media for differentiation, said series comprises utilizing one to four media selected from the group consisting of medium 1, medium 2, medium 3, medium 4 and medium 5, each medium comprises mineral salts, vitamins, sucrose and a hormone in an amount sufficient to insure differentiation to plantlets having shoots and roots after culturing on said series, said hormone of medium 1 comprising 2,4-D and coconut milk, of medium 2 comprising IBA and BA, of medium 3 comprising 2,4-D, GA3, BA and coconut milk, of medium 4 comprising 2,4-D, BA and coconut milk, and of medium 5 comprising the hormone of said callus induction medium, with the proviso that medium 5 alone is not said series when the tissue is from wheat or corn wherein medium 1 is capable of enhancing proliferation of embryogenic callus tissue and sustaining donor tissue, medium 2 is capable of separating embryogenic tissue

into a loose mass and enhancing differentiation of somatic embryoids or morphogenic structures, medium 3 is capable of promoting shoot and root formation from somatic embryoids, medium 4 is capable of promoting differentiation to shoots and roots from morphogenic callus and medium 5 is capable of promoting plantlet formation; and (c) culturing said plantlets on an establishment medium comprising mineral salts, vitamins and sucrose, whereby plants are obtained capable of growth in soil.

2 Sexual.sup.b ICRISAT (IP8627) pn - US5811636A pa - The United States of America as represented by the Secretary of Agriculture, Washington, DC, US. ti - Apomixis for producing true-breeding plant progenies. We claim: 1. A cultivated apomictic Pennisetum plant comprising a genome which contains a genetic material from E111, designated by ATCC accession No. 97273, for the expression of apomixis, wherein said material is transferred from Pennisetum squamulatum.

These brief illustrations serve to demonstrate the range of possible references to CGIAR Centres that we encountered in the data and make it clear that CGIAR Centres may appear in patent texts for a variety of reasons. These examples also illustrate some of the challenges that need to be addressed in text mining patent data for PGR referring to these Centres.

In methodological terms, if it is desirable to generate information on the role of CGIAR collections in future patent activity, it will be important to introduce a clear and unambiguous unique identification system, possibly as part of material transfer agreements. A useful example of this is provided by the reference to ATCC accession No. 97273 in example 6. This refers to an accession from the American Type Culture Collection (ATCC) and can be readily retrieved through a search for the term 'ATCC accession'. Furthermore, patent applicants are already familiar with requirements to provide information on accessions under the Budapest Treaty on the International Recognition of Microorganisms for the Purposes of Patent Procedure (as amended in 1980), which established a number of International Depositary Authority (ISA) organizations such as the American Type Culture Collection.

In the case of CGIAR Centres, the role of accessions from the centres in research and development could be greatly clarified by drawing on lessons learned from the Budapest Treaty and focusing on clarifying information on accessions within patent documents. The importance of clarification of information inside patent data comes into very sharp focus when considering the results of research to identify germplasm accession codes in the patent data.

4.4.3 Identifying plant germplasm accession codes

In an effort to more accurately target the plant genetic source materials, we identified the 12 311 parent documents (first family members) from our Plant Treaty Index using Latin species names for Annex 1 crops and forages. We then restricted the results to only those documents that were classified in either A01H or C12 in the IPC system. This has the effect of removing documents that involve species in areas such as foodstuffs or cosmetics (where, for example, Solanum tuberosum or the potato is an important ingredient). The result of this exercise was a dataset consisting of 4 287 documents. The full texts of these documents were then exported for further processing using Wordsmith.

As we have seen in some of the examples above, in some cases, patent applicants include references to particular genetic resource names, i.e. S-5704 (CIMMYT 1981). However, from a research perspective, the reference to the genetic resources is not commonly accompanied by uniform use of the full name or abbreviation of the source collection.

In order to improve data capture, we also searched the document subset on a smaller variety of terms directed towards capturing references to genetic resources through their codes, i.e. S-5704. The objective of this exercise was to use commonly used terms for varieties in order to identify variety code references adjacent to the common terms. Based on a manual review of results, the search terms chosen were "parent*, parental line*, breeding line*, seeds of, seeds from, crossing with, cross with, variety, varieties". The aim of this approach was to move closer inside our 4 287 texts to the likely location of an accession code.

This produced a dataset of 348 454 concordance lines, including many duplicates from duplicate publications in the dataset, for further work. The results were exported from Wordsmith to an Excel dataset based on a search horizon of 100 characters from the target term. The aim here was to try to capture complete codes as far as possible. The Excel table consisted of simple lines of 100 characters of text and the patent file name from Thomson Innovation. An example of the results is provided in Table 4.11.[8]

Table 4.11 Targeting variety codes through adjacent terms

Concordance	Set
iological and morphological characteristics of the variety, and of regenerating plants having substa	variety
tantially the same genotype as other plants of the variety. Examples of some of the physiological an	variety
tissue culture of regenerable cells of a plant of variety CV914011 is provided. The tissue culture	variety
be pollinated by a maintainer version of the same variety, which has a normal cytoplasm but lacks t	variety
can be restored by a restorer version of the same variety, which must have the restorer gene(s) in	variety

This table demonstrates that it is possible to capture the text around a target term (variety) and that, in some cases, a variety code will be included in the results (entry 3).

In order to focus on the codes for the target species of wheat, rice and maize, the 348 454 Wordsmith Concordance lines were imported into Vantage Point analytics software in order to exploit its Natural Language Processing functions. Natural Language Processing involves an algorithm that breaks text into its constituent words and phrases.

8 File: First Family Breeding Line Related Searches.xls

The result of this exercise was a reduced dataset of 71 520 multi-word phrases. These phrases were manually reviewed to select results containing obvious plant variety codes (i.e. corn variety CV914011) or likely plant variety codes (i.e. DP 488 BG/RR). This allowed to create separate datasets for corn/maize (8 595), rice (130), and wheat (216), respectively. We would emphasize that our purpose was not to achieve comprehensive coverage, since this would only be possible by searching using lists of variety codes and denominations from PGR datasets within the whole texts of the sample; rather our aim was to test whether it might be possible to link variety codes with International Crop Information Systems (ICIS) PGR databases for generating mendelgrams and assessing the link between PGR from collections and patent activity as an indicator of commercial activity.

A short sample of the results of this exercise is provided in Table 4.12.

Table 4.12 Plant variety codes sample in patents for corn

Records	Concordance results
53	Corn variety I156024
53	Corn variety I161538
52	Corn variety I180421
51	Corn variety I294213
51	Maize variety 34Y02
50	Corn variety CV443328
50	Corn variety CV875318
50	Corn variety I322683
48	Corn variety CV897903
48	Maize variety 35K02
47	Corn variety CV338423
47	Corn variety CV589782
47	Corn variety I130248
47	Maize variety 39B22
47	Maize variety 6746633

Our experimental results were then separated into datasets for rice (130), wheat (216) and corn/maize (8 595), respectively.

In order to retrieve information on the parentage of the plant variety referenced in the patent document, it was first necessary to look up the variety code in an effort to identify the corresponding germplasm IDs (GIDs). This could have provided the foundation for generating mendelgrams, as explained in Chapter 2.However, our efforts in this area using this sample data failed. We presume that this was because the codes in our sample referred to commercial varieties that are not referenced in public collection databases. Furthermore, we encountered significant variations in the formats of codes,which makes reading data across databases difficult. We propose that any future work to text mine patent data for accession or variety codes should actually begin by obtaining a comprehensive list of accession or variety codes from public collections. These accession codes should then be used to text mine the corresponding data. In this way the research would proceed from known codes to establish the link with the patent data.

4.4.4 Informatics development

One of the challenges involved in the research presented here has been the need to use large-scale data from a range of different sources. In particular, we wished to provide support for the analysis of the parentage of commercial plant varieties as a basis for economic assessment of the contribution of materials under the Multilateral System.

Plant genetic information exists in a variety of public databases notably the International Crop Information System (ICIS). However, we confronted challenges in accessing the data on the scale that was needed.

To address this we created a web-based portal to the International Crop Information System (ICIS) that provides automated access to the crop genealogy tools. ICIS is a platform available on Windows 32 bit systems that allows interaction with the Genealogy Management System (GMS) and the Data Management System (DMS) for environmental, characterization and evaluation purposes. ICIS was developed by research centres under the umbrella of the CGIAR. Central implementation of the GMS and DMS exist for major crops including Wheat, Maize (by CIMMYT) and Rice (by IRRI). Information on ICIS is available at http://www.icis.cgiar.org/icis/index.php/Main_Page.

The problem for our partners was that extracting data from the GMS was limited by the platform characteristics. Of interest was the calculation of Mendelgrams, a table of

Figure 4.16 Mendelgram for wheat variety Sonalika (Germplasm 6387)

```
MENDELGRAM FOR GID     6387 - SONALIKA
CONT IS THE PROBABILITY THAT AN UNSELECTED ALLELE COMES FROM THAT PROGENITOR
TYPE IS THE TYPE OF PROGENITOR: T - TERMINAL,
IG - INTERMEDIATE GENERATIVE, ID - INTERMEDIATE DERIVATIVE

 NO    GID  NAME OF PROGENITOR                         TYPE  CONT COUNT CTY
 1   4982372 HALYCHANKA                                  T  0.22878 157 UKR
 2 500008960                                             T  0.10205  33 UKR
 3        67 HARD RED CALCUTTA                           T  0.08337  68 IND
 4   5822570 LV-FUKUI                                    T  0.07471   8 JPN
 5   5820942 LV-ITA                                      T  0.06982  28   ?
 6   5820938 LV-SEVERNAYA-ROSSIYA                        T  0.06445   7   ?
 7    250782 RICHELLE-DE-NAPLES                          T  0.05035  20 ITA
 8        68 MARIA ESCOBAR                               T  0.04688   2 CIM
 9 500018037                                             T  0.03735   8 PRT
10      6380 B4946.A.4.18.2.1Y                           T  0.03125   1 CIM
11 500018379                                             T  0.03125   1 BRA
12        39 KENIA RF 324                                T  0.03125   3   ?
13         9 EXTRA-SQUAREHEAD (SVALOF)                   T  0.02802  16   ?
14   5820731 LV-MEDITERRANEAN                            T  0.02588   4   ?
15       100 YAROSLAV                                    T  0.02417   9 CIM
16         3 POLYSSU                                     T  0.01221   3   ?
17   5821811 LV-RIO-GRANDE-DO-SUL                        T  0.01221   3 BRA
18        11 ZEEUWSE WITTE                               T  0.00934   8 CIM
19       219 EGYPT NA101                                 T  0.00781   1   ?
20   5820747 LV-GUNMA                                    T  0.00781   1   ?
21   5820749 LV-ENGLAND                                  T  0.00635   3 GBR
22        49 INDIAN G                                    T  0.00420  10 CIM
23   5820956 LV-PAL                                      T  0.00391   1   ?
24       137 DIEHL                                       T  0.00244   2   ?
25   5820975 LV-MEX                                      T  0.00195   1 MEX
26       142 ETAWAH                                      T  0.00122   2 IND
27   5823266 LV-RUS                                      T  0.00098   2 CIM
RICHNESS INDEX=0.9040 (PROBABILITY THAT TWO RANDOMLY CHOSEN,
UNSELECTED LOCI HAVE ALLELS FROM DIFFERENT TERMINAL SOURCES)
ENTER SEARCH OR COMMAND STRING (.n=DISPLAY ITEM n, .0=NONE, .HLP=HELP, ./=END)
```

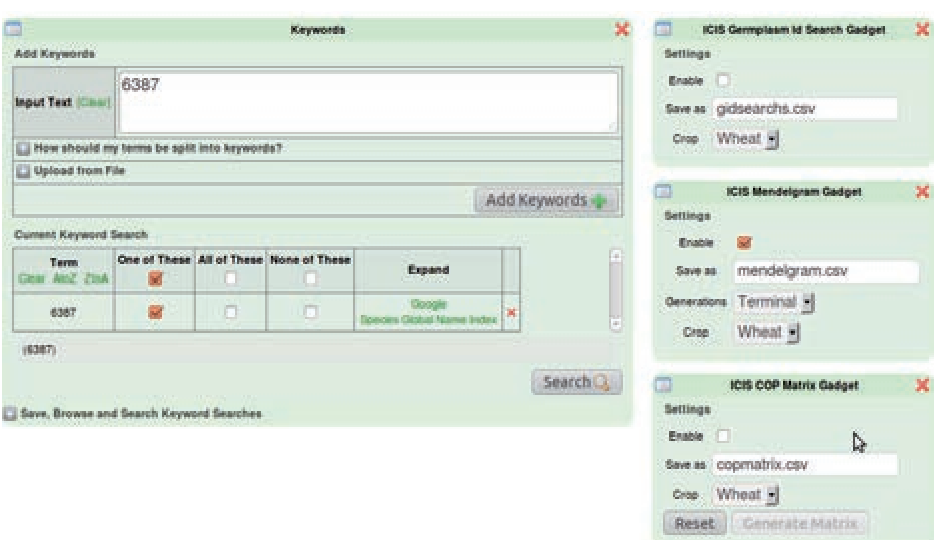
progenitors for a given germplasm and their relevant contribution as shown in Figure 4.16. Additionally, our partners needed to calculate matrices of Coefficient of Parentage (COP).[9] The existing ICIS browse interface, known simply as 'browse', made it difficult and time-consuming for our partners to copy data into a spread sheet enabling proper data interrogation and reporting.

Our proposal was to host the existing ICIS tools and wrap them in an internet service (the ICIS service) in order to provide the data in tabular form to our partners on demand. To streamline access to the ICIS services, we provided gadgets within our web platform the Research Desktop (available at http://researchdesktop.org/).

Co-hosted with the ICIS installation upon the Windows 32 machine, we created an ASP. NET (v4) and Internet Information Services (IIS v7.5) installation. Development took place in Visual Studio 2010. The ICIS service simply started an invisible instance of the browse tool. Our service ensured that the browse tool was pointing at the relevant GMS database (IWIS, IRIS or IMIS). We then sequentially called the browse function for each germplasm input returning the results in tabular format. In addition to the information from the browse application, our installation was able to access the database of the GMS directly to obtain data such as germplasm creation and naming dates. Another service we provided was germplasm identifier discovery by given variety names. This accessed the GMS database directly.

The Research Desktop simply called upon our ICIS Internet service to provide the data as a streamed download. Germplasm identifiers or variety names are entered through the desktop keywords gadget, which allows them to be uploaded in large numbers from a file.

Figure 4.17 The ICIS Web Interface on the Research Desktop



9 http://cropwiki.irri.org/icis/index.php/TDM_GMS_Browse

The appropriate ICIS gadget is enabled by the user, and when the search is initiated from the keyword gadget a save as box will be shown. This allows the data to be downloaded or opened with a spread sheet application such as Excel, as shown in Figure 4.17.

The development of these apparently simple tools took approximately four weeks to create, mainly due to the specific requirements of the different ICIS installations. For example, IWIS (Wheat) requires MySQL server to be installed, but only works on Windows 32.

4.4.5 Plant varieties and plant breeders' rights

One important research question was whether specific plant varieties could be identified in the patent data and whether a link could be established between any PBR over these varieties and the pursuit of patent protection. A twin-track approach was adopted to these questions.

Unique identifiers

On the first track we searched the patent collections for a list of 23 000 PBR unique identifiers. Using the HEC, this produced zero results. To cross test the validity of these results, we searched for 1 000 PBR identifiers in the Thomson Innovation whole text patent database. This also produced zero results.

Search terms

As a further test, we then searched in the commercial Thomson Innovation database across the major patent jurisdictions for the simple term 'PBR' to stand for plant breeders' rights. This generated 20 978 results. The result set was exported for processing in Vantage Point text mining and analytics software. Specifically, we were concerned with testing whether any instances of the term PBR fell into areas of the patent system known to be associated with new varieties of plants, specifically under IPC code A01H for New Varieties of Plants. This revealed 442 results for the simple PBR term search falling into IPC code A01H. The publication numbers for these records were imported into Thomson Innovation and the whole texts of the results were exported for review in Word Smith text mining software.
To improve data capture, we conducted additional searches in the main jurisdictions for PBR and PVP using Thomson Innovation for the period from 1900 to 2012. The raw results and results of manual review are provided in Table 4.13.

Table 4.13 PBR searches

Term	Raw Results
PBR	20 978
Plant Breeders Rights or Plant Breeders Right	1 422
Plant Variety Protection	3 450
Community Plant Variety	181
PVP (A01H only)	1 706

This raw data suggested that, at least in principle, it would be possible to text mine the patent data for data relating to PBR. However, we would emphasize that the above data could include very significant noise (i.e. on the term 'PBR') and should be regarded as experimental.

4.4.6 Text mining patent data for PBR information

In the third step of the research on PBRs, we focused on obtaining data on PBRs from UPOV to use in text mining the patent data. In practice, we experienced difficulty in obtaining the required information from the UPOV CD ROM and instead used the new UPOV PLUTO database to extract information for rice, wheat and maize. However, we would note that downloads of this data are formally restricted to 2000 records at a time. We therefore believe that it would be helpful if UPOV could make a data product available permitting the download of all data (i.e. in an XML format) to aid with large scale research of the type conducted for this study. Nevertheless, the PLUTO database is a major improvement in accessing UPOV data.

Our text mining efforts using UPOV data focused on experimenting with the variety name or denomination. Table 4.14 shows a partial sample of data for wheat downloaded from the UPOV database for wheat.

Table 4.14 Sample data for wheat from the UPOV PLUTO database

Denomination	Latin Name	Record Type	Country	Denom Text	Parties
CHATSWORTH	Triticum aestivum L.	PBR	GB	: CHATSWORTH: proposed;2000-06-01: CHATSWORTH: approved	LIMAGRAIN UK LTD: Applicant;LIMAGRAIN UK LTD: Breeder;LIMAGRAIN UK LTD: AGT
CHAUCER	Triticum aestivum L.	PBR	GB	: CHAUCER: proposed;1995-09-01: CHAUCER: approved	ELSOMS LTD: Applicant;ELSOMS LTD: Breeder;ELSOMS LTD: AGT
CHEETAH	Triticum aestivum L.	PBR	GB	: CHEETAH: proposed;: PANTHER: proposed;1990-01-03: PANTHER: rejected	LIMAGRAIN UK LTD: Applicant;LIMAGRAIN UK LTD: Breeder;LIMAGRAIN UK LTD: AGT
Chelsea	Triticum aestivum L.	PBR	US	1993-09-14: Chelsea: proposed;1994-03-14: Chelsea: published;1996-11-29: Chelsea: approved	Michigan State University: Applicant;Michigan State University: Breeder;Michigan State University: Title holder
Cheops	Triticum aestivum L.	PBR	NL	1997-02-20: Cheops: proposed;1997-03-16: Cheops: published;1997-05-07: Cheops: rejected	Wiersum-Zelder, De Samenwerkende Graankweekbedrijven Postbus 26, 6590 AA GENNEP, NL: Applicant;Wiersum-Zelder, De Samenwerkende Graankweekbedrijven Postbus 26, 6590 AA GENNEP, NL: Breeder;Wiersum-Zelder, De Samenwerkende Graankweekbedrijven Postbus 26, 6590 AA GENNEP, NL: Title holder
CHEQUER	Triticum aestivum L.	PBR	GB	: CHEQUER: proposed;2000-07-01: CHEQUER: approved	SYNGENTA SEEDS LTD: Applicant;SYNGENTA SEEDS LTD: Breeder;SYNGENTA SEEDS LTD: AGT
Cherokee	Triticum aestivum L.	PBR	US	1990-02-27: Cherokee: proposed;1990-08-27: Cherokee: published	Agripro Seeds, Inc.: Applicant;Agripro Seeds, Inc.: Breeder

Box 4.1 Selected results of text mining for UPOV-protected variety denominations

chatsworth EP1997899A1//20081203 description nium hydrochloride) on a Ni2+-NTA-agarose column, according to the manufacturer's protocol (Qiagen, |**Chatsworth**, CA). After dialysis against PBS, a mixture of the soluble and insoluble APP polypeptides was used to immunize two New Zealand White rabbits following a standard immunization protocol (Harlow and Lane, 1988). For the Western blot analysis, proteins were resolved by denaturing SDS-PAGE (Sam

chevalier EP2128251A1//20091202 description lication cell cycles --> more for less. Cell 105, 297-306. (Non-Patent Document 2) Joubes, J., and |**Chevalier**, C. (2000) Endoreduplication in higher plants. Plant Mol. Biol. 43, 735-745. (Non-Patent Document 3) De Veylder, L., Beeckman, T., Beemster, G.T., Krols, L., Terras, F., Landrieu, I., van der Schueren, E., Maes, S., Naudts, M., and InzÃ©, D. (2001) Functional analysis of cyclin-dependent kin

chiyohonami EP0902089A2//19990317 description present invention is not limited to such examples. (Example 1) Production of a transgenic rice (cv. |**Chiyohonami**) (1) Preparation of a thionin gene A thionin gene was obtained by PCR using a cDNA clone of a thionin gene designated LTH92 (Japanese Laid-open Publication No. 8-266279, supra) and one pair of primers, in which additional restriction sites for BamHI and SacI were respectively added to eac

christine EP1293569A2//20030319 description "9) of "Method in Molecular Biology" (Humana Press) series, "Chaperonin Protocols" (Eds., Schneider, |**Christine**, 2000); "Development and/or differentiation-related protein" " Developmental Biology Protocols" (Eds., ROBERT EISENTHAL and MICHAEL J. DANSON, 1992) of "Method in Molecular Biology" (Humana Press) series;" DNA- and/or RNA-binding protein" " DNA-Protein Interactions Principles and Protocols" (Ed"

chukar EP1270746A1//20030102 description Ovomucoid (third domain) from Aburria pipile, Aepypodius arfakianus, Afropavo congensis, Alectoris |**chukar**, Alectoris rufa, Anas platyrhynchos, Chloephaga picta, Cyanochen cyanop --> tera, Neochen jubata, Tadorna radjah, Lophonetta specularioides, Anas capensis, Aix galericulata, Aix sponsa, Sarkidiornis melanotos, Alopochen aegyptiaca, Mergus cucullatus, Anhinga novaehollandiae, Anser anser anser,

churchill EP0969092A1//20000105 description ing, the 89th meeting). In the analysis, the pool sampling method was applied to minimize the task (|**Churchill** *et al.*, Proc. Natl. Acad. Sci. USA 90 16-20 (1993)). To increase the accuracy of linkage analysis, it is necessary to increase the number of DNA markers near the target gene and to enlarge the sampling population. Accordingly, YAC clones carrying the Pi-b locus, which was determined by the

cl121 EP2113172A1//20091104 description nde Gen aus E. coli wurde als Selektionsmarker eingefÃ¼hrt, um Transformanten zu identfizieren. B-82 |CL121, CL141, CFX51 Oryza sativa (Reis) BASF Inc. Toleranz fÃ¼r das Imidazolinonherbizid Imazethapyr wurde durch chemische Mutagenese des Enzyms Acetolactatsynthase (ALS)

clemens EP1427285B1//20070822 description HÃ¼bner), navel orangeworm (Amyelois transitella Walker), corn root webworm (Crambus caliginosellus |**Clemens**), sod webworm (Herpetogramma licarsisalis Walker)); leafrollers, budworms, seed worms, and fruit worms in the family Tortricidae (e.g. codling moth (Cydia pomonella L. (L. means Linnaeus)), grape berry moth (Endopiza viteana Clemens), oriental fruit moth (Grapholita molesta Busck));

We would note that Table 4.14 does not show all available data fields from the PLUTO database, such as grant date. We were interested in the Denominations and the possibility of text mining our data for denomination names.

For each of the three target species (rice, wheat and maize), we conducted searches of the patent data using high-end computing. In the case of the USPTO, this generated 1.3 gigabytes of raw data; at the EPO, this was 122 megabytes, and at WIPO, 480 megabytes.

The results were then cleaned. A selection of the results from text mining is shown in Box 4.1 with search terms highlighted in bold.

As will readily be appreciated, the results of text mining patent data for UPOV denomination names reveals many of the same problems that were exposed in searching for CGIAR centre names. Specifically, the denominations used to designate varieties for UPOV protection are frequently, but not exclusively surnames. This produces the problem of many irrelevant results in a given patent dataset even where, as in this case, the searches are conducted in a dataset focusing on PGR.

As the situation stands, in the absence of other search criteria or criteria that can be used to cross-reference and thereby filter the results, our research has reached a temporary impasse.

4.4.7 Conclusion

This section was concerned with using text mining to interrogate patent data on PGR for references to the CGIAR collections, variety and accession codes and for UPOV variety denomination names. The wider objective of this exploratory work was to investigate the linkage between accessions from public collections and commercially oriented research and development. While it was possible to mine the data for relevant search categories, in practice, the results revealed large- scale problems with noise. Based on these exploratory results, the authors believe that the most practical way forward for any follow-on research would be to compile distinctive variety and accession codes as the basis for searching the patent data. In our view, this would provide the most reliable means for retrieving data. This would also greatly facilitate the identification of the contribution of accessions from public collections to commercial research and development involving PGR.

While the experiments conducted within the constraints of this study did not establish a clear linkage between plant germplasm in public collections and patent data, this should not be interpreted to mean that this relationship does not exist. Furthermore, in practical terms, an important insight was acquired into practical measures that might be taken by CGIAR Centres to ensure the increased visibility of information on CGIAR accessions. This would have to include a requirement and a standard format for recording CGIAR contributions in material transfer agreements. This approach would mean that the Centres would be able to readily retrieve information on accessions appearing in patent data and that policy makers would be provided with an insight into the role of germplasm from public collections in patent activity.

4.5 Non-monetary benefit-sharing and the scientific literature

4.5.1 Introduction

Non-monetary benefit sharing is generally acknowledged as being important in international agreements involving genetic resources. However, non-monetary benefit sharing is frequently seen as the poor relation of monetary benefit sharing for the straightforward reason that non-monetary benefit sharing is much more difficult to count. The vagueness of non-monetary benefit sharing is the greatest enemy of its full recognition.

In preparing this research, a discussion was held between the team on possible approaches to addressing non-monetary benefit sharing. Drawing on the relevance of scientometrics or bibliometrics (the analysis of scientific literature), it was realized that published research is generally the outcome of monetary investments in particular research projects (which can be accounted for in national systems and by research organizations). Second, it was recognized that in the 21st century, research is typically international in nature and serves to promote international collaborations between countries. This is particularly true in the biosciences where research in areas such as genomics frequently involves research teams in multiple countries and investments by multiple funding organizations crossing both the public and private sector. A good example of such collaborations is provided by the sequencing of the rice genome by the researchers at the Beijing Institute for Genetics of the Chinese Academy of Sciences (ssp. indica) and Syngenta (ssp. japonica) in 2002.

In order to explore the possibilities of mapping non-monetary benefit sharing in the scientific literature, we selected a sample of 1 314 publications recorded in Thomson Reuters Web of Science for 2011 of a total of 17 350 publications containing this topic. Using a combination of Vantage Point analytics and Tableau visualization software, it becomes possible to visualize the global distribution of researchers publishing on rice in 2011, the subject category areas in which they are publishing and the affiliations of the authors. This data is summarized in Figure 4.18.

4.5.2 Exploratory mapping of research networks on rice (Oryza sativa)

We can immediately see that, in 2011, research on rice was led by research organizations in China, followed by the United States. We can also see that most publications were in the plant sciences, followed by agriculture, biochemistry and molecular biology. A selection of titles is shown to illustrate the research being published.

In practice, publications frequently involve collaborations between countries and organizations. These networks can be mapped using network visualization tools such as Gephi. Figure 4.19 shows the network of cooperation between researchers involved in the publications, and demonstrates multiple linkages between countries where node sized is based on the number of publications and the strengths of the links indicates the strength of co-publication. Due to the complexity of the network, there may be overlaps between nodes and connections.

This type of approach can also be applied to authors and to institutions, but involves intensive data cleaning. Figure 4.20 shows the network of relations between organizations publishing on rice in 2011 with nine or more records in the data.

In considering Figure 4.20, we are coming closer to identifying non-monetary benefits in terms of actual collaborations between researchers and in terms of the training of students, post-doctoral researchers and staff, and their exchange between institutions.

These collaborations embody knowledge exchange and transfers within networks and can be considered a major component of non-monetary benefit-sharing.

We can, however, move a step closer to the monetary dimensions of research through the recent inclusion of information on the funding bodies supporting research in scientific publication data (Figure 4.21). These data are inherently noisy and require extensive cleaning; Figure 4.2.1 is therefore for illustration purposes.

Figure 4.18 Distribution of researchers publishing on Oryza sativa/rice (Web of Science, 2011)

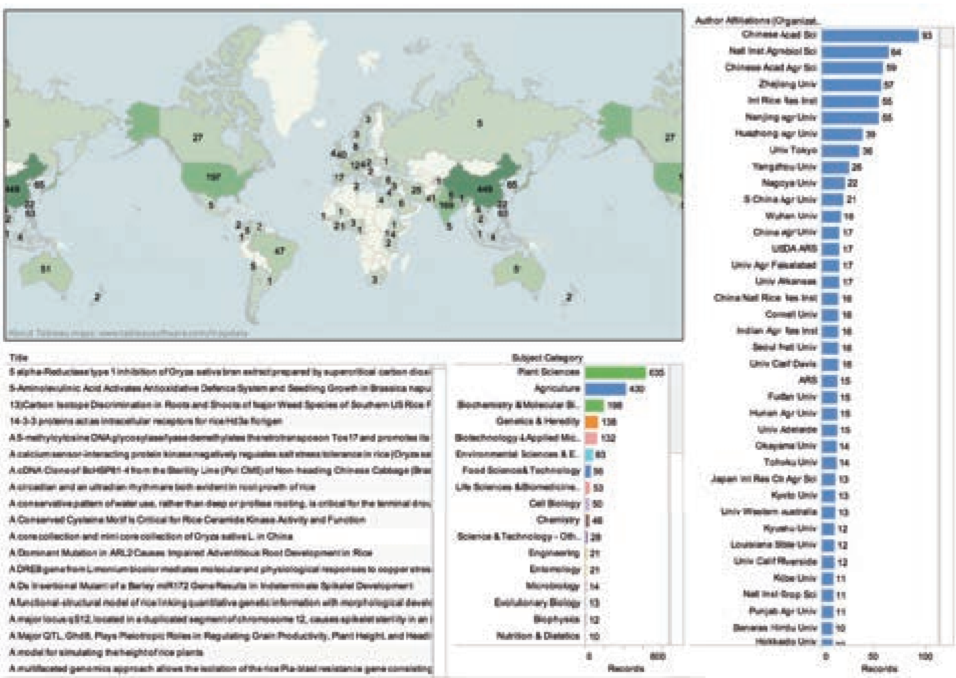


Figure 4.19 Country Co-publication network on Oryza sativa (Web of Science, 2011)

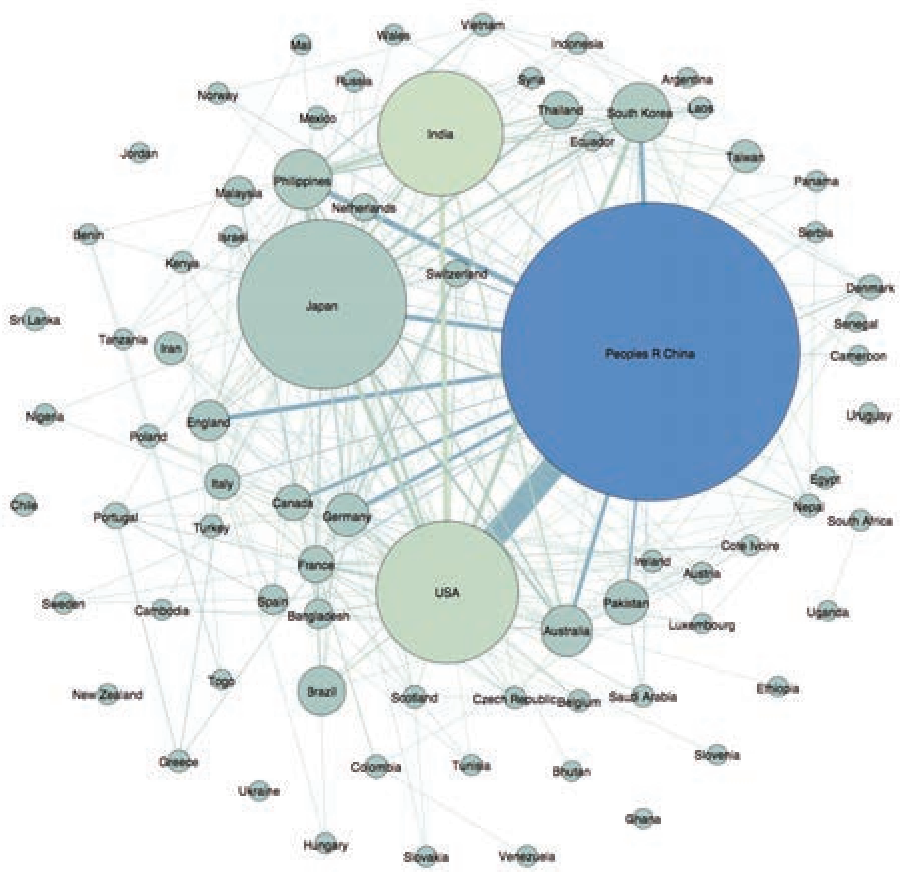


Figure 4.20 Institutional co-authorship network (+9 records)

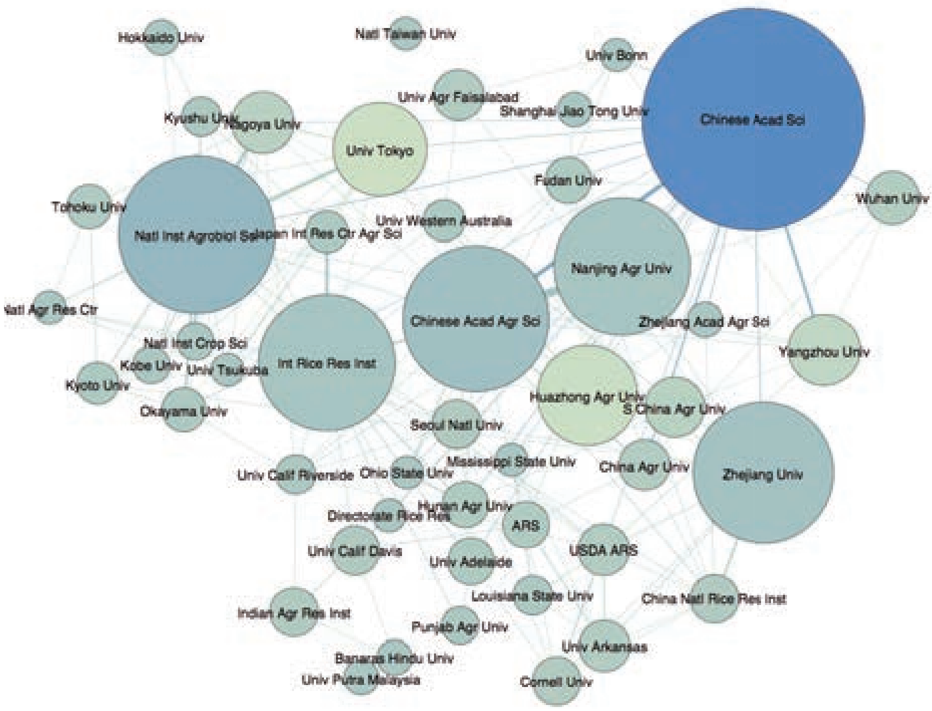
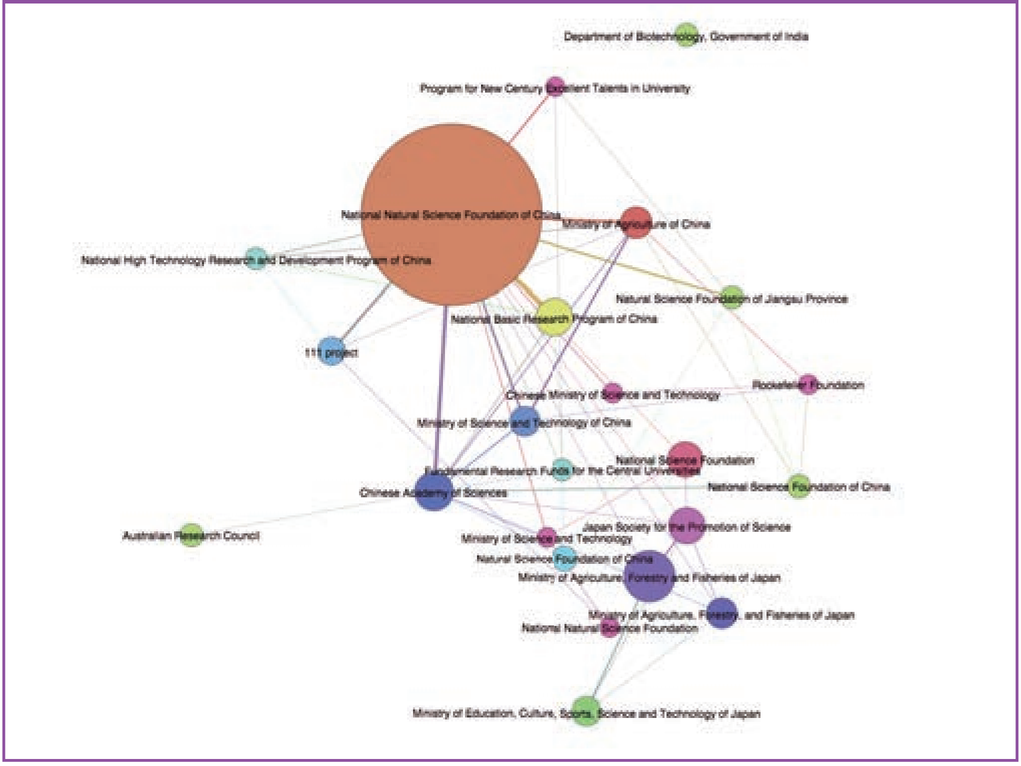


Figure 4.21 Funding Organization 9 plus records for Oryza sativa or rice in 2011



4.5.3 Conclusion

This section has provided an exploratory analysis of the potential of scientometrics techniques for examining non-monetary benefit-sharing focusing on a sample of the scientific literature. While the importance of non-monetary benefit sharing is widely recognized as a major area of benefit sharing, its quantification has proved elusive. This exploratory analysis has demonstrated that it is possible to map one of the primary routes for non-monetary benefit sharing: the generation and exchange of new knowledge about important agricultural species.

With respect to future work, it would be possible to develop fuller datasets of scientific literature on specific species covered by Annex 1 and to map networks of countries, organizations, researchers and funding agencies involved in research for particular species. This would also open the way for examining which of the organizations in these networks have signed the SMTA and to model non-monetary benefit sharing under the Treaty. Although this will involve significant challenges, notably in terms of acquiring and analysing data, this would provide a new path for the analysis of non-monetary benefit sharing in the field of genetic resources.

4.6 Key findings and further research

4.6.1 Patent activity in the main jurisdictions

In the period from 1900 to 2010, a total of 23 193 patents applications were filed for PGR at the major patent offices consisting of the EPC, the Patent Cooperation Treaty, the United States and Japan (Dashboard 1 Priority Filings).[10] Trends in the first filings of patent applications provide a proxy indicator for Research and Development investments and for innovative activity in a given field.

As regards the EPC and Japan (JP), patent filings show a declining trend from the late 1990s onwards. In contrast, patent filings in the United States displayed a rising trend until 2000, followed by sharp decline and gradual recovery before accelerating in 2007. A steep decline in filing after 2008 may reflect the impact of the financial crisis. This trend is reflected in activity under the International Patent Cooperation Treaty (WO), which provides applicants with a means to seek protection in multiple countries. For the PCT, a declining trend in first filings was observed between 2000 and 2006 when applications began to show a marked upward trend.

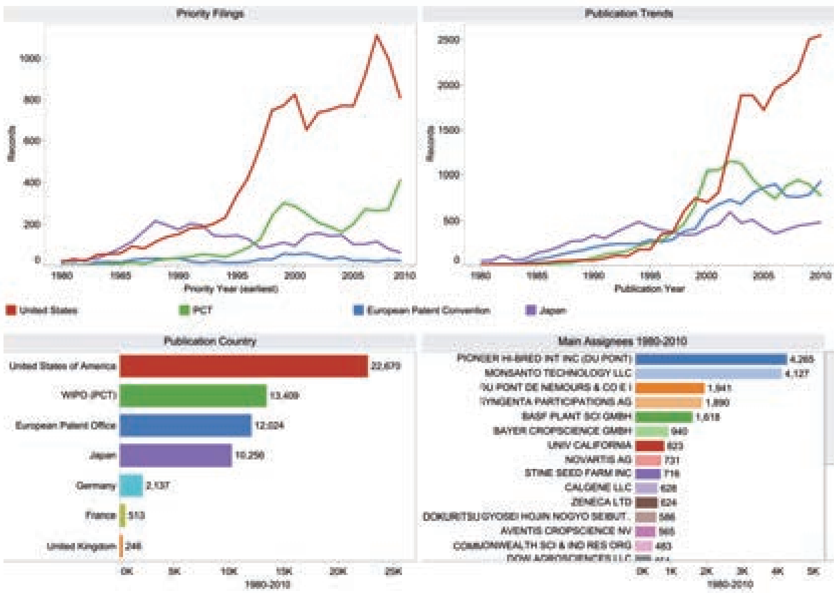
As patent applications move into the system they are published and republished multiple times as applications and grants (Dashboard 1 Publication Trends). In total, we identified 68 111 patent publications in the major jurisdictions for PGR in the period to the end of 2010. This data excludes 21 795 US Plant Patents which offer a lower form of protection than standard utility patents. We would note that the data do not provide an insight into the number of patent grants in force at a given time. In the case of the United States, an apparent sharp increase in the number of patent applications is observable from 2001 onwards throughout the statistics. This sharp increase is in fact a reporting effect originating from a change in US Patent Office practice that initiated publication of patent documents at the application stage from 2001 onwards.

Patent applications within the major jurisdictions were originally filed in a total of 58 countries led by the United States, Japan, Germany, the United Kingdom and France followed by Australia. The top assignees pursuing protection for PGR in the main patent jurisdictions include Pioneer Hi-Bred (Du Pont), Monsanto, Du Pont, Syngenta, BASF Plant Science, Bayer Cropscience, the University of California and Novartis (Dashboard 1 Main Assignees). However, the data do not address the structure of corporate ownership in the sector (i.e. Pioneer Hi-Bred is owned by Du Pont).

The main strength of research on trends in the main patent jurisdictions is that it provided a means to clearly define patent activity for PGR within patent data and to chart activity in the jurisdictions that account for over 80 percent of global patent activity. This section of the report therefore provided a platform for the analysis of global trends in patent activity using the EPO World Patent Statistical Database (PATSTAT, October 2011 edition).

[10] The main jurisdictions include the United States, the Patent Cooperation Treaty, the European Patent Convention, Japan, Germany, France (applications only) and the United Kingdom (applications only).

Dashboard 1 Main trends



4.6.2 Global trends

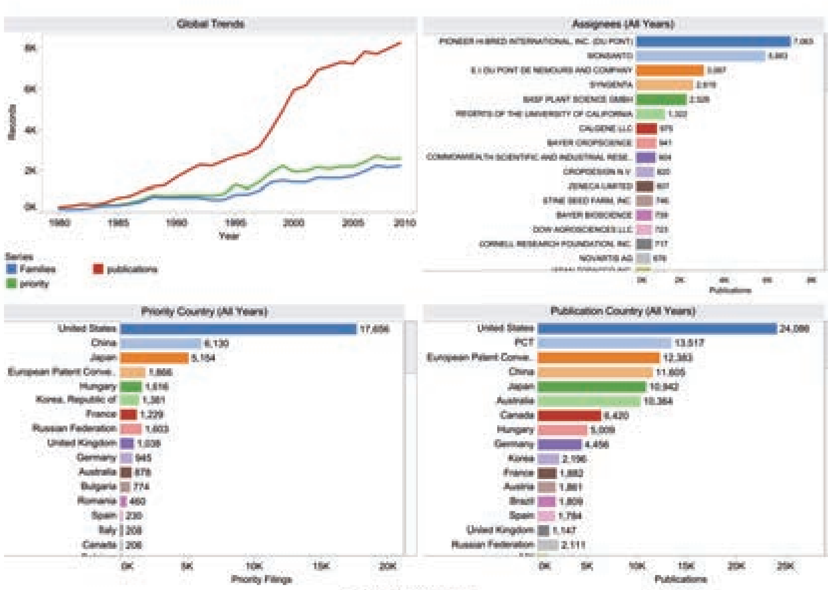
The EPO World Patent Statistical Database (PATSTAT, October 2011 edition) provides the gold standard for the generation of international patent statistics. Dashboard 2 summarizes the available data for global patent activity for PGR in the period from 1900 to October 2011.[11]

Analysis of patent activity for PGR in the 1980–2010 period revealed 40 970 first filings belonging to 32 391 patent families, and 116 795 patent publications linked to 131 505 family members worldwide. When viewed from a global perspective the top countries of first filing of patent applications were the United States, China and Japan with Hungary and the Republic of Korea rising in the rankings (Dashboard 2 Priority Country). Important changes were also observed in terms of the countries of publication of patent applications as an indicator of where patents are being sought. On this measure, the top five countries were the United States, China, Japan, Canada and

[11] Since data for 2011 are incomplete and will therefore show a declining trend, they are excluded.

Australia (Dashboard 2 Publication Country).[12] This clearly shows that other countries, notably China, are emerging as important actors in patent activity and as countries where patent rights are important to companies and research institutions. In terms of patent activity, the top organizations involved mirror those in the main jurisdictions and include, Pioneer Hi Bred (Du Pont), Monsanto, Du Pont, Syngenta and BASF Plant Science (Dashboard 2 Assignees). However, while specific companies dominate the top rankings, it is also important to highlight that universities, such as the University of California, and government institutions such as the Commonwealth Scientific and Industrial Research Organization (Australia), the National Institute of Agrobiological Sciences (Japan) and National Research Council of Canada also feature prominently in the top 50 results. As such, it is important not to lose sight of the various types of organizations involved in patent activity for PGR. Furthermore, while falling outside the present study, it is possible that patent applications originate from networks of collaboration in research and development between organizations of more than one type. This is an important avenue for future research in examining patent activity for PGR of relevance to the Treaty.

Dashboard 2 Global trends



12 Patent data for Australia are affected by patent counting practices for Patent Cooperation Treaty applications. For a period from 1900 to the early 2000s, designations under the PCT were recorded as actual applications. This practice will therefore overcount actual demand for patent rights in Australia. For this reason, data on Australia should be approached with caution pending further clarification.

4.6.3 Annex 1 of the Treaty

The analysis above focuses on the global context of patent activity for PGR and contributes to advancing knowledge and understanding by establishing a straightforward definition that can be used for the future elaboration of patent statistics. However, Annex 1 of the Treaty sets out a list of specific genera and species that are covered under the Treaty. It is therefore important to identify patent activity on the species level.

In practice, Annex 1 of the Treaty focuses on the genus level and contains specific inclusions and exclusions for species (i.e. Lepidium meyenii) arising from the concerns of Parties at the time that the Treaty was negotiated. The patent system and the IPC do not provide a ready guide to the identification of Annex 1 species for statistical purposes. We recommend that the EPO and WIPO contribute to statistical analysis through the further elucidation of classification codes or, as appropriate, tags for Annex 1 genera in electronic patent databases.

The analysis of patent activity for Annex 1 species exploited the availability of a High-End Computing facility. This involved text mining 11 million patent documents from the United States PTO, the EPO and the Patent Cooperation Treaty for Latin species names falling under Annex 1. Analysis of patent claims from the main patent jurisdictions in Section 4.2 revealed that patent applicants in this sector generally use the common names of food crops. We responded by identifying the main common names for these species. To limit the possibility of noise, the searches by common names were confined to documents falling within the definition of PGR identified in Section 4.2 and further restricted to data appearing in the Titles, Abstracts and Claims of patent documents. This has the effect of limiting the data on common names to those documents that are in an important sense ‘about’ the species concerned. The results were then grouped on the accepted scientific names for the species. The results are summarized in Dashboard 3.

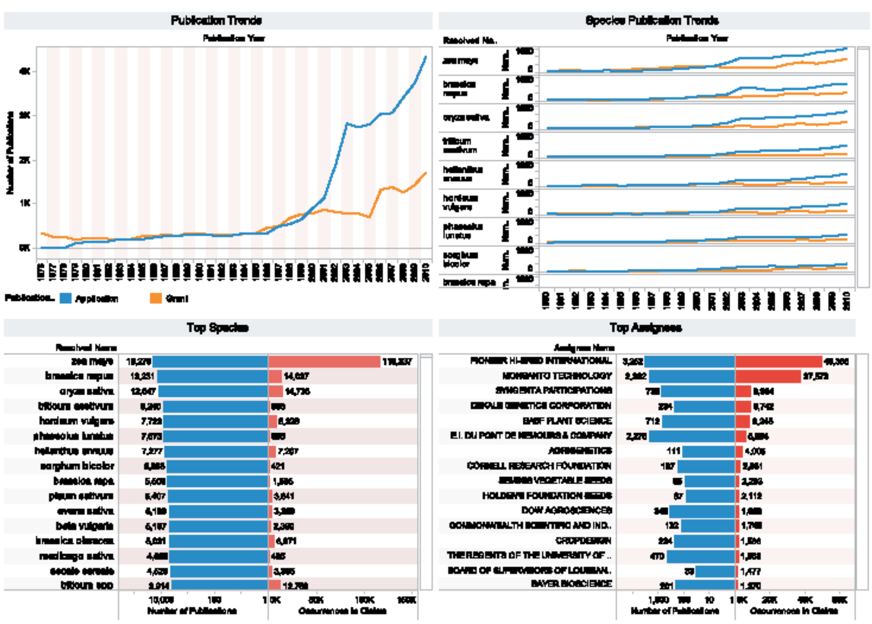
In total, we identified 1 014 species falling under Annex 1 within the three patent jurisdictions, including non-specific applications involving members of a particular genus (i.e. Triticum spp.). In total, we identified 55 531 patent publications originating from 26 145 original filings in the 11 million documents from the main jurisdictions. This strongly suggests that patent activity for PGR is likely to be dominated by Annex 1 species.

With respect to individual Annex 1 species, patent activity is dominated by maize, rice and Brassica napus (rapeseed), followed by wheat (Triticum spp.). In the case of beans, we experienced difficulty in allocating common name data to specific species within the bean group and have marked the data accordingly. In terms of patent claims, Dashboard 3 makes it clear that patent claims relating to Annex 1 species are dominated by maize by a very considerable margin, suggesting a concentration of research and development in maize. In an important methodological advance, we were also able to chart patent activity by applications and grants for the individual species covered by Annex 1. This raises the possibility of longer- term analysis of patent activity on an individual species basis.

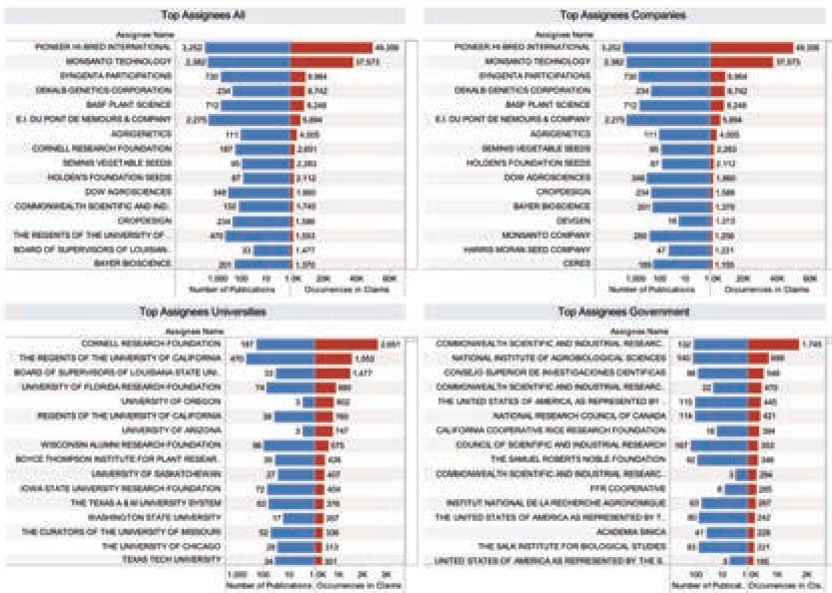
Dashboard 3 also reveals that the top applicants for patent rights in relation to Annex 1 species mirror the applicants from the main jurisdictions and globally using PATSTAT.

However, it is also possible to break down the applications by organization type as set out in Dashboard 4. Looking beyond the top ranking companies, Dashboard 4 reveals that universities and government organizations (principally government research organizations) are also significant actors in patent activity involving Annex 1 species. This type of data opens the possibility of increasing engagement with companies, universities and government research organizations in pursuing the objectives of the Treaty by opening a constructive dialogue with the range of actors involved in patent activity.

Dashboard 3 Annex 1 patent activity



Dashboard 4 Annex 1 assignees by sector



4.6.4 CGIAR Centres, plant varieties and UPOV

One of the significant challenges involved in this research was identifying the role of PGR under the multilateral system and applications for PBR. This poses a formidable challenge because there is no standardized system for identifying accessions from CGIAR Centres within patent or similar documents, and we know of no existing methodologies or tools for retrieving such data.

Our research therefore focused on exploring this issue using informatics techniques. As a starting point, the research focused on searching the whole text of patent collections for references to the names and abbreviations for CGIAR Centres. The results were then reviewed line by line using corpus linguistics tools to examine the contexts in which references occurred.

In the majority of cases, the analysis revealed that references were being made to research and publications from CGIAR Centres and general references such as: "In 1993 the Consultation Group of International Agricultural Research (CGIAR) suggested that increasing the mineral uptake of plants could be used to address the problems associated with deficiency of zinc and other nutrients (Ruel and Bouis, 1998)." In other cases, specific references were made to the acquisition of biological material from a specific collection, for example, "The reverse drooping flag leaf character can be introduced into the perennial female fertile male seed parent by crossing with RGS20, which is publicly available from IRRI (Philippines)" (US5304722A). However, as this data suggest, the provision of this information is inconsistent and varies in form, making data retrieval difficult and time-consuming.

We then turned to the identification of plant germplasm accession codes. During the experiments, it became clear that patent applicants routinely make reference to accessions with an estimated 178 805 patent publications in the main jurisdictions making reference to the term accessions across all patents. In particular, under the Budapest Treaty on the International Recognition of the Deposit of Microorganisms for the Purposes of Patent Procedure (1977, amended 1980), patent applicants routinely deposit samples with recognized international depositary authorities and refer to accessions, i.e. at the American Type Culture Collection (ATCC) with the corresponding accession number in their applications.

To test this type of approach we searched the whole texts of 4 287 patent documents containing Latin species names for Annex 1 species. Due to the lack of uniformity of accession codes, which typically take alphanumeric form, the research focused on identifying accession codes that were adjacent in the texts to relevant terms, such as parent, parental line, breeding line, seeds of, cross with, variety, and varieties, among others. This resulted in 348 454 lines of text containing these terms. We then reviewed the texts within 100 characters of these target terms to identify accession numbers, i.e. CV914011 and DP488/BG/RR. The largest number of results appeared for corn/maize (8 595), rice (130) and wheat (216) in our sample.

We then sought to use the identified variety codes to track back to the ICIS germplasm databases to see if we could link back from the patents into the data to generate mendelgrams. However, we were unsuccessful in this experiment with the sample data available to us. In our view, this probably arose because our sample contained references to commercial varieties that are not present in the ICIS public database. In addition, since the form of expression of variety codes is not uniform across the data, the same variety code may not map across databases.

We believe that it should be possible to link accession information from patents back into the public germplasm collections. However, the most efficient method for achieving this goal would be to reverse the methodology that we employed; that is, in any future work, effort should focus on acquiring a complete list of accession numbers from the public collections for a target species (i.e. maize/rice/wheat) and then text mining the patent data for these codes.

We then turned to testing patent data for information on PGR protected under UPOV. We were able to obtain UPOV data for rice, wheat and maize from the new UPOV PLUTO database and conducted searches of the relevant data from the major collections using the plant variety denominations recorded in UPOV data. This generated large numbers of results but exposed significant problems with noise in patent data. Specifically, UPOV denominations are frequently, but not exclusively, surnames, place names and other common names. This produces very large levels of background noise, even in data related to PGR. Our experiments suggest that retrieving UPOV-related information from patent databases will be a major undertaking that would require additional match criteria to filter for noise. One possibility in this area would be to use narrow search margins where a denomination would only be included for further review where it is adjacent to the Latin species name.

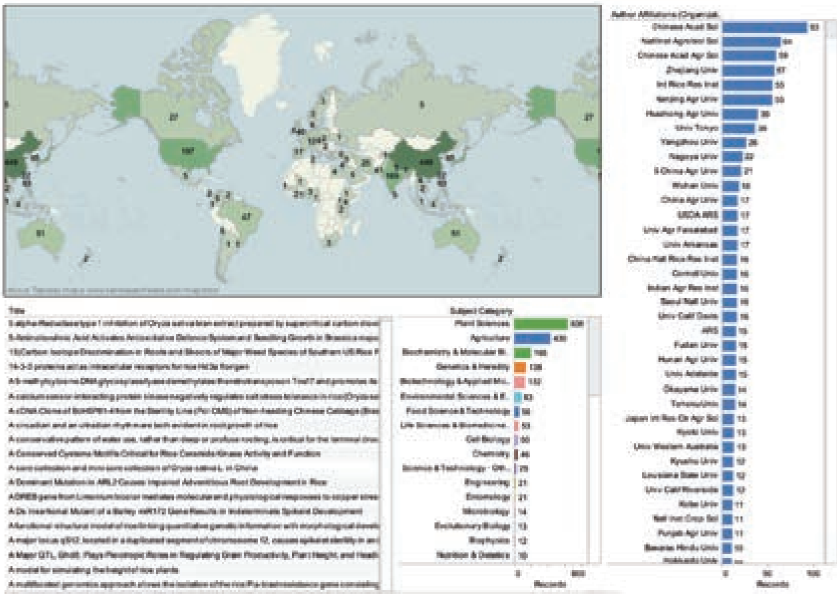
4.6.5 The scientific literature and non-monetary benefit-sharing

Non-monetary benefit-sharing has repeatedly been highlighted as an important form of benefit-sharing for PGR and in wider international policy debates on genetic resources and benefit-sharing. However, the measurement, quantification and visualization of non-monetary benefit-sharing have proved elusive. As a contribution to methodological development in this area we engaged in an experiment with the application of scientometrics techniques to the analysis of non-monetary benefit-sharing. Scientometrics focuses on the analysis of scientific literature to identify key topics, networks and trends in specific areas of science and technology.

For this experiment we selected a sample of 1 314 scientific publications on Oryza sativa (rice) in 2011 from Thomson Reuters Web of Science. Using a combination of Vantage Point Analytics software and Gephi network visualization software, we were then able to map networks of collaboration between countries, research organizations and funding organizations (Dashboard 5).

The key insight that emerges from the application of scientometrics approaches to benefit-sharing is that it becomes possible to identify and visualize networks of collaboration between countries, research organizations, funding bodies and ultimately researchers involved in research on Annex 1 species. Each of these areas involves investments in research that are potentially measurable and also provides a potential route to the identification of knowledge transfer as a form of benefit-sharing (i.e. exchange and training of staff and students between countries and organizations). As such, network mapping of this type provides a potential route forward in the evidence-based analysis of non-monetary benefit-sharing. This approach could usefully be used to examine inter-country collaborations in particular areas of plant genetic research or to target issues of particular relevance to developing countries.

Dashboard 5 Networks of collaboration



4.6.6 Recommendations

The research presented in this chapter provides the most complete overview to date of patent activity for PGR and represents a major advance in the analysis of patent activity for Annex 1 species and genera. Any future work in this area would ideally focus on:

- testing and refining the IPC based definition of PGR developed for this chapter;
- aggregating patent assignee data using verifiable data on the structure of corporate ownership within the sector;
- examining legal status data to identify the number of patents in force at a given time and trends in the maintenance of patent rights over time;
- analysing patent activity by organizational sectors provided in this chapter, which provides opportunities for engagement with the users of PGR directed towards realizing the objectives of the Treaty. Any future work should consider using patent data by organizational sector as an engagement tool;
- analysing licensing data and licensing practices within this sector;
- testing and refining large-scale text mining of patent data for Annex 1 species by focusing on common names for species in claims over PGR improving the transparency of patent information on PGR under Annex 1 of the Treaty by

developing classification codes or tags for the major genera or species within patent databases in close collaboration with information systems specialists at the EPO and the WIPO to identify the most appropriate means for meeting information needs in this area;

- improving the transparency of information on the origin of plant germplasm and especially on the uses of germplasm from public collections by including requirements for recipients of germplasm to use standardized codes in patent documents as part of Material Transfer Agreements;
- improving the transparency of information on plant germplasm originating with public collections or in the UPOV system. This would be achieved by drawing on lessons learned by the International Depository Authorities under the Budapest Treaty on the International Recognition of the Deposit of Microorganisms for the Purposes of Patent Procedure, which could provide practical guidance on meeting informational needs while minimizing any possible requirements from applicants or patent offices;
- developing the application of scientometric techniques to the analysis of the scientific literature as a promising route for the quantification and visualization of non-monetary benefit-sharing;
- applying scientometrics approaches to the analysis of networks of research organizations and patent applicants by focusing on particular species or particular issues of relevance to developing countries.

Annex

PLANT BREEDING AND THE USE OF THE STANDARD MATERIAL TRANSFER AGREEMENT: CONSULTATION WITH PLANT BREEDING EXPERTS

Maryline Guiramand, Nina Isabella Moeller

and Mario Marino

A.1 Summary

This report presents the results of a survey of plant breeding practitioners, which was carried out in order to inform the mathematical model presented in Chapter 3. Rather than generating representative data at the initial stage of the project, this survey has focused primarily on establishing initial contacts with industry and other experts, providing best estimates for those factors of the mathematical model for which information was difficult to obtain elsewhere.

Six questions regarding aspects of breeding of three major crops (wheat, maize, rice) were posed (see the Questionnaire in section A.3 below) and 34 completed questionnaires were received, covering 13 countries for data on wheat, maize and rice. Additionally, we received responses with regard to tomato as well as single data on canola, forage and lettuce, which were included in the evaluation in order to provide a comparison to the main crops of analysis.

The average number of years for the development of a variety using landraces or wild species as parent lines is 16.9 for wheat, 12.4 for maize, 11.5 for rice and 9.8 for tomato, which decreases to 9.5, 8.1, 7.9 and 5.9, respectively, when using pre-bred and improved material rather than landraces or wild species. Improved material is used mostly for breeding with 92 percent for wheat, 94 percent for maize and 87 percent for rice and tomato. Varieties remain on the market 6–8 years for wheat, maize and tomato, and 10–11 years for rice. The use of SMTA is low, on average 5–6 percent for wheat, maize, tomato, and 12 percent for rice. The experts indicated that there is a clear trend to avoid SMTA since the commercial results of the incorporation of materials accessed under SMTAs are so uncertain. The private holdings differ widely by crop and country. On average, world holdings are estimated at 32 percent for wheat, and 27 percent for rice, and at a much higher level for maize and tomato, at 63 percent and 65 percent, respectively.

The questionnaires provide a view from practitioners and as such are extremely helpful as another source of information for the algorithm. The results, however, need to be taken with great caution, because this survey has two major weaknesses, the small sample size and the limitations of the questionnaire itself, both of which will be discussed in section A.5 below. The main objective has been to pave the way for future work in this area.

A.2 Methodology

A questionnaire was developed to obtain information from practitioners in order to provide figures to populate the algorithm developed in Chapter 3 to estimate the future income into the Benefit-sharing Fund of the Treaty under a number of different scenarios. In particular, it was designed to provide a better estimate of some of the factors of the algorithm (see Table A.1).

Table A.1 Factors for which data were requested, by questionnaire

κ	Development time		Average time, per crop/crop group, from access to product.
γ	Ratio of improved/ unimproved **A**		The ratio, per crop/crop group, of improved/unimproved accessions released under SMTAs.
L	Product life		The average period of sale of a product, per crop/crop group.
u	Avoidance		Deliberate avoidance of material under SMTAs.
C	Crops		Total world holdings of PGR for food and agriculture. The first iteration of the model initially tracks five crops/crop groups: rice, wheat, maize, other Annex I, non-Annex 1 crops/crop groups.

The questionnaire includes six questions (see section below) to cover information for these factors. At this stage, the data were used in conjunction with data from other sources (including those presented in Chapter 2 and 4) to populate the algorithm and check its functioning. Due to limited time and data constraints, the research project was restricted in order to focus its analyses on the three key crops – rice, wheat, and maize; other crops had to be grouped into the two crop groups, "other Annex 1 crops" and "non-Annex 1 crops", making reference to the 64 crops covered by the Multilateral System of Access and Benefit-Sharing (the Multilateral System of Access) of the Treaty, which are listed in its Annex 1. The initial draft of the questionnaire was elaborated by the research team and revised according to the feedback received from experts in private industry as well as in public institutions.

The questionnaire was to be filled by plant breeders or other experts in plant breeding. Contact with respondents was made through the International Seed Federation (ISF), Plantum NL, the Global Partnership Initiative for Plant Breeding Capacity Building (GIPB), the Generation Challenge Programme (GCP) of the CGIAR, the Treaty Secretariat as well as by direct initiative of the research team. Since the objective of the questionnaire was to collect some initial data and not to generate geographically representative data, the above approach aimed to establish an initial contact with some of the main breeding organizations.

A total of 34 completed questionnaires have been received. Most of the answers were obtained in writing and for three of them, the data we recollected during a phone interview. Three of the questionnaires combined the views of several experts, one received through the International Seed Federation (ISF) and two from Italy (nine answers in Italy representing 19 experts). Twenty-four questionnaires covered wheat; 18 covered maize; 15 covered rice; five covered tomato; and one covered rapeseed. A list of the respondents is included at the end of this report. Global geographical coverage was not expected for this phase of the project; nonetheless, 13 countries were represented as in Table A.2.

Table A.2 No. of answers by countries and crops

Country	No. of respondents	Wheat	Maize	Rice	Other
Argentina	1	1	1	1	
Australia	1	1			Rapeseed 1
China	2	2	1	2	
France	5	3	2	1	
Germany	3	2	2	1	
Italy	9	8	8	7	Tomato 5
Kenya	1	1	1	1	
Norway	1	1			
Peru	1		1		
Switzerland	2	2			
Thailand	1			1	
USA	1	1	1		
Venezuela	1		1	1	
Anonymous	5	4	3		1 forage, 1 lettuce
Total	**34**	**26**	**20**	**15**	**6**

Twenty out of 34 answers, or 59 percent, were from Europe, two (6%) from Latin America, one (3%) from the United States, three (9%) from Latin America, three (9%) from Asia, one (3%) from Oceania and one (3%) from Africa; five answers (15%) were anonymous.

The results will be presented by crop, and the impact of the geography will be highlighted when and where it adds variability. Among the 34 institutions from which responses were received, 15 were public and 20 are private. This is likely to explain further some of the variability in the answers. The sample size is obviously too small to allow drawing anything more than merely indicative conclusions; however, the discussion below provides a good entry point for further work in this area.

A.3 Questionnaire

For plant breeders and other PGRFA experts

How long would you say it takes on average to develop a commercial variety (from access of parent lines to market introduction) for each of the following crops? Please specify an average number of (A) years and (B) breeding cycles for development with (1) landraces or wild species as parent lines, and with (2) improved or pre-bred varieties as parent lines.

	Average no. of years for development of commercial variety		**Average no. of breeding cycles for the development of commercial variety**	
	Landraces or wild species as parent lines	Pre-bred and improved material as parent lines	Land races or wild species as parent lines	Pre-bred and improved material as parent lines
Wheat				
Maize				
Rice				

What do you believe to be the proportion of pre-bred and improved materials vs. unimproved materials (landraces, wild species) that are currently being used in breeding for each of the following crops?

	Proportion improved (pre-bred): unimproved (landraces, wild species)
Wheat	
Maize	
Rice	

Please indicate what you believe to be the average length of time that a seed variety remains on sale for each crop.

	Average length of time (in years)
Wheat	
Maize	
Rice	
Tomato	

What do you estimate to be the percentage of materials accessed via an SMTA that are currently being used in breeding for the following crops?

	Percentage of breeding material that was accessed via an SMTA	
	In all breeding programmes	**In breeding programmes of your organization**
Wheat		
Maize		
Rice		

Do you think that there is a tendency to avoid use of materials brought under SMTA conditions in commercial breeding?

YES /NO
If so, why do you think that is? ______________________

Of the world's total PGR of each of the following crops, what do you estimate to be the percentage that is held by the private sector?

	Percentage held by the private sector in your country	Percentage held by the private sector globally
Wheat		
Maize		
Rice		
Other Annex 1 crops (taken together)		
Non-Annex 1 food and agricultural crops		

A.4 Data

This section presents the results for each question.

Question 1: How long would you say it takes on average to develop a commercial variety (from access of parent lines to market introduction) for each of the following crops? Please specify an average number of (A) years and (B) breeding cycles for development with (1) landraces or wild species as parent lines, and with (2) improved or pre-bred varieties as parent lines.

Table A.3 Results of Question 1

	Average no. of years for development of commercial variety		Average no. of breeding cycles for development of commercial variety	
	Landraces or wild species as parent lines	**Pre-bred and improved material as parent lines**	**Landraces or wild species as parent lines**	**Pre-bred and improved material as parent lines**
Wheat	16.9 Range: 4–50 Average: 13.8–20 Mini: 4–30 Max: 4–50	9.5 Range: 1–40 Average: 7 –11.9 Mini: 1.7–11 Max: 1–40	10.1 Range: 1–25 Average: 9.2–10.9 Mini: 1 –25 Max: 1.7–25	6.7 Range:1 –16 Average: 5.8–7.5 Mini: 1–16 Max: 1–16
Maize	12.4 Range: 5–20 Average: 7.3–8.9 Mini: 5–20 Max: 6–20	8.1 Range: 2–12 Average: 7.3–8.9 Mini: 2–9 Max: 3–12	9 Range: 3–16 Average: 8.6–9.3 Mini: 3 –16 Max: 3 –16	8.2 Range: 1–12 Average: 7.9–8.5 Mini: 1–10 Max: 1–12
Rice	11.5 Range: 5–16 Average: 10.6–12.3 Mini: 5–15 Max: 6–16	7.9 Range: 3–12 Average: 7.4–8.4 Mini: 3–10 Max: 4–12	14 Range: 5–24 Average: 13.8–14.1 Mini: 5–24 Max: 5–24	9.5 Range: 3–17 Average: 9.3–9.6 Mini: 3–17 Max: 3–17
Tomato	9.8 Range: 5–16 Average: 6.5–13 Mini: 5–8 Max: 6–16	5.9 Range: 2–12 Average: 4–7.7 Mini: 2–6 Max: 3–12	6.3 Range: 5–10 Average: 5–7.5 Mini: 5 Max: 5 –10	5.7 Range: 3–8 Average: 5–6.3 Mini: 3–8 Max: 3–8
Forage	21–24	13–15	9–10	7
Lettuce	8	5	10	7

A data point has been calculated using simple averages in the table. Given the small sample size and the large data variability, the global range, the average range as well as the lowest and highest values range are presented.

The average number of years for the development of commercial varieties of wheat from landraces or wild species is much higher, i.e. 16.9 years compared to 12.4 for maize; 11.5 for rice; and 9.8 for tomato. Wheat has also the largest variability, since breeding a successful variety can take as long as 50 years, depending on the desired traits, while only up to 20 years, 16 years and 13 years are indicated for maize, rice and tomato, respectively. The use of pre-bred or improved material as parent lines shortens the time to commercialization by almost seven years to 9.5 for wheat, by four years to 8.1 for maize, and by three years to 7.9 for rice and to 5.9 for tomato. Wheat requires the longest time on average in comparison to maize, rice, and tomato, with the use of both landraces/wild species and pre-bred material. It must be noted, however, that the use of modern breeding techniques (such as molecular markers) can reduce the total time period to 4–5 years for unimproved material and one year for improved material in some cases.

The average number of breeding cycles is highest for rice, with 14 and 9.5 cycles for landraces/wild species and pre-bred, respectively, whereas wheat has 10.1 and 6.7 average cycles, respectively; maize has 9 and 8.2 average cycles, respectively; and tomato has the smallest number, 6.3 and 5.7, respectively. Wheat has the highest variability for the unimproved material, ranging from 1 to 25, followed by rice, ranging from 5 to 24; maize and tomato are much lower, 3 to 16, and 5 to 10, respectively. Improved material displays a shorter range, 1 to 16 for wheat; 1 to 12 for maize; 3 to 17 for rice; and 3 to 8 for tomato.

The data provided for forages show the longest development time of all crops (21–24 years with landraces, 13–15 years with improved material), whereas lettuce has the shortest development time, of eight years using landraces and five years with improved material.

Question 2: What do you believe to be the proportion of pre-bred and improved materials vs. unimproved materials (landraces, wild species) that are currently being used in breeding for each of the following crops?

Table A.4: Results of question 2

	Proportion improved (pre-bred): unimproved (landraces, wild species)	Range for improved materials (%)	Range for unimproved materials (%)
Wheat	92: 8	70–100	1–30
Maize	94: 6	80–100	0–20
Rice	87: 13	50–98	2–50
Tomato	87: 13	80–90	10–20
Forages	98: 2		
Lettuce	90: 10		

All questionnaire responses pointed to a wide use of improved material, 92 percent and 94 percent, respectively, for wheat and maize, and about 5 percent less for rice and tomato, at 87 percent. Some experts reported that they use up to 100 percent of improved material for wheat and maize, and 98 percent for rice, while for tomato, the maximum was 90 percent. The proportion of landraces and wild species may increase to up to 50 percent for rice, while their maximum estimated utilization is 30 percent for wheat, and 20 for maize and tomato. Forages and lettuce are presented on the basis of a single data point only. Forages would be the highest user of improved material with 98 percent while lettuce with 90 percent would be slightly above tomato and rice.

Question 3: Please indicate what you believe to be the average length of time that a seed variety remains on sale for each crop.

Table A.5: Results of Question 3

	Average length of time (in years)	Range
Wheat	7–8 years	2–15
Maize	6–8 years	3–25
Rice	10–11 years	3–30
Tomato	6–9 years	4–15
Lettuce	5 years	

On average, wheat varieties remain on the market for 7–8 years; maize varieties for 6–8 years; rice varieties a little bit longer, an average of 10–11 years; and tomato varieties, 6–9 years. As different varieties bring different traits to the market, those with particularly desirable characteristics have a much longer market life. This is the case for rice with 30 years, maize with 25 years and wheat and tomato with 15 years each. There are important exceptions like for example one wheat variety in Switzerland which has been on the market for 30 years, but this value was not included so as not to distort the average. On the lower end of the spectrum, certain wheat varieties remain on the market for only two years, certain maize and rice varieties for only three years and a few tomato varieties for four years. The single data point for lettuce presents the shortest length of market presence.

Question 4: What do you estimate to be the percentage of materials accessed via an SMTA that are currently being used in breeding for the following crops?

Table A.6: Results of Question 4

	Percentage of breeding material that was accessed via an SMTA		Range of values for the percentage accessed via an SMTA	
	In all breeding programmes	In breeding programmes of your organization	In all breeding programmes	In breeding programmes of your organization
Wheat	8.7 (5.2)	5.4 (2)	0–60	0–60
Maize	7 (2.4)	5.9 (1.5)	0–65	0–40
Rice	12.3 (5.9)	13.3 (7.0)	0–70	0–90
Tomato	6.2		1–10	

Lettuce		3.3		

On average, the percentage of breeding materials accessed via an SMTA in all breeding programmes is estimated to be 8.7 percent for wheat, 7 percent for maize, 12.3 percent for rice and 6.2 percent for tomato. Most figures provided were below 10 percent, but one expert estimated it at 60 percent, 65 percent, and 90 percent, respectively, for wheat, maize and rice. When this estimate is excluded, the global average is 5.9 percent, 3.0 percent, and 5.9 percent, respectively.

The estimate of the percentage of breeding materials accessed via an SMTA in the respondents' organizations was reported at 3 percent and 1 percent lower for wheat and maize compared to the percentage given for all breeding programmes, while it was reported at 1 percent higher for rice. The single data point for lettuce 3.3 percent is much lower than the other crops.

Question 5: Do you think that there is a tendency to avoid use of materials brought under SMTA conditions in commercial breeding?

Table A.7 Results of Question 5

Answer	No. of respondents
Yes	20
No	11
Not available	3

Most of the respondents (20) affirmed the tendency to avoid the use of materials brought under SMTA conditions, while 11 disagreed, three of which answered in the negative for maize; three respondents did not know.

Some of the reasons given for the lack of a tendency to avoidance were linked to the usefulness, quality of material and ease of SMTA exchange, as indicated in the following comments received:

- If the genetic material accessed through an SMTA is useful to a particular breeding programme, then the payment of a royalty will not be an issue.
- Scientists need to understand the new possibilities offered. Use of such material is more for scientific research than for practical breeding, but there is no special avoidance of the SMTA.
- Since the material from gene banks already has a certain age, breeders are unlikely to find interesting material. There is a limited knowledge among breeders on what material is actually available in a gene bank and what traits this material has. Some traits such as disease resistance do not always transfer. Therefore, there is no special avoidance; only a generally limited use of material in gene banks among commercial breeders.
- Exchange is important to provide variability if the administrative burden to access it is not too high.

- For maize in particular, genetic modification is widespread and current techniques work with specific alleles found in isogenic lines in order to facilitate introgression into elite lines. In this context, the material available via SMTAs is not very interesting, but there is no explicit avoidance.

The main reason for avoiding the use of SMTAs is the perception that one thereby avoids issues related to rights for commercial use. The uncertainty of the commercial results of the incorporation of materials accessed under SMTAs is the main driver behind avoiding SMTAs. One respondent noted that this tendency is changing as the understanding increases that SMTAs do not call for mandatory benefit sharing if a new variety is protected under PVP rather than patents. The implication being that voluntary payments are in practice likely to be minimal. Below are some additional rationales evoked:

- Firms use their own material.
- Given the unpredictability of success, there is a lack of knowledge about what needs to be paid in case of success. Furthermore, if some exotic gene was used initially without real added value, it is also costly to get rid of it, thus remaining in the genome and calling for payment. Given this uncertainty and the costly tracking that this would be required, there is a general tendency of avoidance. Some companies even view this uncertainty as an unacceptable business risk except under rare circumstances.
- One company had concerns about the SMTA definition of "available without restriction", the minimum threshold for a genetic resource to be eligible for benefit sharing, and benefit sharing in perpetuity. However, it is the cost of compliance due to the excessive uncertainties created by the SMTA that make the business risks too great.
- "We are facing a new situation with the status of genetic resources (GR). On one hand, we are very pleased with the Treaty because it is simpler than what has been agreed with the CBD. Nevertheless, the new concept of property for the genetic resources is impacting the way to do breeding. In the past, we were using GR without any concern or restriction. We also did so in our country (France) since varieties are freely accessible for further breeding due to the UPOV convention. Now we have to pay more attention to the use of genetic resources (GRs). One key point is to evaluate the real interest of a GR in a breeding programme. This delays and restricts the introduction of GR in our programmes. In addition, the uncertainty about the consequence in terms of ABS also limits this use."
- In wheat breeding, there is so little profit made that no money is available for benefit sharing with regard to SMTA-derived varieties. Additionally, resistances that mostly come from landraces or wild species are not paid much attention in agricultural practice.
- One Asian respondent feared that using SMTA materials may increase the cost of developing varieties for the poor farmers.
- For rice, a specific tendency to avoid the SMTA in Thailand was pointed out because only one particular rice variety (KDML105, the number one export variety) is to be used for research. In another country, avoidance was noted for phytosanitary reasons as well as due to a lack of knowledge of the specific performances of the accessions.

Question 6: Of the world's total PGR of each of the following crops, what do you estimate to be the percentage held by the private sector?

The average percentage of the genetic resources held by the private sector varies substantially from country to country, as shown in Table A.8.

Table A.8 Percentage of genetic resources holdings by country

	Wheat		Maize		Rice		Tomato	
	Country	World	Country	World	Country	World	Country	World
France	70	50	70	80	10	10		
Italy	61	65	91	84	50	47.5	76	65
Germany	30	15	73	60	n.a.	n.a.		
Switzerland	0	n.a.	n.a.	n.a.	n.a.	n.a.		
Norway	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.		
Europe	40	43	78	75	30	29		
Australia	n.a.		n.a.		n.a.	n.a.		
USA	30	20	80	75	n.a.	n.a.		
Kenya	5	15	20	25	1	5		
Argentina	30	30	60	60	30	30		
Peru	n.a.	n.a.	60	60	n.a.	n.a.		
Venezuela	n.a.	n.a.	99	90	20	20		
Latin America	30	30	73	70	25	25		
China	7	30	20	38	30	50		
Thailand	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.		
Asia	7	30	20	38	30	50		
Country average	29	32	64	63	24	27	76	65

Given the small sample size and the predominance of data points for European countries compared to other geographical zones, the results are only indicative of the private holdings in the country, and the variation of holdings between crops as well as in the world. All these estimates are likely to be biased towards Europe.

The tomato holdings by private sector are the highest, at 76 percent in the country and 65 percent globally; this was followed by maize, at 64 percent and 63 percent respectively; wheat, 29 percent and 32 percent, respectively; and rice, the lowest, at 24 percent and 27 percent, respectively. It is also interesting to note that the average of the 13 countries covered provide an estimate in a similar range than the world estimate. While the figures have to be taken with caution, they nevertheless show that for hybrid plants like tomato and maize, holdings tend to be higher in the private sector.

In wheat, France has the highest percentage of resources held by private sector, with an estimated 70 percent, followed by Italy at 61 percent, Argentina and US private holdings estimated at 30, China at 7 percent, and Kenya at 5 percent. In Switzerland, all research is conducted publicly. The world private holdings in wheat are estimated at an average of 30 percent.

The Bolivarian Republic of Venezuela has the highest percentage of private holdings of maize, at 99 percent, followed by Italy at 91 percent, the United States at 80 percent, Germany at 73 percent, France at70 percent, Argentina and Peru at 60 percent, and Kenya and China at 20 percent. The average world private holdings of maize are estimated at 63. The highest percentage of private holding of rice is in Italy at 50 percent, followed by Argentina and China at 30 percent; Bolivarian Republic of Venezuela at 20 percent; and finally, Kenya at 1 percent. The world's private holdings are estimated at 27 percent.

The only estimates available for private resources holdings of tomato have been made by Italian experts, at 76 percent for Italy and 65 percent globally.

These figures do not provide a complete worldview, but are indicative of how public versus private research is distributed in the countries of the respondents.

A.5 Discussion

The questionnaires provide a view from practitioners and are thus extremely helpful as another source of information for the algorithm. The results need to be taken with great caution due to two major weaknesses in this survey – the small sample size and the limitations of the questionnaire. The time to perform the study did not allow to target breeders more widely and systematically; hence, the sample size was relatively small. In order to facilitate the engagement of experts, the questionnaire was intentionally restricted to six major questions.

A.5.1 Sample size

Thirty-four answers were received through different channels. The respondents were both from the private and the public sector. Small- and medium-sized enterprises, as well as some of the large seed companies were represented from the private sector, which shows a general willingness to engage with Treaty work. The current structure of the seed sector, where a few large seed companies are dominating the market, led us to try to systematically engage with the major companies. Different strategies were adopted, and contacts with the major players in the seed market were made both through ISF and through a direct initiative by the research team. While we received a few completed questionnaires from the largest companies, several others declined to answer. The reasons for this were particularly well expressed by this reply: "Unfortunately, it will not be possible for us to answer your questionnaire. The scientists are reluctant to give any information on breeding because our company does not allow us to make such communication."

The five answers received through ISF were anonymous, possibly showing caution from some actors in the seed industry towards the study.

In order to increase the sample size as well as the geographic distribution in the future, we envisage a more systematic coverage by contacting all national seed associations.

A.5.2 Geographical representation

This study did not focus on having a full geographic coverage. Due to varying climates, geography influences the type of traits and crops being considered in breeding; thus, geography is likely to influence the length of breeding and number of breeding cycles (Question 1). The sample size did not allow such differentiation to be part of the analysis. Question 6 results differed widely according to the country of the respondent in terms of the holdings between private and public sector of genetic resources.

The country where the respondent was based corresponded to the country under consideration (question 6). The answers have not been differentiated by company size for statistical purposes. Since the country was a key factor of differentiation, this should be clarified in future work. In order to capture the geographical difference, large companies having a presence in different countries could have several answers where they specify their location. This would have to be weighted by their relative importance in the country, and an exact methodology remains be determined in order not to outweigh the answers of smaller companies.

A.5.3 Limitations of the Questionnaire

Some respondents found that it was difficult to answer the questionnaire because several of the questions included ambiguities.

Question 1 particularly needs to be modified in order to be more specific and to allow for several possible answers:

1. It was pointed out that 'landraces' and 'wild species' are not the same. A definition should be provided and the two terms used separately since they require for different answers.
2. 'Pre-bred and improved' should be defined. It was suggested to include another distinction between 'improved' and 'elite lines'.
3. The question should allow a specification of the type of wheat. Durum wheat and soft wheat results are different. Winter wheat and spring wheat also require a different commercialization time.
4. The type of breeding technique used, for example, the use of marker, can shorten the commercialization time. Reference to the specific techniques is extremely important because it can have a huge impact on the data (Question 1 as well as Questions 2 and 3).

Question 2 should refer to the definition of terms landrace, wild race, pre-bred, unimproved and improved.

Question 3 should allow for information specific to the market of reference since the average time the crop remains on sale will depend on the country. Question 6 should allow for specific information on the country of reference of the respondent (see geographic representation).

The ambiguities of the questions were partly a result of the fact that the questionnaire was purposely designed to minimize the time involvement of industry experts, and hence simplified and shortened the issues at hand. The questions were of technical nature and not on the company information itself, except Question 4b. Given the ambiguities in the questions and the potential reluctance of some companies to answer, it is also possible that some of the data are underestimated; the sample size did not make it possible to analyse this.

A.5.4 Use of SMTA

Several respondents of Question 5 questioned the value of the genetic resources available under SMTAs. It would hence be important to improve the accessibility of information with regard to the genetic resources available under SMTA by having a better reference to the type of resources, traits and age of the material in order to better communicate its value and thereby facilitate the use of the material in the Multilateral System.

The uncertainty of the results of the use of SMTA material was a key impeding factor linked to the uncertainty about the fees associated with the use of SMTA. Furthermore, it was indicated that, at times, genetic materials might be used initially, but not actually bring any valuable traits to the final plant variety in the end, and yet, removal of such material is impractical. Hence, if such material was accessed by means of an SMTA, payment provisions would still apply. This uncertainty is the main factor of avoidance of use of SMTA. A different payment system could be explored to minimize such uncertainty.

A.6 Conclusion

Despite all these weaknesses, this preliminary survey enabled an initial appraisal of the use of PGR for food and agriculture in plant breeding, which is required for the modelling of benefit flows to be expected under the Treaty. It is an important part of the research project "Identifying the potential monetary and non-monetary benefits arising from the utilization of PGR under the Multilateral System of the International Plant Treaty", since it will enable a confrontation of the practitioners' views with the results of the algorithm simulation and data gathered elsewhere.

The following are some of the areas to be considered for future work, as suggested by the answers received:

- Revise the questionnaire to be more specific in its terminology as suggested, and especially to include the subcategory of the crops (e.g. winter wheat), the countries of reference, and to distinguish between type of plant breeding technologies used.
- Expand the questionnaire to cover the other Annex 1 crops.
- Engage the plant breeding sector more broadly in order to validate the information and to open dialogue on the SMTA funding mechanism. As such, the result of this survey as well as the initial estimates from the algorithm provide a concrete basis and should reassure the seed industry, thus promoting a greater engagement in the future. It provided an initial contact. Creating an open communication channel with the SMTA system users to better understand their perspectives is extremely important. This would allow the SMTA system to be adapted, if needed, to better serve the goals of the seed industry while achieving the Treaty's goals to protect genetic resources and farmers' rights and while contributing to the benefit-sharing mechanism.
- The passport data of the genetic resources available for use with SMTA should be improved and information should be better disseminated to the potential users. Having a strong communication strategy would facilitate the use of the material.

As an initial step to engaging the plant breeding sector, this survey is important. However, it must be carried much further, beyond the study, to become a usual way of operating. Setting up an open dialogue channel between the Treaty, the various gene banks and the plant breeding sector is essential for the various partners to better understand each other, and in order to more accurately value the benefits of the available genetic resources and of the Treaty work in general.

A.7 List of respondents

We would like to thank all the experts, institutions and companies who answered the survey.

1	Argentina	INTA
2	Australia	Nufarm Australia Ltd.
3	China	CAAS
4	China	Yunnan Academy
5	France	BAYER
6	France	Limagrain
7	France	RAGT
8	France	Secobra
9	France	Syngenta

10	Germany	Dow AgroSciences
11	Germany	DSV Saaten
12	Germany	Maisadour
13	Italy	Agricultural University of Perugia
14	Italy	Agricultural University of Pisa
15	Italy	Agricultural Research Council (CRA)
16	Italy	Agricultural Research Council (CRA)
17	Italy	CGS Sementi Spa
18	Italy	INRAN-ENSE
19	Italy	ISTA Sementi
20	Italy	ISI Sementi
21	Italy	Pro Sementi
22	Kenya	Kenya Agricultural Research Institute, Mwea-Tebere
23	Norway	Nordgen (Nordic Council)
24	Peru	CGIAR
25	Switzerland	Agroscope
26	Switzerland	Agroscope
27	Thailand	Kasetsart University
28	USA	Monsanto
29	Venezuela	Fundación Danac Venezuela
30	ISF members	
31	ISF members	
32	ISF members	
33	ISF members	
34	ISF members	

APPENDIX

CONCLUSIONS AND RECOMMENDATIONS FOR FURTHER RESEARCH

REFERENCES

Appendices

Appendices to Chapter 1

Appendix 1.1 Search-theoretic frameworks

Search-theoretic frameworks attempt to simulate the stochastic nature of breeding research and they successes and failures. When the probability of failure is non-zero, the search must be conducted in order to determine whether particular genetic traits may be useful. Thus, the search process may be time-consuming and costly due to all the activities required for the trait evaluation, such as molecular screening or agronomic tests (set by Zohrabian *et al*., 2003, at approximately $7 per accession, per single trait), in addition to the acquisition-transaction costs. This aspect of the research enterprise is worth emphasizing because often the germplasm stored in public gene banks lacks detailed information concerning genetic characterization and the likelihood that a single accession will be useful. In addition, breeding outcomes can be quite unpredictable because of the unpredictable nature of genotype environment interactions. The search methodology assigns a present value to the expected future benefits of the research activity wherein benefits are compared to costs in order to optimize the search activity. In the specific case of PGR for food and agriculture, the probability of discovering a valuable trait during the search process is combined with its expected yield enhancement effects in order to evaluate the worth of a single germplasm accession.

Seminal work of Evenson and Kislev (1976) gave impetus to several studies in valuing genetic stocks through this approach. This methodology, which is the first to apply search theory to genetic resource evaluation, has roots grounded in a classic paper by Stigler (1961), who models consumer demand when a consumer, facing a price proposition, is uncertain as to whether it is a minimum among possible alternatives. It is worth mentioning that this basic idea of Stigler (1961) spawned a large and growing literature related to job search, unemployment and related macroeconomic phenomena. An introduction to search formal analysis is contained in Sargent (1987) and Rogerson *et al*. (2005) present a recent literature survey on the subject. In the context of genetic resources, Evenson and Kislev (1976) consider the discovery of sugar-cane varieties and model search within a distribution of the genetic trait – the random variable of interest – and assume that research effort can shift the mean of the distribution, change the variance or generate new distributions when new technologies are discovered. In their context, it is possible to determine an optimal search strategy, and evaluate the impact that a gene stock might have, at least conceptually.

A subsequent application by Gollin *et al.* (2000) extends the basic idea that search, which is costly, generates potential benefits and that these benefits have probability distributions attached to them. By exploiting the basic principle that the marginal cost of an accession search should never exceed the marginal expected benefit that it generates, the authors simulated a search process and conducted Monte Carlo experiments, drawing probability distributions for the 'useful' trait from the Monte Carlo simulations. Gollin *et al.* (2000) evaluate the optimal size of a 'search' for a genetic trait, judging the usefulness of large collections characterized by low utilization, modelling the search for a resistance trait in wheat germplasm. Significantly, they note that a gene bank's existence value is justified, despite possible infrequent utilization whenever maintained traits are rare and economically relevant. Clearly, determining the latter is sometimes very difficult, given the data constraints that typically occur.

Notwithstanding this feature of the data-generating environment, search theory has inspired several noteworthy recent contributions. For example, with reference to crop breeding, Zohrabian *et al.* (2003) estimate the marginal value of the genetic material held in the U.S. National Plant Germplasm System. The genesis of their work is the common denominator in the contributions exploring search, namely the notion that search, which is costly, generates potential benefits. Exploiting this notion, they employ maximum entropy methods to estimate research success probabilities of discovering the trait for resistance to soybean cyst nematode. Data on soybean prices and area planted are used in order to evaluate the present value of the benefits deriving from search. Finally, the authors determine that even when the marginal values of accessions are low, they may still outweigh their maintenance costs.

Along similar lines, Simpson *et al*. (1999) assess the probability for a marginal species to be used in a commercial product for pharmaceutical purposes. They consider the search process as a sequence of Bernoulli trials in which the outcome is a discrete random variable assuming one of the two results, namely 'success' or 'failure'. The Bernoulli distributions adapt well to simulate the search for both qualitative (discrete) and quantitative genetic traits. Even if the characteristic of the quantitative trait is a continuous outcome, by imposing a threshold value it can be easily adapted to a Bernoulli trials; success if the value exceeds the threshold and failure otherwise. They use their model to assess the marginal economic value of a single 'species' held *in-situ*. The authors conclude that, in general, genetic resources stocks are characterized by low value and diminished attractiveness for pharmaceutical purposes.

Using the search-theoretic framework, it is possible to derive a function of germplasm demand, and therefore to infer factors determining the distribution of germplasm. Any changes in trends of distribution of PGR for food and agriculture reflect changes arising in the perceived costs and benefits of sourcing accessions. Following this idea, Gotor and Caracciolo (2010) empirically analysed the influence of a change in policy environment (the 1994 In-Trust Agreements, or ITAs, signed by the CGIAR Centres with FAO, under the International Undertaking on Plant Genetic Resources, the non-binding predecessor of the Treaty) on the genetic stocks' distribution held by IRRI. Empirical analysis suggested that demand of IRRI accessions benefitted the establishment of a stable policy environment provided by the ITAs.

Appendix 1.2 Returns to plant breeding

Several recent empirical studies (e.g. Alene *et al*., 2009; Maredia *et al*., 2010; Brennan and Malabayabas, 2011) focus their effort only on the estimation of the direct use value of crop germplasm stocks, valuing the monetary benefits of breeding resulting from the improvement of crop varieties on agricultural productivity, or as a result of cost reduction. These studies also focus on the overall plant breeding research, because it becomes trickier for economists to separate the contribution of human capital from that of the unimproved genetic resources' contribution in the breeding and genetic selection activity. For the above reason, many authors prefer simply to focus the study on 'genetic enhancement' valuation (Rubenstein *et al*., 2005). The basic idea behind these studies is simple: 'genetic enhancement' generates benefits when the resulting improved crops are effectively adopted and grown by farmers.

From an empirical point of view, the economic benefit of 'genetic enhancement' has been often measured using the Griliches (1958) approximation: the benefits are measured by the value of production ($P{\cdot}Q$), where P is the price and Q is the produced quantity of the crops, multiplied by the proportional gain in yield (k) associated with the crop improvement (Pardey *et al*., 2006):

(4) Benefit = $k\ P\ Q$

In order to assign a specific contribution k to the evaluated genetic resource, several approaches have been applied, most of which refer to hedonic price modelling and "breeding production function" analysis (Evenson *et al*., 1998; Milne *et al*., 2002).

A hedonic approach makes use of a resource's market value, through regression estimation of the explicit price of the tradable product against the implicit prices of the non-marketable good's individual attributes. An analogous principle has been applied by Evenson and Gollin (1997) to assign the contribution of the International Rice Germplasm Collection at IRRI.

Pardey *et al*. (2006) applied two different rules to assess the incidence of a crop improvement in the pedigrees of crop varieties, namely, the 'last-cross' rule and the geometric rule.

a) "Last-cross rule. This rule gives all the credit for a particular variety to the breeder who produced it, none to its parents that still exist as varieties in their own right. This is a 0 or 1 index, which is 1 for varieties (or breeding lines) released by the program and 0 for all others".

b) "Geometric rule. This rule uses a geometrically declining set of weights, mimicking somewhat the share of genetic material carried forward from earlier nodes in the pedigree into the present variety according to Mendel's law of heredity. When the allocation stops at generation G, $1/2^{(2G)}$ *of the benefits are attributed to that generation, in order to arrive at attribution shares that sum to 1. Thus, applying the rule through the level of grandparents,* $1/2^3$ *(that is 1/8) of the benefit would be attributed to the breeders of* *each of the parents (generation 1) and* $1/2^4$ *(that is 1/16) to the breeders of each of the grandparents (generation 2)."*

Finally, Brennan and Malabayabas (2011) employed a simpler 'rule of thumb' approach, as can be seen in Table a.1.2, to attribute the IRRI contribution to commercial rice varieties, given limited data availability.

Table a.1.2 IRRI contribution to varieties released

Origin of variety	IRRI contribution
IRRI cross with two IRRI lines as parents	100
IRRI cross with one IRRI line as a parent	50
IRRI cross with no IRRI lines as parents	0
NARES cross with two IRRI lines as parents	100
NARES cross with one IRRI line as a parent	50
NARES cross with other IRRI ancestry	25
NARES cross without IRRI connection	0

Source: Brennan and Malabayas, 2011.

Although there is merit in the simplicity of the approach, several empirical problems occur in applied works, which, according to Morris and Heisey (2003), can be grouped in three categories: (i) problems in estimating the effective magnitude and the dynamics of the improved crop adoption; (ii) problems in estimating the specific benefits of the improved crop; and (iii) problems involved in considering research lags and research spillovers. Alston *et al*. (2010) note that identifying the 'by whom' part of the attribution problem and the lag structure involved in the research processes (the 'when' part) represents a 'tricky business'.

Problems related to the first area include specifically the identification of the varieties produced by the 'genetic enhancement' through time: genetic changes may occur intentionally or not over successive generations of crop grown from replanting seeds. Although the area planted to the specific varieties at a given point in time may be evaluated through seed sales data and survey micro-data (Morris and Heisey, 2003), the rate of crop adoption and diffusion varies over time with several unpredictable factors, most notably pest infestations, pedoclimatic changes, seed premiums, crop prices and all the related structural economic factors.

As concerns the problems stated in (ii), attributing the right agronomic gains to the conserved germplasm used in a crop production system seems empirically highly problematic (Pardey *et al*., 2001). Although during experimental yield trials the agronomic gains associated with the introduction of a variety causing higher crop production or lower tilling costs may be easily observable, in the open field, several components can interact with each other, enhancing or thwarting the effects. This makes it hard to separate the productive gain resulting from the breeding activity from new agricultural adoptions, changes in crop management practices, and specific climatic and soil characteristics. This is why, according to Pardey *et al*. (2001), methodologies developed to date are mainly unreliable.

The last set of problems, (iii), refers to the fact that 'genetic enhancement' is a continuous process wherein new varieties are bred by crossing already enhanced parents. Since improved crops are often the product of generations of informal innovations (Drucker *et al*., 2005), overall benefits are increased by the existence of research spillovers, but problems occur in attributing the share of a specific stream of benefits to all the different contributors (Pardey *et al*., 2006). An outstanding example of latter is represented by the sorghum variety S 35, developed from the ICRISAT breeding programme in India, and later advanced and promoted in Cameroon and Chad (Yapi *et al*., 1999).

Appendix 1.3 Examples of CGIAR collection impacts

Centre	Output	Outcome	Ultimate impact
CIMMYT	The CIMMYT-derived wheat varieties make better use of water and nutrients, are more tolerant of environmental stresses, and possess durable resistance to diseases.	New varieties that reduce the amount of fertilizer and pesticides that farmers apply to their fields.	Increasing yields, bringing environmental, economic and health benefits. In developing countries, some 55 million ha are now sown to CIMMYT-based bread wheat, representing 80 of production.
ICRISAT	Pigeon pea variety resistant to fusarium wilt	The variety now holds sway in the wilt-epidemic regions of India through farmer-to-farmer distribution of seeds.	Increasing yields. The variety also out-yielded the best cultivar previously available by about 57 percent. It reduced the unit cost to farmers by 42 percent and added a value of $62 million to the Indian economy. The variety is now extensively used in the wilt-epidemic regions of Karnataka, Andhra Pradesh and Maharashtra through farmer-to-farmer seed distribution.
ICRISAT	Researchers from Cameroon selected the drought-resistant sorghum variety S35 from the collection held by the Centre	During the 1984 drought in northern Cameroon, scientists recorded a yield of 1 300 kg per ha for S35, compared with 719 kg per ha for the farmers' local variety – a gain of 85 percent. This was achieved without the use of irrigation or fertilizers.	Supporting livelihoods in marginal environments. By 1995, S35 covered around 44 000 ha in Cameroon and 64 000 in Chad – around 32% and 27%, respectively, of each countries' rainfed sorghum areas.

WARDA	NERICA (New Rice for Africa) varieties combine the high yields of Asian rice with the suitability of African rice to the continent's harsh growing conditions.	About 150 000 ha across the continent are planted with NERICA varieties.	Supporting livelihoods in marginal environments. Numerous reports from sub-Saharan Africa document the positive impact of the new rice on the livelihoods of farm families.
CIP	CIP developed 40 new varieties of the orange-fleshed sweet potato that have high levels of beta-carotene and are well adapted to growing conditions in Africa.	These were distributed to farmers and consumers in several countries and awareness-raising campaigns and community education programmes were carried out, focusing on the health of young children.	Combating human and crop diseases; approximately 50 million children under six could benefit from this.
IITA/ CIAT	Cassava varieties resistant to the major pests and diseases that occur in Africa.	In 1996, IITA distributed plantlets from 308 new clones held in tissue culture to national institutes for test planting by farmers in East, Southern, West and Central Africa.	Combating human and crop diseases. Farmers reported yields up to five times greater than many susceptible varieties damaged by disease.
ICARDA	Seven new pest and disease-resistant faba bean varieties for cultivation in the diverse environments in the Nile Valley region.	Development of the new varieties.	Combating human and crop diseases. The new variety stemmed yield losses and, by 1983, self-sufficiency in faba bean production was restored. By 1996, Egypt was able to export the crop and is now the world's third-highest producer of faba beans.
CIAT/IITA Bioversity/ ICRISAT/ IRRI/ICRAF	During the 1991 war in Rwanda, the Centres helped aid agencies obtain good quality seed of appropriate crop varieties for large-scale multiplication and targeted distribution to farmers in need.	ICRAF assisted returning refugees by training students, field technicians and farmers who would play leading roles in rehabilitating the country's agriculture.	Helping communities recover from natural disasters and human conflicts.
IRRI	Scientists had collected more than 750 rice accessions when the Khmer Rouge were gaining power, adding them to the 55 Cambodian rice varieties already in the IRRI gene bank. These materials were duplicated and the duplicates eventually repatriated to Cambodia.	IRRI scientists collected an additional 3 800 traditional rice varieties as well as 1 100 wild rice accessions in cooperation with Cambodian researchers	Helping communities recover from natural disasters and human conflicts.
IRRI	As a response to the 2004 Tsunami, IRRI, which had more than 40 salt-tolerant rice varieties, answered calls for assistance, providing six tolerant varieties suited to the hard-hit countries.	Since then, Sri Lanka's and Malaysia's rice production has increased by 70%, and for the past ten years, it has produced small rice surpluses for export	Helping communities recover from natural disasters and human conflicts.

Source: SGRP. Available at: http://www.sgrp.cgiar.org/?q=impact

Appendix 1.4 Types of non-monetary benefit (Visser *et al*., 2005)

Exchange of information	Information on collaborative efforts Sharing of research and development results Access to databases General sharing of information relevant for conservation and use Access to scientific information relevant to conservation and use of plant genetic Resources for food and agriculture Improved knowledge of plant genetic resources for food and agriculture Improved knowledge of natural environment
Access to and transfer of technology	Access to materials Access to collections Access to products Access to commercially released varieties for further research and breeding Access to relevant technologies Transfer of knowledge and technology Transfer of equipment, software, know-how Joint ventures for the creation of technological foundations Participation in product development Participation in planning and decision- making Undertaking commercial production, processing or manufacture Creation of alternative industries or crops Partnership in the economic exploitation of processes and products Sharing of rights Joint ownership or sole ownership of intellectual property rights Free licensing for the utilization of patented processes and products
Capacity building	Cooperation in scientific research and development programmes Facilitation of research partnerships Formation of collaborative agreements with local institutions Co-operative scientific research and technological development Consolidation of scientific research infrastructure Providing institution conducting fields trials Research directed to priority needs, such as food security Participation of source country scientists in research Cooperation in conservation efforts In-kind support for conservation (e.g. genebank facilities) Benefits in kind e.g. augmentation of national collections Increased opportunities for developing multilateral strategies for conservation and use Voucher specimens to be left in national institutions Cooperation in education and training Training in bio-prospecting methods etc. Training in science, in situ and ex situ conservation and management, information Technology and management/administration of ABS Institutional capacity –building Increased scientific capacity Strengthening capacities for technology transfer Investment in research and development infrastructure Investment in the capacity of local industry Undertaking commercial production, processing or manufacture Resources for the implementation of access regulations Institutional and professional relationships Exchange of staff

Appendix 1.5 Interdependence of genetic resources

As can be seen in Table a.1.5.1, the main staple foods, largely covered in Annex I, represent, on average, 70 of all the dietary energy supply in developing countries. The relevance of crop germplasm collections increases when considering that all countries are heavily dependent on PGR for food and agriculture from other regions (according to some estimates, by more than 50) (Palacios, 1998; Fowler and Hodgkin, 2004), which is likely to increase in the future under climate change (Jarvis *et al.*, 2011). Gollin (1998) analysed the pedigrees of 1709 rice varieties, discovering that more than 90 of the parents of the investigated varieties come from other countries (Table a.1.5.2).

A common example in literature is provided by Sonalika wheat variety developed by CIMMYT and largely used in breeding programmes (Srinivasan, 2003; Smolders, 2005): its pedigree includes more than 30 parents from more than 15 countries, demonstrating again the entity of countries interdependence and the importance of access, use and exchange of PGFRA to agriculture and food security (Fowler and Hodgkin, 2004).

Table a.1.5.1. Dietary energy supply (DES) of main staple foods

	Total food	Vegetable products	Cereals	Wheat	Rice	Maize	Roots	Pulses	Oilcrops
	kcal per capita per day	Des (%)	Des (%)	Des (%)	Des (%)	Des (%)	Des (%)	Des (%)	Des (%)
World	2 796	82.8	55.7	22.9	23.0	6.0	6.0	2.6	2.3
Net food-importing developing countries	2 326	90.1	60.0	18.2	22.6	11.6	9.7	4.2	1.9
Least developed countries	2 157	93.0	61.6	8.3	30.0	11.7	13.0	4.5	2.2
Eastern Africa	2 045	92.9	53.6	8.8	7.3	24.6	17.2	6.7	1.8
Central Africa	1 860	95.2	34.4	7.0	5.7	13.5	37.7	3.1	4.1
Northern Africa	3 016	88.9	65.5	39.2	6.3	11.3	2.3	2.4	1.4
Southern Africa	2 918	86.3	62.0	18.6	7.2	34.3	3.1	1.4	0.9
Western Africa	2 649	95.5	49.2	5.6	12.8	8.9	19.2	3.8	3.4

Source: Authors, based on FAO, 2007.

Table a.1.5.2. Summary of international flows of rice landrace ancestors in selected countries

Country	Total landrace progenitors in all released varieties	Own landraces	Borrowed landraces
Bangladesh	233	4	229
Brazil	460	80	380
Myanmar	442	31	411
China	888	157	731
India	3 917	1 559	2 358
Indonesia	463	43	420
Nepal	142	2	140
Nigeria	195	15	180
Pakistan	195	0	195
Philippines	518	34	484
Sri Lanka	386	64	322
Taiwan	20	3	17
Thailand	154	27	127
United States	325	219	106
Viet Nam	517	20	497

Source: Gollin, 1998.

Appendix to Chapter 2

Appendix 2 PVP certificates granted for Annex I crops/genera in UPOV member countries

Crop group	Crop	Genus	1960–64	1965–69	1970–74	1975–79	1980–84	1985–1989	1990–1994	1995–99	2000–04	2005–09	2010–14	Total PVP grants
Food														
Cereal	Oat	Avena	0	10	26	37	58	66	123	192	190	208	81	991
Cereal	Finger millet	Eleusine												0
Cereal	Barley	Hordeum	1	26	64	136	267	327	578	708	697	752	212	3768
Cereal	Rice	Oryza				13	50	86	119	191	421	321	144	1345
Cereal	Pearl millet	Pennisetum								2	3	1	1	7
Cereal	Rye	Secale			5	8	13	18	47	81	76	58	18	324
Cereal	Sorghum	Sorghum				3	3	26	83	63	85	123	60	446
Cereal	Triticale	Triticosecale				1	4	18	77	106	115	165	38	524
Cereal	Wheat	Triticum		8	93	136	320	403	688	1065	1282	1527	474	5996
Cereal	Maize	Zea			4	180	380	631	1605	1984	1855	1649	554	8842
Fruit	Breadfruit	Artocarpus												
Fruit	Strawberry	Fragaria			24	29	51	85	240	281	316	321	97	1444
Fruit	Apple	Malus		2	7	11	57	142	249	411	415	436	116	1846
Fruit	Banana/ plantain	Musa							1	2	9	1	2	15
Oilseed	Brassica complex	Brassica	0	1	18	60	124	204	386	917	792	921	412	3835
Oilseed	Coconut	Cocos												0
Oilseed	Sunflower	Helianthus				15	49	239	523	593	355	348	125	2247
Pulse	Pigeon pea	Cajanus										1		1
Pulse	Chickpea	Cicer							4	16	8	19	6	53
Pulse	Citrus	Citrus					34	28	35	49	56	129	31	362
Pulse	Grass pea	Lathyrus			1	7		1	1	2	10	23	4	49
Pulse	Lentil	Lens					1	0	5	5	6	12	6	35
Pulse	Faba bean / Vetch	Vicia			6	8	11	66	81	96	80	80	18	446
Pulse	Cowpea *et al.*	Vigna				2	4	7	12	11	13	15	7	71
Root and tuber	Major aroids	Colocasia						1	2	0	1	3	1	8

Crop group	Crop	Genus	1960–64	1965–69	1970–74	1975–79	1980–84	1985–1989	1990–1994	1995–99	2000–04	2005–09	2010–14	Total PVP grants
Root and tuber	Major aroids	Xanthosoma												0
Root and tuber	Yams	Dioscorea						1	3	6	11	4	0	25
Root and tuber	Sweet Potato	Ipomoea					2	11	5	15	33	47	33	146
Root and tuber	Cassava	Manihot												0
Root and tuber	Potato	Solanum	1	22	104	142	265	353	668	1133	886	1049	378	5001
Vegetable	Asparagus	Asparagus	0	0	0	3	1	7	12	26	32	25	12	118
Vegetable	Beet	Beta	0	3	15	30	25	59	55	89	174	100	38	588
Vegetable	Brassica complex	Armoracia										1		1
Vegetable	Brassica complex	Barbarea												
Vegetable	Brassica complex	Camelina,							4	8	1	2	3	18
Vegetable	Brassica complex	Crambe								6	2	5	3	16
Vegetable	Brassica complex	Diplotaxis										4	1	5
Vegetable	Brassica complex	Eruca										2	6	8
Vegetable	Brassica complex	Isatis												0
Vegetable	Brassica complex	Lepidium						1	1	1	0	1	0	4
Vegetable	Brassica complex	Raphanobrassica												0
Vegetable	Brassica complex	Raphanus					32	24	47	73	83	111	56	426
Vegetable	Brassica complex	Rorippa												0
Vegetable	Brassica complex	Sinapis				3	5	16	22	41	45	37	16	185
Vegetable	Carrot	Daucus			1	2	5	21	16	37	45	63	48	238
Vegetable	Beans	Phaseolus		2	79	140	152	219	376	291	367	336	108	2070
Vegetable	Pea	Pisum		3	71	129	174	258	434	461	452	369	115	2466
Vegetable	Eggplant	Solanum						5	15	5	17	53	19	114
Forage														
Grass	Andropogon	gayanus						1						1
Grass	Agropyron									1	4	2	0	7
Grass	Agrostis	tenuis			6	5	6	5	15	28	34	45	2	146
Grass	Alopecurus	pratensis					2	1	1	1	4	1	0	10
Grass	Arrhenatherum	elatius						1	2	1	0	1	0	5
Grass	Dactylis	glomerata			1	5	12	6	20	43	38	27	6	158

Crop group	Crop	Genus	1960–64	1965–69	1970–74	1975–79	1980–84	1985–1989	1990–1994	1995–99	2000–04	2005–09	2010–14	Total PVP grants
Grass	Festuca			7	17	40	84	138	165	194	249	247	56	1197
Grass	Lolium			4	22	76	164	251	337	458	445	444	139	2340
Grass	Phalaris					1	0	3	4	8	4	4	4	28
Grass	Phleum				2	8	9	13	14	32	26	32	4	140
Grass	Poa		1	1	15	37	37	68	65	67	123	89	29	532
Grass	Tripsacum	laxum									1	2	0	3
Grass	Atriplex										1			1
Grass	Salsola	vermiculata												0
Legume	Astragalus	Chinensis							2					2
Legume	Astragalus	Cicer								1				1
Legume	Astragalus	arenarius											0	0
Legume	Canavalia	ensiformis												0
Legume	Coronilla	varia												0
Legume	Hedysarum	coronarium							1	2	1	0	0	4
Legume	Lathyrus	cicera												0
Legume	Lathyrus	ciliolatus												0
Legume	Lathyrus	hirsutus												0
Legume	Lathyrus	ochrus												0
Legume	Lathyrus	odoratus							2	8	6	21	3	40
Legume	Lathyrus	sativus			1	0	1	1	0	2	1	2	1	9
Legume	Lespedeza								2	2				4
Legume	Lotus				1	0	2	3	5	8	6	3	2	30
Legume	Lupinus				2	0	2	7	20	52	47	57	12	199
Legume	Medicago				8	18	33	66	123	166	86	65	13	578
Legume	Melilotus								1	0	1	1	0	3
Legume	Onobrychis	viciifolia					2	0	0	0	0	1	3	6
Legume	Ornithopus	sativus						2	1	4	4	3	2	16
Legume	Prosopis	pallida												0
Legume	Pueraria	phaseo-loides												0
Legume	Trifolium				15	13	24	28	55	108	147	99	28	517
	Total Annex1 crops		3	89	608	1 298	2 465	3 917	7 352	10 153	10 161	10 468	3 547	50 061

Crop group	Crop	Genus	1960–64	1965–69	1970–74	1975–79	1980–84	1985–1989	1990–1994	1995–99	2000–04	2005–09	2010–14	Total PVP grants
All crops	All crops		4	124	965	2 313	5 560	10 283	20 122	28 916	33 196	35 599	11 321	148 403
	Share of Annex I		75	72	63	56	44	38	37	35	31	29	31	34

Source: UPOV PLUTO PVO Database.

Appendices to Chapter 3

Appendix 3.1 Values used in Scenario 1: the current situation

Table a.3.1.1 World crop genetic resources and material available under SMTAs

Table a.3.1.1 lists the information available, per crop/crop group, for **H** (*ex situ* holdings, by country or international institution); (π, the percentage of **H** known to be available for access under an SMTA); and **H***π (holdings actually available). This is the basic set of data that the model manipulates to project the build-up of SMTA material in the breeding pool, and from that, the build-up of products containing material accessed from the Multilateral System in the product pool, and the partition of the annual market values of seeds and plant materials of the crops/crop groups, **C1**–**C5**.

The sum of all **H** = the sum of all **C**, that is, all world *ex situ* holdings of accessions of PGR for food and agriculture. These data are drawn from the World Information and Early Warning System (WIEWS).[1] These are the same, slightly updated data that were used in SoWPGR-2.[2]

H*π is established, for the *Annex 1* (**C1**–**C4**) holdings of Contracting Parties, on the basis of notifications to the Secretariat of material made available through the Multilateral System,[3] in accordance with Treaty Article 11.2.[4] In most cases, the notifications did not provide actual figures for **H***π, but provided references to websites where the information was available, which have been analysed in order to populate the table. For countries in the European Region, the information in EURISCO[5] was used, because it indicates materials offered for access from the Multilateral System. For international institutions that have concluded an Article 15 agreement with the Treaty, it is assumed that π = 100.

It should be noted that the countries' notifications vary widely, by country and by crop/crop group. This is an indication of limitations to the accuracy of projections by the model, stemming from less than complete data on either **C** or **H**.

For the countries known to be releasing **C5** materials under the terms and conditions of the SMTA, information on **H****π* for **C5** is included in Table a.3.1.1. In Europe, these countries are: Armenia, the Czech Republic, Estonia, Germany, Ireland, Poland, Romania, Switzerland and the United Kingdom. For Nordic countries (Denmark, Finland, Iceland,

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1 Available at: www.fao.org/agriculture/crops/core-themes/theme/seeds-pgr/wiews/en.

2 Commission on Genetic Resources for Food and Agriculture, FAO, Rome, 2010, Table A2, *Germplasm collections by* crop, pp. 244-283. These figures are as at 28 December 2009.

3 Available at: www.planttreaty.org/inclusions.

4 "The Multilateral System … shall include all plant genetic resources for food and agriculture listed in Annex I that are under the management and control the Contracting Parties and in the public domain."

5 Available at: www.eurisco.ecpgr.org.

Norway and Sweden), the situation is nuanced. These countries hold most of their PGR for food and agriculture in common, in the Nordic Gene bank. The Nordic Council of Ministers decided that "the Nordic Gene Bank should provide access to all its accessions on equal terms, regardless of whether they are covered by the scope of the multilateral system of the IT-PGRFA or not."[6] In implementing this, however, the Nordic Gene Bank is using a separate material transfer agreement (MTA, which does not distinguish between products to which mandatory monetary benefit-sharing applies (i.e. the provisions of SMTA Article 6.7) and those to which voluntary benefit-sharing applies (i.e. the provisions of SMTA Article 6.8), but applies the provisions of SMTA Article 6.8 to both. Canada has informed the Secretariat that the "[P]lant genetic resources [in the collections that it indicated] are available under the terms of the whether they are within the MLS or not."

Table a.3.1.2: Examples of countries making non-Annex 1 materials available with SMTAs

	C1–C4 **Annex 1**	**C5** **Non-Annex 1**
Canada (releases, July 2008 to June 2010)	87	13
Germany (releases, July 2010 to June 2011)	41	59
NorGen (releases, 2011)	69	31

The volume of **C5** materials being distributed under an SMTA is creating a substantial potential income for the Benefit-sharing Fund.

α: Introduction of material into the breeding pool (C)				
C1 Wheat	**C2** Rice	**C3** Maize	**C4** Other Annex 1	**C5** Non-Annex 1
4.2	4.2	4.2	4.2	4.2

α is calculated from SoWPGR-2,7 which provides information on the distribution of germplasm by Ethiopia, China, India, Japan, Germany, Pakistan, Poland, Switzerland and the CGIAR. Taking into account only countries, **annual distributions/H***π = 6.7. The figure for the CGIAR is 3.3. A weighted average for countries and CGIAR combined (allowing for the relative numbers of accessions each holds) is 4.2. It is assumed to be the same for all crops/crop groups and to be a good proxy for the rate of introduction of material.

α comprises three elements: non-SMTA materials (α**1**), SMTA materials from national collections (α**2**), and from international institutions (α**3**).

For the purposes of Scenario 1 (run 1), it is assumed that materials that Contracting Parties have not yet designated as being in the Multilateral System are not being distributed.

[6] By *Nordic Ministerial Declaration, Access and Rights to Genetic Resources, 2003*.

[7] Section 3.9, *Germplasm movement*, pp. 84-86.

υ : Avoidance					
	C1 Wheat	**C2 Rice**	**C3 Maize**	**C4 Other Annex 1**	**C5 Non-Annex 1**
Standard	5	5	5 + 13	5	0
High	10	10	10 + 26	10	0
Value-based	10	10	10 + 57	10	0

Studies 3 and 5 consider the likelihood of breeders and breeding companies avoiding the use of materials that must be accessed under an SMTA.

This factor is constructed to contain two elements, a 'background rate' of avoidance for all crops/crop groups except **C5**, which is set to 0, plus a specific rate for maize. This is because the likelihood of avoidance is highest where intellectual property rights (IPRs) over commercial products are most prevalent, and give rise to mandatory payment obligations, which is the case for maize: "An important factor … is the significant share (26) of transgenic maize in the global maize area. … transgenic (GM) varieties are invariably protected by patents rather than PVP" (p. 58).

Three levels of avoidance, υ, are tested in scenario 6. The 'standard' rate applied in most scenarios assumes a background rate of 5 percent, and an avoidance of maize equal to half the area planted to transgenics. The 'high' rate assumes a background rate of 10 percent, and an avoidance for maize equal to the full area planted to transgenics. However, both these rates are conservative, because, while transgenic varieties represent 26 percent of the *area* planted to maize, they represent fully 57 percent of the *value* of the international maize seed market.[8] A 'value-based' rate is therefore also tested. This assumes a background rate of 10 percent, plus an avoidance for maize equal to the full share in value of transgenic maize in the seed market.

λ Crossing rate

No empirical evidence could be found regarding the frequency with which SMTA material is crossed with SMTA material, within the breeding pool. A number of simulations were made, to estimate what appears to be a reasonable rate, which has arbitrarily been set at 2.

κ: Development time (in years)				
C1 Wheat	**C2 Rice**	**C3 Maize**	**C4 Other Annex 1**	**C5 Non-Annex 1**
9.8	8.4	6.7	8.3	8.3

κ is derived from a questionnaire (see Annex) responded to by some 30 experts or breeders, in the public and private sectors in 13 countries, whose opinion was asked

8 This is calculated from Table a.3.1.3.

as to the development time for products derived from (a) improved materials and (b) unimproved materials (landraces). The question was asked regarding only the three crops: wheat, rice and maize, and the following ranges of values were suggested:

C1, wheat, years				C2, rice, years				C3, maize, years			
Improved		**Unimproved**		**Improved**		**Unimproved**		**Improved**		**Unimproved**	
Min.	**Max.**	**Min.**	**Max.**	**Min.**	**Max.**	**Max.**	**Max.**	**Min.**	**Max.**	**Min.**	**Max.**
7.0	11.5	12.7	19.3	5.5	7.2	10.5	12.8	7.4	8.4	10.6	12.3

In response to the same questionnaire, the ratio of improved/unimproved material in breeding programmes was estimated as follows.

C1, wheat		C2, rice		C3, maize	
Improved	**Unimproved**	**Improved**	**Unimproved**	**Improved**	**Unimproved**
92	8	87	13	93	7

κ has therefore been calculated as the mid-point of the ranges of each of these crops, weighted by their ratio of improved/unimproved materials. The average of these three ratios has then been applied, on an arbitrary basis, to **C4** and **C5**, for which there are no direct estimates.

β: Research intensity				
C1 Wheat	**C2 Rice**	**C3 Maize**	**C4 Other Annex 1**	**C5 Non-Annex 1**
120	30	150	100	100

β represents research intensity in each crop/crop group, as a function of variation from an average research intensity for all crops generally. Because of the different agricultural economies of developed and developing countries, separate indicators for these two groups of countries were first calculated and then combined into a single average, weighted using the area harvested (FAOSTAT, 2010).

For developed countries, the indicator of innovation activity of crops/crops group used was the number of PVP certificates issued from 1960 to 2010, taken from UPOV's PLUTO: Plant Variety Database.[9] For developing countries, the certificates are not a good indicator, because most of them have not implemented PVP or intellectual property rights, or are at the very early stages of doing so. The indicator used was therefore the FTE of plant breeders in a country, weighted by the resources allocated to the crop/crop groups, drawn

9 International Union for the Protection of New Varieties of Plants (UPOV); PLUTO is available at http://www.upov.int/pluto/en/.

from the Global Partnership Initiative for Plant Breeding Capacity Building (GIPB) capacity assessment database.[10]

γ: Proportion of improved materials released by international institutions				
C1 Wheat	**C2 Rice**	**C3 Maize**	**C4 Other Annex 1**	**C5 Non-Annex 1**
94.2	85.2	94.2	89.8	15

It is assumed that most improved materials for *Annex 1* crops accessed under SMTAs originate from CGIAR Centres and other international institutions, because these maintain substantial breeding programmes, in addition to their gene banks, release the products of their breeding programmes under SMTAs. Little empirical evidence is available for the relative amounts of improved and unimproved germplasm released by others. In these circumstances, γ has therefore been applied only to the improved materials of the CGIAR Centres (their **H**), and serves to distinguish their contributions to α**3** only.

The CGIAR Centres reported to the Governing Body in March 2011 on their distributions from both their *ex situ* collections and their breeding programmes.[11] γ has been calculated by comparing the ratios of improved/unimproved materials distributed by CIMMYT (for wheat and maize, **C1** and **C3**), by IRRI (for rice, **C2**), and by other Centres (for other *Annex* 1 crops, **C4**). **C5** has been established arbitrarily. This is in all likelihood an underestimation of γ, because the improved materials of CGIAR Centres are probably accessed more frequently than most materials, and because materials are released directly from their breeding programmes, as well as from their *ex situ* collections.

δ: Speed of uptake of materials				
C1 Wheat	**C2 Rice**	**C3 Maize**	**C4 Other Annex 1**	**C5 Non-Annex 1**
58	69	55	60	60

δ**1** is derived from Question one of the questionnaire. It calculates the variance around the average development time, for wheat, rice and maize, of the maximum and minimum suggested development times, and expresses this as a ratio applied to κ, representing the shortening of time when using improved materials. The averages of these three crops have been assumed for **C4** and **C5**.

10 Available at http://km.fao.org/gipb/.

11 IT/GB-4/11/Inf.5, *Experience of the International Agricultural Research Centres of the Consultative Group on International Agricultural Research with the implementation of the agreements with the Governing Body, with particular reference to the use of the Standard Material Transfer Agreement for Annex 1 and non-Annex 1 crops* (www.itpgrfa.net/International/sites/default/files/gb4i05e.pdf). *Table 2* of the document reports on distributions from *ex situ collections,* and *Table 3* reports on distributions from breeding programmes.

δ2 : Proportion of materials leading to products				
C1 Wheat	**C2 Rice**	**C3 Maize**	**C4 Other Annex 1**	**C5 Non-Annex 1**
217	296	180	197	204

δ2 estimates the probability of the increased incorporation of improved material in products, based on the area share of varieties incorporating CGIAR germplasm, on the basis of samples of varieties per crop/crop group (about ten each for wheat, rice and maize). Their pedigrees have been expanded to five generations for wheat, six generations for rice and ten generations for maize (on the basis of information from the survey presented in the Annex to this book), and the ratio of CGIAR materials (assumed to be largely improved) to non-CGIAR materials (assumed to be largely unimproved) has then been calculated.[12]

C1 Wheat	C2 Rice	C3 Maize	C4 Other Annex 1	C5 Non-Annex 1
659	896	545	597	618

However, these figures give an unnaturally high effect and probably overestimate the effect of the use of improved materials. This is probably because a bias towards the use of improved materials has already entered the average, as is shown by breeders' responses when asked about the relative quantities of improved and unimproved materials used, in the Annex. Breeders estimated the ratio of improved/unimproved material in breeding programmes for wheat, rice and maize as the follows:

C1 Wheat		C2 Rice		C3 Maize	
Improved	**Unimproved**	**Improved**	**Unimproved**	**Improved**	**Unimproved**
92	8	87	13	93	7

An arbitrary decision was therefore made to use a rate of 33 percent of the above calculations. **δ2** is applied to the T/P ratio, for **α3** only.

V: Commercial value of the world seed and planting materials market (US$ billion)				
V1 Wheat	**V2 Rice**	**V3 Maize**	**V4 Other Annex 1**	**V5 Non-Annex 1**
3.07	1.87	8.86	5.6	17.4

12 The contribution of unimproved material appears to be greater in wheat and rice than in maize, possibly because maize has seen much more breeding activity and thus many more cycles of improvement than wheat or rice.

Chapter 2 investigates the commercial value of the world seed and planting material market, and the figures cited here are drawn from it.[13] Table 2.22 of Chapter 2 summarizes the information available on the total current annual value of the global market of seeds and planting materials, for food and agriculture: the total estimated value is **$36.8 billion**. Table 2.23 of Chapter 2, reproduced below, provides the basis for estimating **V** per crop/crop group of the model.

Crop group/value segment	Share of Annex I crops in total area harvested (2010) (%)[b]	Share of Annex I crop in total production (2010)b (%)	Commercial seed market for crop group/ value segment (US$ billion)[a]	Commercial seed market value for Annex I crops (US$ billion)
Cereals/grains	99.5	99	13.94	**13.8**
Pulses and lentils	92	92	n.a	**n.a**
Roots and tubers	98	98	n.a	**0.2***
Oilseeds	33	17	5.40	**0.9**
Vegetable seeds	20	19	4.34	**0.8**
Fruit seeds	42	54	2.51	**1.4**
Forage seeds	n.a.	n.a	2.89	**2.3****
Total				**19.4**

a Source: Seeds, a Global Strategic Business Report – MCP-4055. Global Industry Analysts, Inc., USA.

b FAOSTAT data.

* Represents the value of annual exports of potato seeds, based on average international export prices.

** On the assumption that temperate forage seeds account for 80 percent of commercial seed sales.

In order to distribute this commercial value among the five crops/crop groups, the following information is used.

1. The commercial seed market of Annex I crops is worth $19.4 billion.
2. Annex I cereals and grains (which include maize, wheat and rice) are worth $13.8 billion (Chapter 2, Table 2.23).
3. The GM maize market is estimated at $5.063 billion (Chapter 2, Figure 2.12).
4. Chapter 2 estimates the upper bounds of the potential contributions to the Treaty,

13 The information available on the seed market is highly aggregated at the level of crop groups. The figures used here include some flower seeds, lawn seeds and miscellaneous seeds. In all EU and OECD statistics, the output value of ornamentals is included in the value of 'agricultural' output.

resulting from sales of conventional seeds of rice (Figure 2.15), maize (Figure 2.17) and wheat (Figure 2.19). These can be used as proxies to divide up the value of the total conventional cereal seed market.[14]

5. The GM canola market is worth $0.26 billion (Chapter 2, Figure 2.12).

6. The total market for GM sees is worth $10.57 billion (Chapter 2, Figure 2.11).

With this information, it is possible to estimate **V1–V5**, as follows;

Table a.3.1.3 Values of the International Seed Market

		US$ billion
Wheat	V1	3.07
Rice	V2	1.87
Genetically modified (GM) maize		5.06
Conventional maize		3.80
Total maize	V3	8.86
Total grains		13.80
Other Annex I (GM)		0.26
Other Annex I (conventional)		5.34
Total Other Annex I	V4	5.6
Non-Annex I (GM)		5.25
Non-Annex I (no GM)		12.15
Total Non-Annex I	V5	17.4
Total		36.8

ι: Intellectual property status				
C1 Wheat	**C2 Rice**	**C3 Maize**	**C4 Other Annex 1**	**C5 Non-Annex 1**
0	0	57	4.6	30

ι is calculated directly from Table a.3.1.3.

[14] "It should be emphasized that this upper bound figure does **not reflect** a realistic assessment of potential benefit-sharing payments, but is only indicative of the broad orders of magnitude relevant for discussion of the impact of access and benefit-sharing arrangements introduced by the International Treaty." Chapter 2 of this pubication.

ρ **Real voluntary payment**

The SMTA provides for mandatory payment of monetary benefit-sharing in Article 6.7 and voluntary benefit-sharing in Article 6.8. These two revenue streams are modelled as **Q1** and **Q2,** respectively. In the case of payments due under Article 6.7 (**Q1**), the SMTA stipulates the rate of payment as "one point-one percent (1.1%) of the sales of the product or products less thirty percent (30%)". In the case of payments due under Article 6.8 (**Q2**), no rate of payment is specified.

At the time of preparing this study, no voluntary payments (and indeed, no mandatory payments) had yet been made to the Benefit-sharing Fund, and there is no empirical basis for estimating what the real level of voluntary payments may be. For the sake of the model, a rate of payment equal to that for mandatory payments is assumed, and a performance factor, ρ, is applied. In this scenario, it is arbitrarily set at 50 percent.

Appendix 3.2 The mathematical algorithm

The concept of the algorithm is simple. While there is great uncertainty over the volume of products derived from materials accessed under an SMTA, and the timing with which they will come to market, the annual value total commercial value of the world seed and planting material market may be estimated with some degree of accuracy. For this reason, the model evaluates first the segment of the world market of seeds and planting materials of crops that are available under the SMTA, and within this, the proportion, over time, of products that are likely to have been developed from materials accessed under an SMTA. This proportion is simulated for the five crops/crop group, **c** = 1, 2..., 5. For simplicity, the **c** index is suppressed in the following equations.

Table 3.1: *Factors used in the model*, in Chapter 3, lists the variables implemented, and the symbols used. Section 3.1.5 of the chapter describes the structure of the model in mechanical terms. Appendix 3.1 sets out the rationale behind the decisions as to the values used for the base scenario (the 'current situation'), and the data sources. This information is not repeated here, where the same model is described separately in mathematical terms.

$\mathbf{D_d}$ defines the number of germplasm samples distributed per year from the *ex situ* collections listed in the second report, the *State of the world's plant genetic resources for food and agriculture*. **D** is indexed over **c** and over **d**: **d = 1** refers to non-SMTA materials, **d = 2** to SMTA materials from national collections, and **d = 3** to SMTA materials from the collections of international institutions.

The first step is to identify α**d**, the annual rate of introduction of material into the breeding pool, where **H** represents the holdings of Treaty members, and $\boldsymbol{\pi}$ a performance factor, namely that part of their holdings that they are effectively making available:

α**d** is defined as:

(1) $\boldsymbol{\alpha_d = (D_d/H)\,\pi}$ for each **d** = 1, 2... 3.

α_d describes the change over time in the set of breeding materials in the breeding pool, **B**, defined as the total materials being used by plant breeders at any time. In particular, it describes the growing proportion of SMTA materials within **B**: this ratio is defined as $\mathbf{A_t/B}$.

B is a dimensionless quantity, and constant over time. The model computes the $\mathbf{A_t/B}$ dynamics, primarily as a result of annual grow at $\alpha_{\mathbf{d}}$ rate. The dynamics of the $\mathbf{A_t/B}$ ratio do not depend on $\alpha_{\mathbf{d}}$ alone, but must take into account a separate factor, υ (avoidance by breeders of SMTA materials), which directly impacts on $\mathbf{A_t}$. υ, is indexed over **c**, and enters the computation of $\mathbf{A_t/B}$ as a multiplicative parameter, with a negative impact on the dynamic properties of the model.

$\mathbf{A_t/B}$ is therefore calculated as:

$$A_t/B = \begin{cases} 0 & \text{if } t = 0 \\ A_t/B = \dfrac{[\beta(\alpha_2 + \alpha_3)(1\text{-}\upsilon)] + \frac{A_{t-1}}{B}}{+[\Sigma^3_d = {}_1\, \alpha_d(1\text{-}\upsilon)\beta] + \frac{A_{t-1}}{B}} & \text{if } t \neq 0 \end{cases} \quad (2)$$

The diffusion of SMTA materials within **B** is influenced by cross-breeding with non-SMTA materials, since the terms and conditions of the SMTA extend to any material that contains genetic parts and components introduced from a material accessed under an SMTA: this is represented by λ, defined as that part of the breeding pool that is each year randomly crossed with other parts of the breeding pool.

The $\mathbf{A_t/B}$ ratio, including the λ component, can be written as:

$$A_t/B = \frac{[(\alpha_1 + \alpha_2)(1\text{-}\upsilon)] + \frac{A_{t-1}}{B}}{+[\Sigma^3_d = {}_1\, \alpha_d(1\text{-}\upsilon)\beta] + \frac{A_{t-1}}{B}} + f(\lambda) \quad (3)$$

$f(\lambda)$ has been identified empirically and it assumes the following form:

$$f(\lambda) = \lambda \left[2 \frac{A_{t-1}}{B} - \left(\frac{A_{t-1}}{B} \right)^2 \right]. \quad (4)$$

Once calculated, the $\mathbf{A_t/B}$ ratio can be utilized to derive the $\mathbf{T_{t+\kappa}/P}$ ratio (the part of products under the terms and conditions of the SMTA within the product pool), by applying the development time, κ; the value used in the computation is weighted by the improved/unimproved ratio (γ). The effect of γ on κ is expressed by δ_1. δ_1 is indexed over **c** and shortens the product development time, κ, when improved materials are used.

$$\kappa = \delta_1 \, [(\gamma\text{-}\kappa_i) + (1 - \gamma)\, \kappa_u] \quad (5)$$

where κ_i and κ_u are, respectively, the time of product development starting from improved, or unimproved materials.

In order to determine $\mathbf{T_{t+\kappa}/P}$, two other parameters that impact on product development dynamics are taken into account: β (development intensity per crop/crop group), and δ_2 (the effect of γ on the number of products). β is indexed over **c**, and enters the equation as multiplicative parameter, which differentiates the growth of SMTA products among crops/crop groups. δ_2 is indexed over **d**.

On this basis, $T_{t+\kappa}/P$ is computed as:

$$(6) \qquad T_{t+\kappa}/P = \frac{[\beta(\alpha_1 + \alpha_2)(1-\upsilon)] + \frac{A_{t-1}}{B}}{1 + [\Sigma_{d=1}^{3} \delta_2\alpha_2(1-\upsilon)\beta] + \frac{A_{t-1}}{B}} + \lambda \left[2\,\frac{A_{t-1}}{B} - \left(\frac{A_{t-1}}{B}\right)^2 \right].$$

Equation 6 describes the dynamics of products that incorporate materials subject to the terms and conditions of the SMTA. The monetary flows to the Benefit-sharing Fund from commercial products are evaluated as a constituent of **V**, that is, the total value of the world seed and planting material market, per crop/crop group.

Q represents that part of **V** that is subject to the terms and conditions of the SMTA. These differ according as to whether or not the product is available without restriction to others for further research and breeding. The intellectual property status (ι) of products is therefore included in the computation. **Q1** is that portion of **V** that derives from products commercialized under intellectual property protection, and is subject to the mandatory annual payment rate, **μ**, in accordance with Article 6.7 of the SMTA. **Q2** is that portion of **V** that derives from products commercialized without intellectual property protection, and therefore subject to voluntary annual payment, in accordance with Article 6.8 of the SMTA. In order to characterize the stochastic nature of the voluntary payment rate in **Q2**, the μ rate is multiplied by a performance factor, ρ. $\mathbf{Q1}_{t+\kappa}$ and $\mathbf{Q2}_{t+\kappa}$ are then computed as follows:

$$(7) \qquad \mathbf{Q1}_{t+\kappa} = \iota\mu\ (T_{t+\kappa}/P)\ V$$

$$(8) \qquad \mathbf{Q2}_{t+\kappa} = \rho\ (1 - \iota)\ \mu\ (T_{t+\kappa}/P)\ V$$

and the total monetary flow to the Benefit-sharing Fund from commercial products is the sum of $\mathbf{Q1}_{t+\kappa}$ and $\mathbf{Q2}_{t+\kappa}$:

$$(9) \qquad \mathbf{Q1}_{t+\kappa} + \mathbf{Q2}_{t+\kappa} = \mathbf{V}[\rho(1 - \iota)\ \mu + \iota\mu]\ (T_{t+\kappa}/P)$$

Conclusions and recommendations for further research

The Treaty's overall economic benefits are extensive and reach far beyond the commercial value of PGR for food and agriculture. Through promotion of the conservation and sustainable use of PGR for food and agriculture, the Treaty supports climate change adaptation and contributes to food security, both of which underpin global economic and social development. However, quantification of its total economic contribution is complex and requires comparison with alternative institutional arrangements in which the bilateral exchange of PGR and/or open access predominates. An assessment of the most promising methodological approaches to the quantification of the Treaty's overall economic contribution has been provided in Chapter 1.

Chapters 2, 3 and 4 of this book have focused on the potential monetary benefit flows arising from the use of the SMTA. They show that the evaluation of these flows is a challenging proposition, given the paucity of useful and reliable data over a long enough period of time and the lack of experience of the actual workings of the system. The SMTA was only adopted in 2006, and the build-up of a steady stream of monetary benefits will take many years. This is due not only to the slow nature of plant breeding, but also to a large number of Contracting Parties that have not yet made all or part of their PGR available under SMTAs. Moreover, the unpredictability of technological development in plant breeding complicates projections as to the time required for maximum annual levels of income to be reached.

Furthermore, mobilization by the Treaty of international level monetary benefits translates through projects supported by the Benefit-sharing Fund into non-monetary goods and services at the national or local level. Multiplier effects and the generation of a broad range of non-monetary benefits must then be taken into account to provide a full understanding of the total economic values generated. Nevertheless, estimation of possible or probable Benefit-sharing Fund income at least provides a lower-bound value for such non-monetary benefit estimation.

An accurate empirical assessment of the potential magnitude of Benefit-sharing Fund income would require substantially better data on the use of plant genetic materials under SMTAs in product development than currently exists. The complexity of this exercise ought not to be underestimated given that genetic material is exchanged through a complex maze of transactions across institutions and countries. The eventual use of materials exchanged under SMTAs in a final product may occur after a long series of transactions, at a point far removed from the first recipient of the material. Moreover, materials exchanged under SMTAs may be subject to transformation through several rounds of breeding before they are incorporated into a final product. Information on genetic material flows within and across national boundaries, and their use in long-term crop improvement programmes are extremely limited. Empirical assessment of the contribution of materials exchanged under SMTAs requires an identification of relevant products around the globe, and concomitant exploration of their genealogies and detailed breeding histories. Informatics-based approaches could be used to this end, but may be feasible only over the longer term. Given that exchange of material under SMTAs has only been practised for around seven years, and taking into consideration the lengthy process of plant variety development, it may be too early to use informatics-based approaches to discover linkages between exchange of genetic materials and the commercialization of products.

In the light of current data and methodological constraints, this book has presented two separate methodologies to assess the potential magnitude of benefit-sharing payments, neither of which relies upon linking individual PGR to individual products. These were: (i) a data-based approach to the estimation of income through an analysis of past use of CGIAR materials (Chapter 2); and (ii) the development of a mathematical model simulating the various stages of accessing materials and developing and marketing products (Chapter 3), so as to estimate the part of the market to which the terms and conditions of the SMTA apply, at any time. Both approaches lead to the key conclusion that potential income to the Benefit-sharing Fund is high, but that projections based on current arrangements are low, and that obstacles to substantial success under present arrangements cannot be ignored.

Benefit flows are contingent on a range of factors. The scenarios simulated in Chapter 3 underline the single and combined importance of: effective performance of Treaty members, expansion of Treaty membership, levels of avoidance of material under SMTAs, and actual levels of voluntary payments.

A robust, detailed evaluation of the relevant economic values (i.e. of both monetary and non-monetary benefits flowing from the Treaty as a whole, and the workings of its Multilateral System in particular) would be an important contribution to policy discussions involving Treaty stakeholders. The research undertaken by the authors is a first step, and a number of areas for possible future research have been identified.

Data regarding the quantification of benefit flows are currently extremely deficient, and the figures used to populate mathematical algorithm and project benefit flows in alternative future scenarios should be improved as follows:

- Further work on the economics of non-monetary benefits is essential. Chapter 1 indicates that such benefits are substantial, but their quantification remains elusive. Non-monetary benefits, as part of the Treaty's overall economic value, should be assessed in relation to alternative exchange scenarios. The methodologies currently used in the valuation of PGR require significant refining.
- Since there is no obligation to report on non-monetary benefits shared in accordance with Article 6.9 of the SMTA, evidence of these benefits is virtually non-existent. This is a major weakness when evaluating the full economic potential of the Treaty, and ways to document these elusive benefit flows should be explored. Scientometrics offers an innovative approach to this task.
- While information on SMTAs entered into by the CGIAR is relatively rich, much less is known about those issued by Contracting Parties and natural persons. Obtaining such information should be a priority.
- The model of Chapter 3 would benefit from covering not only materials in *ex situ* collections, but also materials from breeding programmes. Similarly, it would be valuable

to develop a methodology to reflect materials made available by natural and legal persons, including through their release as commercial products, and as contributions both to ex situ collections and to further breeding programmes.

- The coverage of *in situ* materials, to be made available in accordance with Article 12.3h of the Treaty, has the potential to more accurately reflect the importance of materials held by developing countries.
- The expansion of the model to other crops, in particular to a representative sample of vegetable crops, is a possible priority for further work. Discussions with breeders suggest that these materials are of high value. An important next step would be to identify individual crop seed market values and calibrate the factors that describe their use.
- It should be a priority to obtain a clearer picture of the degree to which breeders and breeding programmes are replacing or avoiding materials under SMTA conditions.
- The preliminary consultation of plant breeding experts undertaken (see the Annex) highlighted the willingness of industry experts to provide useful information and suggestions. Any further development of the model should seek to draw plant breeders more closely into its design, and into the generation of the data necessary to make it function effectively.
- The feasibility of applying informatics-based approaches such as those tested in Chapter 4 would dramatically improve if: (i) patent and PVP applications for plant variety innovations were required to provide information on the source of parental material used in an innovation, or if intellectual property regulations were amended to make it mandatory for applicants to acknowledge their possible use of material under SMTA conditions; and (ii) if a standardized system of nomenclature or coding were developed and applied for all transfer of Multilateral System materials from international and national gene banks and repositories.

References

Alene, A.D., Menkir, A., Ajala, S.O., Badu-Apraku, B., Olanrewaju, A.S., Manyong V.M. & Ndiaye, A.. 2009. The economic and poverty impacts of maize research in West and Central Africa, *Agricultural Economics* 40, 535-550.

Alston, J.M., Chan-Kang, C., Marra, M.C., Pardey, P.G. & Wyatt, T.J. 2000. *A meta-analysis of rates of return to agricultural R&D: ex pede herculem*? IFPRI Research Report No 113. Washington DC, International Food Policy Research Institute.

Alston, J.M., Andersen, M.A., James, J.S. & Pardey, P.G. 2010. *Research lags and spillovers persistence pays.* New York, Springer.

Alston, J.M., Norton, G.W. & Pardey, P. G. 1998. *Science under scarcity: principles and practice for agricultural research evaluation and priority setting*. Wallingford, UK.CAB International.

Alston, J.M., Pardey, P.G. and Smith, V.H. 1998. Financing agricultural R&D in rich countries: what's happening and why. *Australian Journal of Agricultural and Resource Economics* 42(1): 51-82.

Anderson, J.R., Pardey P.G. & Roseboom, J. 1994. Sustaining growth in agriculture: A quantitative review of agricultural research investments. *Agricultural Economics* 10(2): 107-123.

Asfaw, S. & Lipper, L. 2011. Economics of PGRFA management for adaptation to climate change: a review of selected literature. Background Study Paper No. 60 for the Commission on Genetic Resources for Food and Agriculture. Rome, FAO.

Bellon M., Adato, M., Becerril, J. & Mindek, D. 2007. Improved maize germplasm, creolization and poverty: the case of Tuxpeño-derived material in Mexico. *In* M. Adato & R.S. Meinzen-Dick, eds. *Agricultural research, livelihoods and poverty: studies on economic and social impact.* Baltimore, MD, USA. Johns Hopkins University Press.

Box, G.E.P. & Draper, N.R. 1987. *Empirical model-building and response surfaces.* Hoboken, NJ, USA. Wiley.

Brennan J.P. & Malabayabas, A. 2011. International Rice Research Institute's contribution to rice varietal yield improvement in South-East Asia. ACIAR Impact Assessment Series Report No. 74. Canberra, Australian Centre for International Agricultural Research. 111 pp.

Brennan, J.P. 1992. *Economic criteria for establishing plant breeding programmes*. Economics: Working Paper. Mexico, CIMMYT.

Brennan, J. P., Godden D., Smale, M. & Meng, E. 1999. Breeder demand for and utilization of wheat genetic resources in Australia. *Plant Varieties & Seeds* 12, 113-127.

Brennan, J.P. & Malabayabas, A. 2011. *International Rice Research Institute's contribution to rice varietal yield improvement in South-East Asia*. ACIAR Impact Assessment Series

Report No. 74. Canberra, Australian Centre for International Agricultural Research.

Brown, G. & Goldstein, J. H. 1984. A model for valuing endangered species. *Journal of Environmental Economics and Management* 11, 303-309.

Brown, G.M. 1990. Valuing genetic resources. *In* G.H. Orians, G. M. Brown, W. E Kunin & J.E. Swierzbinski, eds. *Preservation and valuation of biological resources*. University of Washington Press, Seattle, pp. 203-226

Buanec, B.L. 2005. *Enforcement of plant breeders' rights – opinion of the International Seed Federation*. Presentation made by the International Seed Federation (ISF) at UPOV meeting on Enforcement of Plant Breeders' Rights, October 2005, Geneva.

Byerlee, D. & Traxler, G. 1995. National and international wheat improvement research in the post-Green Revolution period: evolution and impacts. *American Journal of Agricultural Economics* 77, 268-278.

Byerlee, D. & Moya, P. 1993. *Impacts of International Wheat Breeding Research in the developing world, 1966-1990.* CIMMYT, Mexico, D.F.

Ceroni, M., Liu, S. & Costanza, R. 2005. The Ecological and Economic Roles of Biodiversity in Agroecosystems. *In* D.I. Jarvis, C. Padoch & D. Cooper, eds. *Managing biodiversity in agroecosystems*. NY, USA., Columbia University Press.

Childs, N. & Burdett, A. 2000. *The US rice export market*. Special article in *Rice situation and outlook*. RCS-2000. Washington, Economic Research Service USA.

Costanza, R., d'Arge R., de Groot R., Farber S.C., Grasso M., Hannon B., Limburg K., Naeem S., O'Neill R.V., Paruelo J., Raskin R.G., Sutton P. & van den Belt, M. 1997. The value of the world's ecosystem services and natural capital. *Nature* 387, 253-260.

Cox, T. S., Murphy, J. P. & Goodman, M.M. 1988. The contribution of exotic germplasm to American agriculture. *In* J. R. Kloppenburg, Jr., ed. *Seeds and sovereignty: the use and control of plant genetic resources*. Durham, N.C., Duke University Press. pp. 114-144.

Craft, A.B. & Simpson, R. D.. 2001. The value of biodiversity in pharmaceutical research with differentiated products. *Environmental & Resource Economics* 18, 1-17.

Day-Rubenstein, K. and Smale, M. 2004. *International exchange of genetic resources, the role of information and implications for ownership: the case of the U.S. national plant germplasm system*. EPTD Discussion Paper 119 – Environment and Production Technology Division, International Food Policy Research Institute. Washington DC, International Food Policy Research Institute.

Di Falco, S. 2003 Crop genetic diversity, agroecosystem production and the stability of farm income. Ph.D. dissertation Environment Department University of York, UK.

Dixon J., Nalley, L., Kosina, P., La Rovere, R., Hellin, J. & Aquino, P. 2006. Adoption and economic impact of improved wheat varieties in the developing world. *Journal of Agricultural Science*, p. 1 of 14.

Dixon, J., Braun, H-J., Kosina P. & Crouch, J. (eds). 2009. *Wheat facts and futures 2009*, Mexico, D.F., CIMMYT.

Drucker, A, Gomez, V. & Anderson, S.. 2001. The economic valuation of farm animal genetic resources: a survey of available methods. *Ecological Economics*. Vol. 36(1) pp. 1-18.

Drucker, A. & Scarpa, R. (eds. of the Special Issue). 2003. Introduction and overview to the special issue on AnGR. *Ecological Economics* Vol. 45(3) pp. 315-317.

Drucker, A.G., Smale, M. & Zambrano, P. 2005. Valuation and sustainable management of crop and livestock biodiversity: a review of applied economics literature. SGRP, IFPRI and ILRI.

Du Plessis, M., Van Looy, B., Song, X. & Magerman, T. 2009. Data production methods for harmonized patent indicators: assignee sector allocation. *Eurostat Working Paper and Studies*, Luxembourg.

Duvick, D.N. 1984. Genetic diversity in major farm crops on the farm and in reserve. *Economic Botany* 38, 161-178.

Dyer Leal, G.A. 2002. The cost of *in-situ* conservation of maize landraces in the Sierra Norte de Puebla, Mexico. PhD Thesis. University of California at Davis.

Ehrenfeld, D. 1988. Why put value on biodiversity? In *Biodiversity*, ed. EO Wilson, pp 212-16. Washington, DC, Natl. Acad. Press.

Ehrlich, P.R. & Wilson E.O. 1991. Biodiversity studies – science and policy. *Science* (Washington) 253(5021), 758–762.

Evenson, R.E. 2001. Economic impacts of agricultural research and extension. *In* B. Gardner & G. Rausser, eds. *Handbook of agricultural economics*. Amsterdam, Elsevier Science.

Evenson, R.E. & Gollin, D. (ed.). 2003. *Crop variety improvement and its effect on productivity: the impact of international agricultural research*. Wallingford, UK CABI Publishing.

Evenson, R.E. & Lemarié, S. 1998. Crop breeding models and implications for valuing genetic resources. *In* M. Smale, ed. *Farmers, gene banks and crop breeding: economic analyses of diversity in wheat, maize, and rice*. Boston, Massachusetts, Kluwer Academic Publishers, pp. 79-92.

Evenson, R.E., Gollin, D. & Santaniello, V. 1998. Introduction and overview: agricultural values of plant genetic resources, Agricultural values of plant genetic resources. CABI Publishing for FAO, Rome, Center for International Studies on Economic Growth and Tor Vergata University.

Evenson, R. & Gollin. D. 1997. Genetic resources, international organizations, and improvement in rice varieties. *Economic Development and Cultural Change* 45(3), 471–500.

Evenson, R. & Santaniello, V. 1998. The economic value of plant genetic resources for agriculture. WCHR-World Conference on Horticultural Research 495:625–631.

Evenson, R. & Kislev Y. 1976. A stochastic model of applied research. *Journal of Political Economy* 84(2):265–282.

Evenson, R.E. & Gollin, D. 2002. *Crop variety improvement and its effect on productivity: the impact of international agricultural research*. CABI Publishing.

Falcon, W. P. & Fowler, C. 2002. Carving up the commons--emergence of a new international regime for germplasm development and transfer. *Food Policy* 27, 197-222.

FAO. 1997. *The state of the world's plant genetic resources for food and agriculture*. Rome.

FAO. 2007. The role of economic analysis in improving farm animal genetic resource conservation and sustainable use, *State of the world's animal genetic resources*. Rome.

FAO. 2010. *Second report on the state of the world's plant genetic resources for food and agriculture*. Rome.

Feder, G. & Umali, D.L. 1993. The adoption of agricultural innovations: A review. *Technological Forecasting and Social Change*, 215-239.

Feder, G., Just R.E. & Zilberman, D. 1985. Adoption of agricultural innovations in developing countries: a survey. *Economic Development and Cultural Change*, 255-298.

Fowler, C. & Hodgkin, T. 2004. Plant genetic resources for food and agriculture: assessing global availability 1, *Annu. Rev. Environ. Resour*. 29, 143-179.

Fowler, C., Smale, M. & Gaiji, S. 2001. Unequal exchange? Recent transfers of agricultural resources and their implications for developing countries, *Development Policy Review* 19, 181-204.

Franco, J., Crossa J., Villasenor J., Taba S. & Eberhart, S.A. 1998. Classifying genetic resources by categorical and continuous variables. *Crop Science* 38, 1688-1696.

Frison, C., Lopez, F. & Esquinas-Alcazar, J.T. 2011 *Plant genetic resources and food security: stakeholder perspectives on the International Treaty on Plant Genetic Resources for Food and Agriculture*. Earthscan, FAO and Bioversity International.

Garforth, K. & Frison, C. 2007. Key issues for the relationship between the Convention on Biological Diversity and the International Treaty on Plant Genetic Resources for Food and Agriculture, Occasional Paper 2, Quaker International Affairs Programme (also available at www.qiap.ca).

Gepts, P. 2006. Plant genetic resources conservation and utilization, *Crop Science* 46, 2278-2292.

GIA. 2010. Seeds – a global strategic business report –MCP-4055. Global Industry Analysts, Inc, USA.

Giao, N.V. 2009. *General overview of the seed industry in Viet Nam*. Viet Nam Seed Trade Association.

Gollin D. 1998. Valuing farmers' rights. *In* R.E. Evenson, D. Gollin & V. Santaniello, eds. *Agricultural Values of Plant Genetic Resources*, ed. pp. 233–45. Wallingford, UK, CABI Publ.

Gollin, D. & Smale, M. 1998. Valuing genetic diversity: crop plants and agroecosystems. *In* W.W. Collins & C.O. Qualset, eds. *Biodiversity in Agroecosystems*. London, CRC Press. pp. 237-265.

Gollin, D. & Evenson, R. E. 1998. An application of hedonic pricing methods to value rice genetic resources in India. *In* R.E. Evenson, D. Gollin, &V. Santaniello, V., eds. *Agricultural values of plant genetic resources*. CAB International., Wallingford, U.K., pp. 139-150.

Gollin, D., Smale, M. & Skovmand, B. 2000. Searching an *ex situ* collection of wheat genetic resources. *American Journal of Agricultural Economics* 82(4): 812–827.

Gore, C. 2002. Realizing Goal 8: development partnership and poverty reduction in low-income countries. United Nations Conference on Trade and Development, Special Programme for Least Developed, Landlocked and Island Developing Countries.

Gotor, E. & Caracciolo, F. 2010. An empirical assessment of the effects of the 1994 In-Trust Agreements on IRRI germplasm acquisition and distribution, *International Journal of the Commons* 4 (1), 437–451.

Gotor, E., Caracciolo, F. & Watts, J. 2010. The perceived impact of the In-Trust Agreements on CGIAR germplasm availability: an assessment of Bioversity International's institutional activities, *World Development*, Vol. 38, Issue 10, October 2010, pp. 1486-1493.

Gotor, E., Caracciolo, F. & Watts, J. 2010. The perceived impact of the In-Trust Agreements on CGIAR germplasm availability: an assessment of Bioversity International's institutional activities. *World Development*, 38 (10), 1486-1493.

Griliches, Z. 1958. Research costs and social returns: hybrid corn and related innovations, *The Journal of Political Economy* 66, 419-431.

Hargrove, T.R. & Cabanilla, V.L. 1988. Twenty years of rice breeding. *Biological Science* 38, 675-681.

Hawkes, J.G., Maxted, N. & Ford-Lloyd, B. 2000. The *ex situ* conservation of plant genetic resources. Dordrecht, Kluwer.

Heisey P.W., Lantican M.A. & Dubin, H.J. 2002. *Impacts of international wheat breeding research in developing countries, 1966-97*. Mexico, D.F., CIMMYT.

Heisey, P.W., Lantican, M.A. & Dubin, H.J. 2002. Impacts of international wheat breeding research in developing countries, 1966-97. Mexico D.F., CIMMYT (International Maize and Wheat Improvement Centre).

Heisey, P.W., Smale M., Byerlee D., & Souza, E. 1997. Wheat rusts and the costs of genetic diversity in the Punjab of Pakistan. *American Journal of Agricultural Economics* 79, 726-737.

Heisey, P.W., Lantican, M.A. & Dubin, H.J. 1999. Assessing the benefits of international wheat breeding research: An overview of the global wheat impacts study. pp. 19-26. *In* P.L. Pingali, ed. *CIMMYT 1998-99 World Wheat Facts and Trends. Global wheat research in a changing world: Challenges and Achievements*. Mexico, D.F., CIMMYT.

Hossain M., Lewis D., Bose M.L. & Chowdhury, A. 2007. Rice research, technological progress and impact on the poor: the Bangladesh case. *In* M. Adato & R.S. Meinzen-Dick, eds. *Agricultural research, livelihoods and poverty: studies on economic and social impact*. Baltimore, MD, USA, Johns Hopkins University Press.

Hossain, M., Gollin, D., Cabanilla, V, Cabrera, N., Johnson, N., Khush, G.S. & Mclaren, G. 2002. International research and genetic improvement in rice: evidence from Asia and Latin America. *In* R.E Evenson & D. Gollin. 2002. *Crop variety improvement and its effect on productivity: the impact of international agricultural research.* CABI Publishing.

ITPGRFA. 2011. Experience of the IARC of the CGIAR with the implementation of the agreements with the Governing Body, with particular reference to the use of the standard material transfer agreement for Annex 1 and non-Annex 1 crops. Item 11 of the provisional agenda. Fourth session of the governing body, Bali, Indonesia, 14–18 March 2011. IT/GB-4/11/Inf. 05.

Jarvis, A., Ramirez, J., Hanson, J. & Leibing, C. 2011. Crop and forage genetic resources: International interdependence in the face of climate change. Chapter II *In* S. Fujisaka, D. Williams & M. Halewood, eds. *The impact of climate change on countries' interdependence on genetic resources for food and agriculture*. Background Study Paper 48. CGRFA.

Johnson, N.L., Pachico D. & Voysest, O. 2003. The distribution of benefits from public international germplasm banks: the case of beans in Latin America. *Agricultural Economics* 29, 277-286.

Just, R. E. & Pope, R.D. 1979. Production function estimation and related risk considerations. *American Journal of Agricultural Economics* 61, 276-284.

King, A. Productive Partnerships – Gene banks working in in-situ conservation. 2003. An unpublished report solicited by the Global Conservation Trust. Rome, Italy.

Koo, B. & Wright B.D.. 2000. The role of biodiversity products as incentives for conserving biological diversity: Some instructive examples. *The Science of the Total Environment* 240, 21-30.

Koo, B., Pardey, P. G. & Wright, B.D. 2004. Saving seeds: The economics of conserving crop genetic resources *ex situ* in the Future Harvest Centres of the CGIAR. Wallingford, UK, CABI Publishing.

Lantican M.A., Dubin H.J. & Morris M.L. 2005. Impacts of international wheat breeding research in the developing world, 1988–2002. Mexico DF, Mexico, Centro Internacional de Mejoramiento de Maíz y Trigo.

Lecocq, F. & Shalizi, Z. 2007. To mitigate or to adapt: Is that the question? Observations on an appropriate response to the climate change challenge to development strategies. World Bank Policy Research Working Paper 4299 1, 1-48.

Magerman T, Grouwels J., Song, X. & Van Looy, B. 2009. Data production methods for harmonized patent indicators: patentee name harmonization. *Eurostat Working Paper and Studies*. Luxembourg.

Maredia, M. K., R. Bernsten & Ragasa, C. 2010. Returns to public sector plant breeding in the presence of spill-ins and private goods: the case of bean research in Michigan. *Agricultural Economics* 41, 425-442.

Meng, E.C.H., Smale, M., Rozelle, S.D., Hu, R. & Huang, J. 2003. Wheat genetic diversity in China: measurement and cost. *In* S.D. Rozelle, & D.A. Sumner, ed. *Agricultural trade and policy in China: issues, analysis and implications*. Ashgate, Burlington, Vermont, USA, pp. 251-267.

Metrick, A. & Weitzman, M.L. 1998. Conflicts and choices in biodiversity preservation. *The Journal of Economic Perspectives*, 1998, 12(3), pp. 21-34.

Milne, M., D. Godden, J. Kennedy & Kambuou, R. 2002. Evaluating the benefits of conserved crop germplasm in PNG managing plant genetic diversity. *In* J.M.M. Engels, V. Ramanatha Rao, A.H.D. Brown & M.T. Jackson., eds. *Managing plant genetic diversity*. Wallingford, U.K., CABI Publishing.

Moore, G. 2010. A cost-benefit analysis of the ITPGRFA regarding ABS. Presented at international expert workshop: "Exploring the need for specific measures for access and benefit-sharing of animal genetic resources for food and agriculture". CGN, Wageningen, The Netherlands. (also available at www.cgn.wur.nl/UK/CGN+General+Information/Education+and+information/Seminars/

Moore, G. & Tymowsky, W. 2005. Explanatory Fuide to the International Treaty on Plant Genetic Resources for Food and Agriculture. Switzerland, IUCN.

Morris, M. L. 1998. *Maize seed industries in developing countries.* Lynne Rienner Publishers.

Morris, M.L. 2001. Assessing the benefits of international maize breeding research: an overview of the global maize impacts study. *In* P.L. Pingali, ed.. *CIMMYT 1999–2000 world maize facts and trends. meeting world maize needs: technological opportunities and priorities for the public sector.* Mexico, D.F., CIMMYT.

Morris, M.L. 2002. *Impacts of international maize breeding research in developing countries, 1966-98.* CIMMYT, Mexico.

Morris, M. L., & Heisey, P.W. 2003. Estimating the benefits of plant breeding research: methodological issues and practical challenges. *Agricultural Economics* 29, 241-252.

Morris, M. L. & López-Pereira, M.A. 1999. *Impacts of maize breeding research in Latin America, 1966-1997*. Mexico D.F., International Maize and Wheat Improvement Centre (CIMMYT).

Morris, M., M. Mekurio & Gerpacio, R. 2002. Impacts of maize breeding research. *In* R.E.

Evenson, & D. Gollin, 2002. *Crop variety improvement and its effect on productivity: the impact of international agricultural research.* CABI Publishing.

Palacios, X.F. 1998. Contribution to the estimation of countries' interdependence in the area of plant genetic resources. Commission on Genetic Resources for Food and Agriculture, Background Study Paper no. 7, Rev.1, Rome, FAO.

Pardey, P.G., Alston J. M., Chan-Kang, C., Magalhaes, E.C. & Vosti, S.A. 2004. Assessing and attributing the benefits from varietal improvement research in Brazil, Research Report – International Food Policy Research Institute, xii+90pp.

Pardey, P. G., Alston, J.M. Chan-Kang, C. Magalhães, E.C. & Vosti, S.A. 2006. International and institutional R&D spillovers: Attribution of benefits among sources for Brazil's new crop varieties, *American Journal of Agricultural Economics* 88, 104.

Pardey, P. G., Roseboomand J. & Anderson, J.R. 1991. *Agricultural research policy: International quantitative perspectives.* Cambridge University Press, for International Service for National Agricultural Research.

Pardey, P.G., Alston, J.M., Christian, J.E. & Fan, S. 1996. *Summary of a productive partnership – the benefits from U.S. participation in the CGIAR*. University of California, Davis and Environment and Production Technology Division, International Food Policy Research Institute, Washington.

Pardey, PG., Koo, B., Wright, B.D., Eric Van Dusen, M.E., Skovmand, B. & Taba, S. 1999. "Costing the *ex situ* conservation of genetic resources: maize and wheat at CIMMYT". EPTD Discussion Paper No. 52. Washington DC, USA, IFPRI and Mexico, CIMMYT.

Pardey, PG., Koo, B., Wright B.D., Van Dusen ME., Skovmand B. & Taba, S. 2001. Costing the conservation of genetic resources: CIMMYT's *ex situ* maize and wheat collection. *Crop Science* 41(4), 1286–1299.

Pearce, D. &. Moran, D. 1994. The economic value of biodiversity. London, IUCN.

Peeters, B., Song, X., Callaert, J., Grouwels, J. & Van Looy, B. 2009. Harmonizing harmonized patentee names: an exploratory assessment of top patentees. *Eurostat Working Paper and Studies*, Luxembourg.

Phillips McDougall. 2010. *Agrifutura Newsletter* (also available at: www.phillipsmcdougall.com).

Pingali, P.L. (ed.). 1999. *CIMMYT 1998-99 World wheat facts and trends. Global wheat research in a changing world: challenges and achievements*. Mexico, D.F., CIMMYT.

Polasky, S. & Solow, A. 1995. On the value of a collection of species. *Journal of Environmental Economics and Management* 29, 298-303.

Randall, A. 1988. What mainstream economists have to say about the value of biodiversity. *In* E. O. Wilson, ed.. *Biodiversity*. Washington, D.C., National Academy Press.

Rao, Y.Y. 2010. Rice seed production scenario in India. Executive Director, Vikky's Agrosciences Pvt Ltd. India (available at www.rkmp.co.in).

Rausser, G. C. & Small, A.A. 2000. Valuing research leads: bioprospecting and the conservation of genetic resources. *Journal of Political Economy* 108, 173-206.

Raymond, R. & Fowler, C. 2001. Sharing the non-monetary benefits of agricultural biodiversity. *Issues in Genetic Resources* No. 5. Rome, IPGRI.

Rejesus, R.M., Smale, M., & v. Ginkel, M.. 1996. Wheat breeders' perspectives on genetic diversity and germplasm use: findings from an international survey. *Plant Varieties & Seeds* 9, 129-147.

Rogerson, R., Shimer, R. & Wright R. 2005. Search-theoretic models of the labor market: a survey. *Journal of economic literature*, 2005, 43(4), pp. 959-88.

Rubenstein, K.D., Smale, M. & Widrlechner, M.P. 2006. Demand for genetic resources and the U.S. National Plant Germplasm System. *Crop Science* 46(3), 1021-31.

Sargent, T. 1987. Dynamic macroeconomic theory. Cambridge, Massachusetts: Harvard University Press.

SAT. 2007. *Seed industry in Thailand – 2004-2006*. Seed Association of Thailand.

Simpson, R.D., Sedjo R.A. & Reid, J.W. 1996. Valuing biodiversity for use in pharmaceutical research. *Journal of Political Economy* 104, 163-185.

Smale, M. & Drucker. A.G. 2007. Agricultural development and the diversity of crop and livestock genetic resources: a review of the economics literature. *In* A. Kontoleon, U. Pasual & T. Swanson. *Biodiversity Economics Principles, Methods and Applications*. Cambridge University Press.

Smale, M. 2005. Economics literature about crop biodiversity. Chapter 2 *In* A.G. Drucker, M. Smale & P. Zambrano. 2005. *Valuation and sustainable management of crop and livestock biodiversity: a review of applied economics literature*, SGRP, IFPRI and ILRI.

Smale, M. & Koo, B. 2003. Introduction: A taxonomy of gene bank value. *In* M. Smale & B. Koo, eds. Biotechnology and genetic resource policies. What is a gene bank worth? [IFPRI] Research at a Glance Briefs 7-12. Brief 7:1–5. Washington DC, USA, International Food Policy Research Institute.

Smale, M. & Day-Rubenstein K. 2002. The demand for crop genetic resources: international use of the US National Plant Germplasm System. *World Development* 30, 1639-1655.

Smale, M., Hartell J., Heisey P. W. & Senauer, B. 1998. The contribution of genetic resources and diversity to wheat production in the Punjab of Pakistan. *American Journal of Agricultural Economics* 80, 482-493.

Smale, M., Reynolds M.P., Warburton M., Skovmand B., Trethowan R., Singh R.P., Ortiz-Monasterio, I. & Crossa, J. 2002. Dimensions of diversity in modern spring bread wheat in developing countries from 1965. *Crop Science* 42, 1766-1779.

Smolders, W. 2005. Commercial practice in the use of plant genetic resources for food and agriculture, Background Study Paper No. 27 for the Commission on Genetic Resources for Food and Agriculture. Rome, FAO.

Srinivasan, C.S. 2003. Exploring the feasibility of farmers' rights, *Development Policy Review* 21, 419-447.

Srinivasan, C.S., Thirtle, C. & Palladino, P. 2003. Winter wheat in England and Wales: what do indices of genetic diversity reveal? *Plant Genetic Resources: Characterization and Utilization*, 1(1), 43-57.

Stigler, G.J. 1961. The economics of information. *Journal of Political Economy* 69(3):213–225.

Swanson, T. 1996. Global values of biological diversity: the public interest in the conservation of plant genetic resources for agriculture. *Plant Genetic Resources Newsletter*, 1-7.

Swanson, T. & Göschl, T. 2000. Property rights issues involving plant genetic resources: implications of ownership for economic efficiency. *Ecological Economics* 32: 75-92.

Ten Kate, K. 1995. *Biopiracy or green petroleum? Expectations & best practice in bioprospectin*g. Overseas Development Administration, London, *cited in:* UNEP/CBD/COP/3/Inf.53 (COP3, Nov. 1996).

Thirtle, C.G. 1985. Technological change and the productivity slowdown in field crops: United States, 1939-78. *Southern Journal of Agricultural Economics*, 33-42.

Thrupp, L.A.. 2000. Linking agricultural biodiversity and food security: the valuable role of agrobiodiversity for sustainable agriculture, *International Affairs* 76, 283-297.

Turner, R. K., Paavola, J., Cooper, P., Farber, S., Jessamy, V. & Georgiou, S. 2003. Valuing nature: lessons learned and future research directions 1, *Ecological Economics* 46, 493-510.

Visser, B., Eaton, D., Louwaars, N. & Engles, J. 2000. Transaction costs of germplasm exchange under bilateral agreements. Global Forum on Agricultural Research. FAO, Rome (also available at www.fao.org/docs/eims/upload/206946/gfar0077.PDF).

Visser, B., Pistorius, van Raalte, R., Eaton, D. & Louwaars, N. 2005. Options for non-monetary benefit sharing - an inventory. CGRFA Background Study Paper 30.

Wale, E. 2011. Introduction: setting the scene for GRPI Economics. *In* E. Wale, A.G. Drucker & K. Z. Zander, eds. *The economics of managing crop diversity on-farm case studies from the Genetic Resources* Policy Initiative. London, Earthscan.

Weitzman, M.L. 1993. What to preserve? An application of diversity theory to crane conservation. *The Quarterly Journal of Economics*, 1993, 108(1), pp. 157-83.

Weitzman, M. L. 1998. The Noah's ark problem. *Econometrica*, 1998, 66(6), pp. 1279-98.

Widawsky, D. & Rozelle, S.D. 1998. Varietal diversity and yield variability in Chinese rice production. In: Smale, M. (ed.) *Farmers, gene banks, and crop breeding: economic* *analyses of diversity in wheat, maize and rice*. Kluwer Academic Press and CIMMYT., Dordrecht, pp. 159-172.

Yapi, A., Debrah, S., Dehala, G. & Njomaha, C. 1999. Impact of germplasm research spillovers: the case of sorghum variety S 35 in Cameroon and Chad. Andhra Pradesh, India, International Crops Research Institute for the Semi-Arid Tropics.

Zohrabian, A., Traxler, G. Caudill, S. & Smale, M. 2003. Valuing pre-commercial genetic resources: a maximum entropy approach. *American Journal of Agricultural Economics* 85(2): 429–436.

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The Governing Body of the International Treaty on Plant Genetic Resources for Food and Agriculture adopted the Standard Material Transfer Agreement (SMTA) in June 2006. However, the potential income for the Benefit-Sharing Fund under the SMTA remains unclear. This book presents the findings of five interlinked technical studies carried out with the financial support of the Government of Australia. They address the overall economic impact of the International Treaty and, in particular, the benefits likely to flow from the use of the SMTA.

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