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What kind of goods are plant genetic resources for food and agriculture? Towards the identification and development of a new global commons

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Abstract: Plant genetic resources for food and agriculture (PGRFA) were once widely considered to be global public goods. Recently, however, access to subsets of PGRFA has been subject to various forms of exclusive technological and legal restrictions. In reaction, numerous voluntary pooling initiatives – from local to global scales – are being experimented with, in an attempt to re-strike a balance more supportive of agricultural research and development. The first part of the paper argues that different subsets of PGRFA can now be accurately described as public goods, private goods, club goods and common pool resources, but that these categories do not fully interrogate important 'exogenous variables' concerning PGRFA. As the products of complex interactions between crops breeding systems and natural and human selection, PGRFA occupy a middle ground between natural resources and human-make cultural resources. The paper identifies which subsets of PGRFA are (or could be) included in an evolving global plant genetic resources commons. The paper uses Elinor Ostrom's eight design principles for long enduring commons to analyze the extent to which the International Treaty on Plant Genetic Resources for Food and Agriculture (ITPGRFA) supports or undermines this evolving global commons. The paper concludes by identifying options for policy reforms to provide better tailored institutional support for the plant genetic resources commons.

Keywords: Design principles, global crop commons, International Treaty on Plant Genetic Resources, plant genetic resources

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> "The spread of the commons discourse in recent years has had a double effect; it has helped identify new commons and, in providing a new public discourse, it has helped develop these commons by enabling people to see them as commons."
>
> David Bollier (2007)

1. Introduction

Over the course of the last forty years, under the auspices of the United Nations Food and Agricultural organization, the international community has been developing the Global System for the Conservation and Sustainable Use of Plant Genetic Resources (FAO 2010). Among other things, the Global System includes a rolling Global Plan of Action, a web-based national information sharing mechanism, genebank standards, and a partnership programme to support capacity building for plant breeders. The pinnacle of efforts to develop this system was the adoption (2001) and coming into force (2004) of the International Treaty on Plant Genetic Resources for Food and Agriculture (ITPGRFA) (Hodgkin et al. 2013). The Treaty creates an international legal and administrative framework for countries to coordinate their activities related to conservation and sustainable use of plant genetic resources for food and agriculture (PGRFA). Most significantly, it creates the multilateral system of access and benefit-sharing, through which Treaty member-states agree to pool and share a range of PGRFA that are particularly important for global food security. FAO's Global System, and the Treaty's multilateral system of access and benefit-sharing in particular, conform in many respects to what is referred to in relevant literature as a 'new commons' (Gulati 2001; Falcon and Fowler 2002; Helfer 2005; Aoki 2008; Bertacchini 2012; Halewood et al. 2013a). Interestingly, neither the reports of the Commission on Genetic Resources for Food and Agriculture, the body responsible for the Global System and the negotiations of the ITPGRFA, nor the information papers it generated to support its efforts, explicitly mention 'commons', much less identify the creation of (or support for) a PGRFA commons among the commission's objectives. The more recent sessions of the governing body overseeing implementation of the ITPGRFA are similarly characterized by the absence of commons-focused discourse.

This paper seeks to achieve the 'double effect' David Bollier refers to in the epigram above. The paper urges wider recognition of globally distributed efforts to cooperate in the generation, pooling, conservation and sharing of plant genetic resources as a commons. The paper also draws upon commons discourse to diagnose

weaknesses in the multilateral system of access and benefit-sharing, and identify ways it could be reformed to better support for a global plant genetic resources commons.

Crop improvement and PGRFA conservation efforts have generally coalesced into a modular organizational architecture (Byerlee and Dubin 2010; Dedeurwaerdere 2013), which facilitates contributions being made by a wide range of actors, with various levels of connection, distributed broadly over time and space. While some of the nodes in these modulated architectures have developed truly global roles, capacities, and commitments – for example, the CGIAR genebanks and their ability and commitment to provide PGRFA to any requestor, anywhere in the world – the shape and function of most of the modulated, informal, interactions in crop improvement and conservation continue to be influenced by extraneous variables, such as farmers' family connections and geographic proximity, scientists' interpersonal or interorganizational relationships, professional organizations, reciprocity in treatment and mutual gain, reputational benefits, intergovernmental political tensions and strategies and so on. In principle, there is nothing wrong with a system that responds to, and is largely constituted by, such relationships. However, for decades, there have been persistent concerns that the system has been failing to address concerns that crop diversity continues to be lost (both from *in situ* conditions, and *ex situ* collections) (FAO 1997, 2010), that actors have been increasingly unwilling to share PGRFA for inputs into others' research programs, and that actors who were on the periphery of the informally coalesced clubs of scientists and organizations were not benefiting from the system as it evolved, and that the system as a whole was failing to benefit from their more robust engagement. One of the motivations for the creation of the ITPGRFA was to create a platform to raise the level and transparency of cooperation among all actors who are involved, in different ways, in the generation, management and use of plant genetic resources. It also seeks to establish outer parameters concerning the kinds of arrangements those actors can make with one another, to keep transaction costs down (to resist an observed tendency for increasing levels of complexity in access arrangements) and to ensure some minimum standards in terms of equity and fairness. In doing so, it sought to shore-up and support the conditions under which existing networks operated, and to create conditions for much more active engagement of actors previously on the fringes.

While the ITPGRFA has been a success story by some measures, there is increasing evidence that is not fully achieving its hoped-for impact, according to measures examined in more detail below. Nonetheless, there continues to be high level of commitment to the ITPGRFA by farmers, breeders, public and the private sector research and development organizations, and northern and southern governments. All of these actors have demonstrated willingness to consider reforms to the multilateral system so that it provides more appropriate institutional support for the global PGRFA commons.

There is an important distinction in commons literature between 'rules in form' (normative instructions that can come in the form of laws or legislation that are not known about by participants or not enforced) and 'rules in

use' (normative instructions that are known and enforced and affect those interacting) (Hess and Ostrom 2006, 342). This paper is based on an active appreciation of the difference between the two, analyzing how the multilateral system be recognized and integrated into the observed rule-in-use of a global crop commons, and does not end-up as a forgotten law on the back shelves of a FAO document repository.

One of the challenges this paper must respond to is the fact that PGRFA do not fit neatly within the institutional frameworks of analysis that have been developed for natural resources commons on one hand (Ostrom 1990), and constructed cultural commons on the other (Madison et al. 2010). Earlier, traditional commons scholarship focused primarily on cases studies of collective management, by a limited set of users, of rivalrous, non-excludible natural resources, distributed over circumscribed geographic areas, that were not exclusively subject to market or government control. 'New commons' literature has expanded in scope to consider non-rivalrous, purely cultural creations – for example, knowledge – which are developed, maintained and used by potentially limitless numbers of people worldwide (Hess and Ostrom 2006, 2007; Madison et al. 2010). Plant genetic resources for food and agriculture are conceptually situated somewhere in between natural resource and cultural commons (Dedeurwaerdere 2012, 2013). As the products of complex interactions between genetic mutations, plants' breeding systems, and natural and human selection, PGRFA represent a combined natural and constructed cultural resource. PGRFA possess both physical components (plant material containing functional units of heredity) and informational components (traits that can be passed down, DNA sequences). Partly as a result of these differences, the production, sustainable use and sharing of PGRFA are subject to social dilemmas that are different from those confronting the management of natural resources on one hand and purely-informational, culturally constructed resources on the other.

Another closely related challenge that this paper must address is the relatively high level of conceptual confusion regarding the status of PGRFA *vis-à-vis* the classic goods quadrant frequently invoked in commons-related literature (see Table 1). Part of this confusion is related to the fact that PGRFA's human-made and human-maintained characteristics are not fully reflected in the quadrant. The confusion is also partly due to the radically different forms of exclusion (or facilitated availability) to which humans have subjected various subsets of

Table 1: Categories of goods.

		Rivalry	
		Low	High
Excludibility	Difficult	Public goods	Common pool resources
	Easy	Toll or club goods	Private goods

Source: Adapted from Hess and Ostrom (2007).

plant genetic resources over the last 50 years. PGRFA were traditionally openly shared, and moved rapidly around the globe, driven or pulled by adoption of agricultural practices and technologies, the need to respond to diseases and climate stresses, adaptation of new foods into local diets, colonialism, international aid, trade, and international public research and plant breeding. As such, they were conceived of, and treated like, public goods. In the last 50 years, however, an increasing proportion of PGRFA have been subject to various forms of capture, as a result of advances in applied biosciences and the promotion of exclusive legal protections. As such, they have been converted into appropriated, private goods. Some of these 'capturing' mechanisms have been so successful that excluding parties have been led to pursue various forms of club-creation and pooling as corrective measures, to lower transaction costs of obtaining access to each others' resources. It is understandable that many readers might not be familiar with all of these developments and the extent to which they affect different subsets of PGRFA.

The first part of the paper seeks to address these two challenges. It considers the rivalry and excludability of PGRFA and argues that different subsets of PGRFA can now be accurately described as public goods, private goods, club goods or common pool resources (see Table 1). It also highlights areas of conceptual obscurity, where these categories do not reflect the biophysical and cultural nature of PGRFA, and therefore fail to fully interrogate the social dilemmas associated with the production and management of those resources. Conceptual clarity regarding these issues is important for further consideration of what PGRFA can or should be 'in' or 'out' of the evolving global PGRFA commons, and how policies can be developed to support those commons.

The second part of the paper identifies those subsets of plant genetic resources along the excludability and rivalry gradients that the literature suggests (mostly by analogy from case studies of other resources) are appropriate candidates for inclusion in a global PGRFA commons. These findings will be compared with the subsets of PGRFA that are actually included in the multilateral system of access and benefit sharing. This analysis will shed light on the extent to which the multilateral system is *ab initio*, oriented to support collective action in the production, management and sharing of the subsets of PGRFA that the literature suggests could or should logically fall within a commons.

Drawing on Elinor Ostrom's eight principles of long enduring commons, the third part of the paper diagnoses some apparent weaknesses in the policy support that the multilateral system of access and benefit-sharing provides for the global PGRFA commons. Clearly it is beyond the scope of this paper to exhaustively analyze current challenges facing the multilateral system and identify the most efficacious possible reforms. However, the paper does demonstrate the potential utility of using commons discourse, institutional analysis, and the principles of enduring commons to analyze the international communities' efforts to develop a globally coordinated system of conservation, sustainable use, and access and benefit sharing related to PGRFA.

2. Part 1: What kinds of good are PGRFA?

Many resources are not entirely rivalrous or non-rivalrous, nor are they entirely excludable or non-excludable. Instead, they fall somewhere on a gradient between these poles. In this section I will identify where different subsets of PGRFA are located on those gradients, and attempt to identify the 'goods' quadrant in which they belong. Working through this exercise, which is useful in its own right, has the added value of revealing some important exogenous variables concerning PGRFA that are not reflected in the rivalry/excludability axes, and the need for institutions that respond to those variables in support of commons-based production of PGRFA.

2.1. PGRFA's rivalry

It has been argued elsewhere (Wilkes 1988; Herdt 1999; Halewood et al. 2013a) that PGRFA are generally not rivalrous, that is to say, one person's use of a PGRFA does not detract from the availability of that resource to be used by others. Only a small number of 'units' of the 'stock' (to use the vocabulary adopted by Ostrom (1990)) of the physical component of the resource is required as inputs into most conservation, plant breeding and research activities. Additional 'units' likely exist in *in situ* conditions or as samples in *ex situ* collections and can be (re)generated at relatively low costs to maintain supply for other users. Wilkes (1988) states that "… genes are usually held in seed and these are one of the most abundant and cheapest of resources. Like water, seeds are absolutely necessary for biological life and are universally available […] the production cost is minimal because of the reproductive capacity of crop plants."

That said, PGRFA may be rivalrous when *in situ* populations are so small that additional collections, even of limited samples, threaten their existence. Or when the number of units/samples maintained in *ex situ* collections is similarly limited, a situation that can arise when a genebank lacks resources to 'regenerate' the reproductive materials of conserved material, creating samples for distribution in the process. In this context, it is worth considering that while the price per sample of an accession in a genebank is relatively low, the entire infrastructure contributing to the conservation of that accession is, overall, expensive. It costs approximately 20 million USD per year to maintain the CGIAR hosted *ex situ* PGRFA collections (CGIAR 2012). In the absence of that annual cumulative investment by a number of governments and organizations, the ability to generate, maintain and supply low cost samples would be lost. Eventually, the number of available samples would be reduced to the point where one person's use of those samples could deprive availability of the underlying accession to be used by others. It is a testimony to the fact that the *ex situ* collections have existed for so long – with relatively solid funding and impressive record of international distributions (Fowler et al. 2001; Byerlee and Dubin 2010; SGRP 2011) – that this way of considering PGRFA's potential rivalry does not 'leap to the fore' more readily. The argument in favour of PGRFA's potential rivalrousness is further

strengthened when one considers that some (possibly much – we don't actually know) of the materials maintained in the international and national genebanks no longer exist 'in the field'. This is perhaps some of the rational behind Kaul's (2010) description of a 'global gene pool to promote biodiversity preservation' as rival goods that are deliberately kept public. This conclusion needs to be tempered however by focusing on the definition of the resource itself, as provided in the Convention on Biological Diversity and the ITPGRFA, that is, material containing functional units of heredity.[1] The clearest example of such material is a seed. If the recipient of the last seeds of a conserved crop grows those seeds to exploit their functional units of heredity, they will be generating more, not less of the resource. Allowed to mature, the plant will produce seeds. The fact that the recipient may not choose to make those new seeds available is a function of the excludability of the resource, which we will consider in the next subsection.

In conclusion, PGRFA is generally non-rival in nature, certainly much less so than the kinds of natural resources that are the focus of most of the traditional commons scholarship. However, some subsets of PGRFA – those constituting or embedded in highly threatened populations – are arguably more rivalrous than PGRFA of populations stored in well-funded, well-stocked genebanks, or planted over wide areas across many countries or continents. The situation with respect to the information component of PGRFA is not subject to such a proviso; one's use of the informational component of PGRFA will not subtract from its availability for others.[2]

2.2. PGRFA's excludability

> "while rivalry can be characterized as a property given by a technology, excludability is man-made"
>
> Ravi Kanbur (2002)

In the absence of human-wrought technological or legal exclusions, it would appear that excluding access to PGRFA would be relatively difficult, more difficult, for example, than to units of flow of the stock of purely natural resources, such a forest, pasture, or watershed. The biophysical units of PGRFA stock can be extremely small (a seed, a plant cutting) and they are extremely portable. One only needs a few viable seeds to be able to carry away full informational and

[1] The Convention on Biological Diversity (article 2) defines 'genetic resources' as 'genetic material of actual or potential value'. It defines 'genetic material' as "any material of plant, animal, microbial or other origin containing functional units of heredity.' The ITPGRFA (article 2) defines 'plant genetic resources for food and agriculture' as 'any genetic material of plant origin of actual or potential value for food and agriculture.'

[2] Sedjo (1992) comes to a similar conclusion, distinguishing between phenotypes (the observable characteristics of a plant influenced by gene expression and the environment) which he considers to be subject to rivalry – he does specify a lot or a little – and genotypes (the set of genes carried by the plant) which he says are non-rivalrous.

biophysical components of the genetic resources of a particular crop variety or species. Seeds and cuttings can be gathered from open fields, road-sides, village markets, seed companies, gardens, and foods bought and sold as commodities. Farmer can select seeds from their own harvests and replant them. It is still harder to control access to the information component of PGRFA. Consider how easy it is to post a DNA sequence on line, and how impossible it is to 'get it back' thereafter.

For millennia, very little (or no) human effort was expended to exclude access to PGRFA. Plant genetic resources were widely dispersed around the world. There was also little to no concern about their conservation, until the 1960s, when concerns started to be expressed about the replacement of farmers' varieties by green revolution cultivars. From the late 1960s onwards, considerable human efforts, coordinated at the international level (under the auspices of FAO and the CGIAR centres), were expended to collect and conserve PGRFA (*ex situ*) and increase its availability through collections coordinated by the International Board on Plant Genetic Resources, establishment of the international network of base collections, and the steady growth of internationally accessible collections hosted by the CGIAR centres, some regionally based organizations, and some national agricultural research programs, such as in the USA, Germany, and the Netherlands (Fowler 1994; Pistorius 1997; Wilkes 1988). The results of these efforts have been so successful that there is now more genetic diversity of some crops represented in single genebank than may exist *in situ* in that crop's historical center of diversity (Wilkes 1988; Fowler et al. 2001).

The outcome of this enterprise is testimony to the accuracy of Ravi Kanbar's quotation above. Now that a vast diversity of PGR of many crops has been centralized in *ex situ* collections – including PGRFA of crops and forages that may no longer exist *in situ* – those PGRFA have become much more (potentially) excludable. The largest, most professionally curated collections of *ex situ* diversity are usually behind locked doors, in refrigerators, in genebanks hosted by international and national public organizations and companies. It would be an easy matter, from a purely physical point of view, to 'turn off' the supply of PGRFA from those collections.[3] Indeed, there were fears in the late 1980s and early 1990s that many of the international collections would be nationalized, or privatized, or taken over by the World Bank and subjected to restricted access (Halewood 2010). Fortunately however, the international collections hosted by the CGIAR Centres were created with the objective of providing world-wide supply of PGRFA to support agricultural research and breeding, and they have committed themselves, legally, to continuing supply (more about legalities below). Most national genebanks (with the exception of those already listed) generally have not provided materials directly to recipients outside their national borders, a situation about which research scientists and plant breeders the world over, including those

[3] Of course, there are duplicates of many of these resources in *ex situ* collections around the world, opening up the possibility of alternative sources of supply.

working in CGIAR Centres, have expressed concern (Lopez-Noriega et al. 2012; Halewood et al. 2013b). However, national genebanks do usually supply samples to domestic researchers and breeders upon request, though they often do not distribute directly to farmers. Private companies generally do not make any of their collections publicly available.

When one increases the scale of collecting to international levels, it is also necessary to consider potential practical limitations on access to *in situ* PGRFA. *In situ* PGRFA diversity often exists in marginal farmlands or 'in the wild' (crop wild relatives) and can most practically be reached by foreign scientists through formal collecting missions, relying on the expertise of national scientists or local farmers to locate the plant populations concerned. Without cooperation of national and local authorities and farmers, the *de facto* availability of those resources can also be limited.

The next subjections will highlight how, in recent decades, humans have developed an array of technical and legal restrictions that surpass any of these potential practical limitations on the accessibility of PGRFA managed *in situ* by farmers, held in *ex situ* collections, and developed by public sector plant breeders.

2.2.1. Technological exclusions

The seed of open pollinated crops can be harvested and replanted. As such, for all of the reasons cited above, it is difficult to exclude others' access to, and use of, such seed. This characteristic, coupled the fact that investment in plant breeding until the 1950s came almost exclusively from the public sector (whose primary objective was to promote the open availability and transfer of improved varieties), accounts for improved varieties being treated as public goods (Herdt 1999; Falcon and Fowler 2002). The first systematic introduction of technological restrictions on access to, and use of, PGRFA came in the form of hybridized maize, in the early part of the 20th century (Swanson 2013). Since then, a range of other hybrid crops have been developed (Kingsbury 2009). Progeny grown from the seed of hybrid crops generally do not perform well, and farmers generally do not have the capacity to create, maintain, and cross the inbred parental lines. As a result, farmers are required to return each growing season to suppliers of hybrid seed (Herdt 1999). This technological ability to exclude the possibility of farmers saving and freely exchanging seed of hybrids created the possibility of a commercial market for hybrid maize seed in the 1940s (Herdt 1999; Falcon and Fowler 2002). The market has grown steadily ever since, with companies keeping the inbred parental lines as trade secrets, and often subjecting the varieties to plant variety protection. A number of crops have been successfully hybridized, including rice, tomato, asparagus, squash, and sorghum. While use of hybrids started in developed countries, they are now widespread in many developing countries as well, particularly in Asia and Latin America. Hybrid maize is now found all around the world, planted on millions of hectars. The use of hybrid pearl millet and sorghum is now widespread in India, and many agencies are working together to support their introduction into Africa.

Other forms of technological restrictions have been introduced in the interim, nicknamed by concerned civil society organizations as genetic use restriction technologies (GURTS).

2.2.2. Legal exclusions

The development of various forms of legal controls over plant genetic resources over the course of the last fifty years has been reviewed exhaustively elsewhere (Crucible Group 2001; Tansey and Rajotte 2008; Santilli 2012; FAO 2010; Esquinas-Alcazar et al. 2013). I will only repeat the barest essentials of that history to support the narrative and analysis in this paper. Until the 1960s, international law was silent with respect to plant genetic resources. Subject to a few notable exceptions of national or colonial governments issuing edicts against exporting the planting material of particular species, plant genetic resources were also largely ignored by national law (Fowler 1994). This situation started to change in the 1960s, with the UPOV Convention 1961 (later revised in 1972, 1978, 1991) which sought to harmonize approaches to plant variety protection laws, but for a long time their membership was limited to a small number of developed countries, mainly in Europe. In 1983, the FAO Council adopted the non-legally binding International Undertaking on PGRFA[4] which proclaimed the 'universally accepted principle that plant genetic resources are a heritage of mankind and consequently should be available without restriction.' Not surprisingly, countries in favour of private appropriation of subsets of PGRFA through plant variety protection laws refused to endorse the International Undertaking. To accommodate the hold-outs, in a remarkable 'about face', the FAO Council adopted a resolution in 1989 which recognized the primacy of plant variety protection law over the common heritage principle.[5] Lingering discontent over this compromise, and the further extension of intellectual property rights through the ongoing Uruguay Round of GATT negotations, (among other things) precipitated an additional FAO Council resolution, in 1991, which recognized that 'nations have sovereign rights over their genetic resources'.[6] The recognition of countries sovereign rights over genetic resources was amplified in the Convention on Biological Diversity (1993), and obligations for tracking, reporting and enforcing access and benefit sharing agreements were recently adopted in the form of the Nagoya Protocol (not yet in force). From the mid-1980s, up to the present day, there has been a rapid world-wide proliferation of national and regional intellectual property, and access and benefit-sharing laws that allow owners, countries, communities, and individuals to exclude others access to various subsets of PGRFA for various purposes (Safrin 2004). The most relevant of those laws are:

[4] International Undertaking on Plant Genetic Resources.
[5] Resolution 5/89.
[6] Resolution 3/91.

- Patent laws: in some jurisdictions, patented PGRFA cannot be used for any purpose without the patent owner's consent. In other jurisdictions, the PGRFA can be used in research and breeding, but must not be included in the final commercialized new product without the rights-holder's consent.
- Plant variety protection laws: protected PGRFA may be used in research and breeding, and the new PGRFA that is produced (in the form of a plant variety) may be commercialized without the consent of the rights-holder (provided it is not 'essentially derived' from the protected material). Some national PVP laws include exemptions for farmers to save seed from harvested protected varieties for use on their own holdings, but also include an obligation on the part of the farmer to pay a royalty to the company in such cases.
- Contractual restrictions accompanying seed sales: Many companies sell seed with 'bag tags' with additional restrictions, beyond those which attend national PVP or patent laws. For example, these contracts sometimes include clauses whereby farmers agree to forfeit their rights that may exist under national law, to save and re-use seed, or to open their farms for inspections by the company for proper use of the seed, etc.
- Bilaterally oriented access and benefit sharing laws: most national laws that were designed to implement the access and benefit sharing provisions of the Convention on Biological Diversity do not allow access to genetic resources (including PGRFA) in the country concerned without the prior informed consent of an appointed national authority (Nijar et al. 2009). Some laws also require permission of the communities or natural or legal persons involved in supplying the resources in question (Cabrera et al. 2011).

It is difficult to identify the impact of these trends. It is certainly logically to assume that they would raise the transaction costs associated with basic research, and create bottle necks when upstream technologies of general application can be restricted from use by downsteam researchers, leading to a 'tragedy of the anti-commons' (Heller 1998; Bertacchini 2012). There is anecdotal evidence from scientists around the world that access and benefit sharing laws are impacting negatively on their abilty to attain germplasm as inputs for the research (UNEP 2006; Jinna and Juncourt 2009). The CGIAR genebankers and breeders partly attribute their reduced ability to acquire new germplasm for their collections and breeding program since the mid-1990s to a combination of political tensions and legal uncertainties related to intellectual property rights and access and benefit-sharing regulations (Lopez-Noriega et al. 2012; Halewood et al. 2013b).

2.2.3. Legal exclusions: the pendulum swings back, part way

Despite (and partly motivated by) these technical and legal developments, the international community continued to investigate mechanisms to facilitate pooling and sharing of at least some portion of the worlds' PGRFA that are

particularly important for food security. Following the direction of the Nairobi Final Act in 1992, the FAO Council invited the FAO Commission on Plant Genetic Resources to renegotiate the International Undertaking, to bring it in line with the Convention on Biological Diversity. These efforts culminated in the adoption of the ITPGRFA, which came into force in 2004. The logic, structure and functioning of the multilateral system are exhaustively described elsewhere (Moore and Tymovski 2005; Halewood and Nnadozie 2008; FAO 2011; Frison et al. 2011; Manzella 2013). Nonetheless, it is important to rehearse some basic information about the multilateral system for readers who may be unfamiliar with it. Based on a re-affirmation of their sovereign rights of control over PGRFA, ITPGRFA member states agree to provide each other with facilitated access to the PGRFA of 64 crops and forages that are 'under the management and control' of national governments and 'in the public domain', for the purposes of training, research and breeding for food and agriculture. This formula was designed partially for the comfort of the member states. In most countries, following this formula, PGRFA in the management or control of companies, farmers, communities, NGOs are not automatically included; nor are any PGRFA that are subject to any intellectual property rights. Most of the PGRFA that are automatically included is *ex situ* material in national genebanks and national agricultural research organizations, and in much smaller proportions, *in situ* PGRFA that exist on federally controlled lands (that is not being managed or controlled by farmers). Any other PGRFA of the 64 crops and forages must be voluntarily included by the natural or legal persons, or provincial governments who manage and control them. While on the one hand, the formula guarantees that many of the world's most diverse public *ex situ* collections will be included in the multilateral system, it allows the national government to take a 'hands off' approach with private industry, farmers groups and civil society. Contracting parties agree that all PGRFA in the multilateral system should be transferred using the standard material transfer agreement (SMTA). Member states agree to make the pooled PGRFA available for free, or for minimal administrative costs. However, the SMTA includes a default liability clause (Bertacchini 2012); if recipients incorporate multilateral system material in a new PGRFA product, and don't allow others (through technological or legal restrictions) to use if for further plant breeding or research, the recipient must pay 1.1% of gross sales to an international benefit sharing fund.

The multilateral system is not limited to PGRFA held by countries. The ITPGRFA also invites international institutions hosting *ex situ* PGRFA collections to place them under the ITPGRFA's framework. The CGIAR centres with collections have legally committed themselves, from January 2007 onwards, to provide facilitated access to ITPGRFA member states using the SMTA. At the same time, at their own initiative, the CGIAR centres confirmed that they will also provide facilitated access under the same conditions to non-ITPGRFA member states, on the basis that nothing in their ITPGRFA legal agreements prevents them from doing so. European genebanks, coordinated under the aegis of AEGIS

(a European integrated genebank system[7]) have also adopted the same policy of making materials to non-ITPGRFA members states.[8]

Natural and legal persons have also developed systems to lower transactions associated with high levels of exclusive protectionism. Patent pools, and research consortia with rules regarding facilitated access to research partners' PGRFA are examples. An important difference between these 'pooling' efforts is that under the multilateral system, the material included is in the public domain, and the system is set up to benefit open groups of users with environmental, development, conservation and social equity objectives. Patent pools on the other hand, are constituted by agreements between private partners to make private property available to one another, for their own mutual, exclusive, benefits.

2.3. PGRFA's distinctive attributes: entropic degradation

The discussion of rivalry above highlighted a critically important difference between natural resources, *strictu sensu*, and PGRFA (as a hybridized natural/cultural resources). The starting point for institutional analysis of natural resources-based commons is the existence of the resource, and institutional analysis then focuses on the mechanisms that support or detract from humans' ability to manage that resources sustainably (Madison et al. 2010). By contrast, PGRFA are partially human creations, the results of millennia of interactions between the environment, the breeding systems of plants, and human intervention in the form of farmer selection and plant breeding. The effectiveness and impact of human intervention in PGRFA development has increased over time, with the Mendelian genetics, modern plant breeding and most recently, biotechnology.

As a result of these differences, PGRFA are subject to some very different 'social dilemmas' than those effecting natural resources. One of the social dilemmas early commons scholarship sought to address was that embodied in Garett Hardin's 'tragedy of the commons' wherein self-interested actors' open access to a rivalrous natural resources led to their exhaustion (Hardin 1968; Ostrom 2008). The principle social dilemma facing PGRFA is quite different: in the absence of human intervention through selection and breeding, the existing diversity of crop species (and diversity within those species) would never have evolved. The corollary is also true: in the absence of continued use (or storage in *ex situ* collections) much

[7] http://aegis.cgiar.org/.

[8] The paper is too short to fully analyze the CGIAR centres' and some ITPGRFA member states' motivations for distributing multilateral system PGRFA to non-ITPGRFA members. However, they appear to involve a combination of a) being concerned about the impact on agriculture research and development in poor countries which, for whatever reasons, have not yet ratified the ITPGRFA, b) administrative efficacy of using the SMTA whenever possible for distributing materials, c) indirectly encouraging non-parties to join by demonstrating to them that receiving materials at least under the SMTA is not problematic, and d) the fact that some of the biggest financial donors to the CGIAR (e.g. USA) are still not Treaty members (Halewood et al. 2013a). Are these factors more important than the advantages of invigorating the multilateral system? It is beyond this paper to offer the required cost-benefit analysis. It will have to suffice for now to point out the tensions involved.

of the existing inter- and intra-specific diversity would cease to exist. Though the processes of domestication and co-evolution with humans, crops have become dependent on human beings for their continued existence; they cannot exist on their own in the wild (Wilkes 1988). Without continuous human-directed selection pressures, they would cease to exist in their current forms, and degrade, through purely natural selection, to forms that can exist on their own.[9] The literature is replete with examples of varieties of crops, trees, forages that no longer exist because they fell into disuse (Fowler and Mooney 1990; Richards and Ruivenkamp 1997; Tsygaye and Berg 2007), and were not subsequently subject to dedicated conservation efforts.[10] Unlike the situation with natural resources, underuse of PGRFA – not overuse – is the biggest threat to their evolution, conservation and availability for use by others. This aspect of PGRFA informs the need for collective action institutions that are necessary to support their continual creation/evolution as well as ensuring that they are conserved and available for use.

By highlighting the importance of PGRFA's entropic degredation, I am following the following the proposal of Madison et al. (2010) for a framework of analysis for constructed cultural commons.

> "…unlike resources in the natural world, resources of information and expression must be created before they can be shared. Because of the public goods character of these resources, a cultural commons must manage both use and production of cultural resources. […] This characteristic of cultural commons produces a more intertwined set of exogenous variables because separating the managed resources from the attributes and rules-in-use of the community that produces them is impossible."

Tom Dedeurwaerdere's (2013) insight that digital commons and PGRFA commons are similarly characterized by modular architecture, with participants motived largely by non-market incentives, provides a useful starting point for a discussion of institutions to support the production/continued evolution of PGRFA.[11] Of

[9] It is important to distinguish PGRFA from PGR. PGRFA is a subset of PGR, those genetic resources which have been developed, to greater or lesser degrees, as a result of human interventions in the context of crop domestication, crop improvement, and agriculture and food production generally. PGRFA do not include most wild plants, with the exception of wild relatives of domesticated crops. Wild relatives, as their name suggestions, have not been domesticated, and can exist on their own, without human intervention or supports. The relative importance of farmer selection in the evolution of a crop variety or population will vary considerably, depending on the crops breeding system, the agro-ecosystem within which is deployed, and the level of innovative activity on the part of the farmer.

[10] In this context it is important to underscore the difference in the assertion being made here, that underuse of a variety or population can contribute to its disappearance, and a more ambitious claim, which I am not making, and don't need to make for the purposes of this paper, that the replacement of farmers' varieties by modern cultivars (which is one of the main drivers of farmers' varieties falling into disuse) leads to an overall reduction in genetic diversity. Van den Wouw et al. (2009) provide a useful review of the literature and evidence assembled to date related to this latter claim.

[11] Of course there are significant differences between digital and PGRFA commons in terms of the quality of the modularity and extent of non-market incentives. Part of the reason that open source

course, the range of actors involved in PGRFA generation, conservation and use – from subsistence farmers around the world, to national public researchers and breeders, to genebanks, to the final, last resort back-up in the doomsday vault in Svaalbard – is considerably broader and more varied in comparison to the range of participants who contribute to web-based knowledge products. Given this complexity, it is not surprizing that the modular organization of PGRFA commons has evolved in separate tiers, involving similarly situation communities of actors, with various levels of connection between them in terms of knowledge and material flow.

The *ex situ* PGRFA collections around the world occupy one tier. Their operations most closely approximate the kind of modular and non-market motivation architecture identified by Dedeurwaerdere (2013). In this context, it is important to note however that *ex situ* collections are primarily conserved with the conservation, and less with the production/evolution, of PGRFA (van den Wouw et al. 2009).[12] Primary responsibility for production of PGRFA rests with formal sector plant breeders and with farmers.

Public sector breeders (both in national and international research organizations) participate in modularly constructed innovation architectures, motivated largely by non-market incentives (Byerlee and Dubin 2010; Dedwaerdere 2013) though some market related incentives are playing an increasing role as centres explore public private partnerships (Lopez-Noriega et al. 2012).[13] In most cases, there are well-established practices for recognizing contributions, which come in the form of new cultivars or genetically modified plants, including naming them after the organizations or individuals that bred them. There are functional connections between public sector breeders and

software, Wikipedia, Jamband, – three of the case studies considered by Madison et al. – have been so successful is that they are 'lightweight' in terms of resource investment and infrastructure to initiate and maintain. Their strength lays partly in their ability to draw upon the largely voluntary contributions of globally distributed producers, who can enter or exit the 'environment' of the cultural creation at whim. Each producer's contributions is developed over relatively short period of time. There is also a direct, traceable contribution from their individual contributions, and the value-added to the resources in question (and the possibility of peer recognition for those contributions). There are some challenges and costs associated with bandwidth and digital storage space (Hess and Ostrom 2007) but these are trivial compared to those associated with globally dispersed costs and time associated with the generation, maintenance and sharing of PGRFA. A global PGRFA commons by contrast is necessarily 'heavy', expensive, complex, and slow to evolve in comparison to digital information commons.

[12] van den Wouw et al. (2009) state, *ex situ* collections do not 'contribute directly to the crop diversity, just as zoos may be considered not to contribute to the biodiversity of a country, although they may function as an important back-up and a source for the re-introduction and restoration of genetic diversity.'

[13] Smaller private sector breeders that both allow and taking advantage of the breeders' exemption to plant breeders' rights laws also participate in modular forms of PGRFA development, though their motivations are market-based. Increasing corporate concentration coupled with patent protection is contributing to much less participation by the larger life-science corporations.

national and international genebanks, with the latter providing the former with materials and information to incorporate into their breeding programs.[14]

As far as farmers are concerned, the situation is considerably more complex. The modularity of their innovation systems is largely limited to informal exchanges of reproductive materials between neighbors, family and in local markets (Badstue et al. 2006). While some 'custodian farmers' are motivated by the respect they receive for providing good seed of local varieties (Meinzen-Dick and Eyzequirre 2009), most farmers' motivation is market-dominated, making decisions about what to select, replant, and exchange to improve their livelihoods (Narloch et al. 2011). While collectively, over millennia, the incremental evolutionary changes to crops wrought by farmers' selection and exchange has been enormous, each increment is hard to identify in the mixed, heterogeneous plant populations they manage. Although the world's farmers are collectively recognized by the ITPGRFA (article 9) for their contributions to the development and conservation of PGRFA, the contributions of individual farmers to the generation of PGRFA is generally unrecognized. Famers' connections to broader, national and internationally distributed modular forms of PGRFA-related innovation are generally very weak, to non-existent, with some notable exceptions in the form of participatory breeding projects, and recent efforts to develop more active two-way linkages between community seedbanks and national genebanks and to participatory monitoring of climate changes and the performance of varieties (Bishaw and Turner 2008; Van Etten 2011; Badstue et al. 2012; Ruiz and Vernooy 2012). National and international organizations collect PGRFA from farmers to store in genebanks, but usually in the form of one-off requests, without complementary research and breeding activities or partnerships. The name of the farmer from whom material is collected is usually not part of the records that collectors and genebanks maintain about the materials in their collections (FAO/IPGRI 2001; Halewood et al. 2006; Gotor et al. 2008). By the time they are formally part of a genebank collections, the connection back to the farmer from whom the PGRFA was originally collected is completely lost.[15]

In parts 2 and 3 I will return to the theme of institutional support for farmers' production/evolution of PGRFA, and the extent to which the multilateral system (or the ITPGRFA as a whole) responds to that need.

[14] Private sector breeders have not historically sought to access much PGRFA from the PGRFA collections hosted by the CGIAR genebanks (SGRP 2011); they appear to have developed adequate supplies of PGRFA to be more or less self-reliant, at least for the time being (Halewood and Nnadozie 2008).

[15] A new set of 'Descriptors for Farmers' Knowledge of Plants' has been developed by The Christensen Fund and Bioversity International (previously IPGRI) which partnered with FAO in development of the standard multicrop passport descriptors which did not include information about farmers from whom the material was collected. It is uncertain at this point the extent to which these descriptors will be adopted and used world-wide.

3. Part 2: Using commons discourse to identify new commons: what PGRFA 'fit' in a global commons?

This section focuses on what subsets of PGRFA 'fit' in the PGRFA commons. This exercise involves comparison of those subsets of PGRFA that the four quadrant analysis and traditional commons literature suggests might be included in such a PGRFA commons, with the PGRFA that are included in the multilateral system. The exercise also involves investigating how the multilateral system accommodates the insight from the new commons literature that there is a need for institutional support for the production, as well as the conservation and sustainable use, of human-made resources.

3.1. Commonalities

As highlighted above, commons scholarship once focused mainly on collective management of rivalrous, non-excludible natural resources (called common pool resources), but has recently expanded in scope to address collective action problems associated with non-rivalrous, non-excludable resources (public goods). Private goods, and voluntarily pooled private goods (club goods), are generally not conceived of as constituent elements of commons.

Interestingly, there is a very high level of similarity between the subsets of PGRFA in the public goods and common pooled resources quadrants in Table 2, and what is included (or at least what is meant to be included) in the multilateral system.

Following the 'under the management and control' 'and in the public domain' formula discussed above, the bulk of what is automatically included in the multilateral system are the *ex situ* collections hosted by national agricultural research organizations, usually in formal genebanks, and in research collections. The same formula operates to automatically include *in situ* PGRFA of the same crops and forages located on national government-controlled lands (unless the PGRFA in question is also managed and controlled by people occupying those lands, in which case, logic suggests it would not be included). These PGRFA are identified on Table 2 somewhere in the gradient between pure public goods and common-pooled resources. This formula reflects the ITPGRFA negotiators' intention to not disturb the pre-existing rights of their constituent interest groups – rights that effectively convert PGRFA under their control to private goods. Instead, the formula limits each member state's commitment to including only those PGRFA that the national government already controls and manages, and would not need to seek cooperation or permission to include.[16]

[16] The ITPGRFA also includes provisions to allow nuanced responses to the possibility that *in situ* PGRFA could be depleted through collecting. Article 12.3.h. states that access to *in situ* PGRFA should be subject to national laws, with the idea that national environmental laws would need to be respected, including those related to sustainable collection.

Table 2: Subsets of PGRFA characterized as different kinds of goods.

		Rivalry	
		Low	High
Excludibility	Difficult	Public goods	Common pool resources
		Ex situ collections hosted by CGIAR centres and many European countries (global public goods)	*PGRFA embedded in threatened situ populations and unique samples/units in threatened ex situ collections*
		Collections in national genebanks (national public goods)	
		In situ PGRFA on lands managed and controlled by national government (in the absence of farmer management)	
		PVP protected PGRFA (for purposes of research, breeding, private, non-commercial use)	
	Easy	Toll or club goods	Private goods
		Patent pools	*PGRFA that is subject to strong national ABS laws including potentially ex situ and in situ PGRFA held by provincial governments, private universities, companies, civil society organizations, and farmers, and in the wild (except those on public public lands)*
		PGRFA subject to facilitated access in research consortia	
		PGRFA subject to humanitarian use licenses	
			Patent protected PGRFA
			PVP protected PGRFA (for commercial exploitation)
			Hybrid parental lines, hybrid seed (that are not shared publicly)

The multilateral system includes the *ex situ* collections hosted by the CGIAR centres. Similar to the case of national genebanks, inclusion of the CGIAR centre-hosted collections in the multilateral was a relatively uncontroversial and logical policy, given the history of the development of, and open public access to, those collections. Indeed, one could argue that the entire multilateral system was modeled on, and intended to expand, the status of PGRFA and style of management of PGRFA by the CGIAR centres (Dedeurwaerdere 2010; Louafi 2013). On Table 2, these PGRFA are also on the gradient between pure public goods and common pooled resources.

The following PGRFA are not included in the multilateral system:

- *In situ* materials located on lands managed or controlled by farmers, provincial or local governments, companies, private universities, civil society organizations.
- *Ex situ* collections, research collections, under the control of provincial governments, companies, provincial and private universities, civil society and community organizations, private individuals

Based on the assumption that those same PGRFA will be subject to what is emerging as a standard form of access and benefit sharing regulation under the Convention on Biological Diversity (whose membership includes 189 state parties), they are listed on Table 2 on the gradient between private and club goods. The multilateral system also does not automatically include any PGRFA that is subject to intellectual property rights, on the basis that they have already been converted to a form of private property.

3.2. (Reconcilable) differences

The multilateral system is limited to the list of 64 crops and forages included in Annex 1 of the ITPGRFA. The generic analysis of the 'goods status' of PGRFA above did not distinguish at the level of species or genera of plants that could or should be included in a crop commons. On the other hand, the basis upon which the ITPGRFA purports to make such distinctions is logical when one considers which subsets of PGRFA are actually being collectively managed at a global scale. The Annex 1 crops were (at least in theory) selected on the basis of their importance to food security and the high degree of countries' interdependence on them. The interdependence criterion reflects an appreciation of the fact that the crops to be included in the multilateral system should be those which have been openly shared for long enough that they have become adopted around the world; that access to, and ability to reassemble, portions of the dispersed gene pool is a necessary precondition for research and breeding; and that that research and development would take place within a modulated architecture described above. To the extent that this criterion is paid-attention to, the ITPGRFA discourages inclusion of crops and forages whose use is limited to specific areas, and whose generation, conservation and sustainable use does not engage an internationally dispersed set of actors.

The multilateral system does not include any materials subject to intellectual property rights, even if the bundle of applicable rights does not interfere with the materials being used in ways envisaged by the ITPGFA. So, while many national plant variety protection laws include exemptions for research and breeding, and private non-commercial uses, PGRFA protected by such laws cannot be considered to be automatically included in the multilateral system. On the other hand, the ITPGRFA does provide a form of preferential recognition of such plant variety protection laws, in as much as such protection would not 'trigger' the mandatory benefit-sharing provisions of the SMTA. This exceptional treatment reconciles

the fact that plant variety protected materials appear as global public goods – for the purposes of research and breeding in Table 2 – but are not included in the multilateral system.

3.3. Missing pieces: production/evolution of PGRFA

Most of what is included in the multilateral system, and most of what is identified in the public goods and pooled resources quadrants are *ex situ* materials, with a very small proportion of *in situ* materials. But as highlighted above, *ex situ* materials *already exist* by the time they make it into collections; in that sense, they are 'a given' like natural resources in traditional commons scholarship.

What is missing is a reflection of the insights from new commons literature about the need for collective action institutions to support the *production or evolution* of PGRFA. For example, farmers modulated systems of *in situ* PGRFA generation and conservation-through-use are not recognized, supported or somehow included in the multilateral system. Instead, the multilateral system accommodates and 'works around' the recognition of farmer-managed diversity as a form of private property.

This apparent asymmetrical focus on conservation is acceptable, if it is compensated for by other, complementary institutional supports for PGRFA production/evolution. The need for such a remedy was part of the justification for subjecting all genetic resources, including PGRFA, to restrictive forms of control under access and benefit sharing regulation pursuant to the CBD. Converting genetic resources from public goods (or common pool resources) to something more like private goods would make it possible to extract use-rents and create incentives for conservation and innovation (Reid 1993). But there are reasons for considering that converting farmer-managed PGRFA to private goods is not well suited to farmers' innovations systems, which are, as described above, characterized by a highly modular structure, taking advantage contributions from a wide range of participants over considerable space and time (Halewood et al. 2006; Andersen and Winge 2013).

Some elements of the ITPGRFA were informed by a more active appreciation of the need to provide nuanced forms of support for farmer innovation. For examples, the intention behind the benefit sharing fund is to support, among other things, on farm conservation and sustainable use. Furthermore, in other parts of the ITPGRFA (beyond the multilateral system) contracting parties undertake, subject to national laws, to explore mechanisms to support *in situ* conservation (article 5), sustainable use (article 6) and farmers' rights (article 9). Furthermore there is at least one other component of the Global System on Conservation and Use (outside the ITPGRFA), which is intended to boost PGRFA production/evolution: the global platform for capacity building for breeders.[17] Unfortunately, to date, the levels of support available through the benefit-sharing fund are

[17] The Global Initiative on Plant Breeding, http://km.fao.org/gipb (last accessed June 18 2013).

relatively low. And there has been almost no international level coordination, pursuant to these other articles, to provide support for farmers engaged in on farm management. And the platform for capacity building for breeders continues to be a very good idea with very low levels of financial support. Overall, the global system continues to be underdeveloped in terms of its support for international cooperation concerning *in situ* conservation, including farmer management and production of crop diversity. Hodgkin et al. (2013) note that '[t]his distinction tends to hamper the development of an effective systems approach that seeks to strengthen the connections between the different parts of the systems and seeds functionality in terms of the effectiveness of the system as a whole'.

4. Part 3: Using commons discourse to develop the PGRFA commons

The multilateral system is a remarkable achievement, representing years of hard work on the part of the international community to strike compromises on very difficult issues to develop a system that promotes conservation, facilitated access and benefit-sharing. While the system may not be perfect, it is by far the best alternative that currently exists. The following critique is not intended as an indictment of the multilateral system; instead, it seeks to identify options to strengthen the support the multilateral system provides for the global PGRFA commons.

On one hand, the rate of ratification of the ITPGRFA has been high, and there has been significant progress at international levels to implement the multilateral system, for examples, the adoptions of the SMTA in 2006 and the compliance standards and procedures in 2011. Some countries have also made significant progress in national level implementation. And there are some signs that the Treaty is having some positive impacts (Halewood et al. 2013b).

On the other hand, by a number of standards, the system is not yet living up to its full potential. For example, most country members have not yet stepped into their anticipated roles under the Treaty as PGRFA providers. Out of the current 127 country members, only approximately 20% have shared information about what PGRFA are available from them through the multilateral system (via a website maintained by the ITPGRFA Secretariat). The result is that the CGIAR centres and a few European and the Canadian genebanks continue to provide almost all of the internationally transferred materials through the multilateral system (as they did before the ITPGRFA). There has also been an extremely low rate of voluntary inclusion of PGRFA in the multilateral system by natural and legal persons (either providing it directly themselves, or by depositing it national genebanks).

Nonetheless, both ITPGRFA contracting parties and non-contracting parties (and natural and legal persons in those countries) continue to request, and receive, PGRFA samples from these genebanks at approximately the same rate as before the Treaty came into force. Free riding in this respect has become an increasingly evident problem (Halewood et al. 2013a).

Almost one hundred per cent of the materials that are being confirmed to be in the multilateral system are in *ex situ* collections. In addition, most of the new deposits of PGRFA to the CGIAR genebanks over the last six years are duplicates of materials already included in national *ex situ* collections (Halewood et al. 2013b). Very little 'new' PGRFA deposited in internationally available collections – new in the sense that it was not previously included in the multilateral system – was recently collected from *in situ* conditions. And subject to only one exception – the potato park in Peru – no notifications have been shared about PGRFA that remains in *in situ* conditions as being included in the multilateral system (Halewood et al. 2013b).

Farmers and civil society organizations tend not to identify positively with the multilateral system. The biggest seed companies in the world are not seeking (in fact, they are actively avoiding) PGRFA from the multilateral system.

In the following paragraphs, I draw on Elinor Ostrom's eight design principles for long enduring commons (Ostrom 1990) to diagnose this state of affairs, and to identify options for reforms to increase the institutional support the multilateral system could provide the global PGRFA commons.

Design principle 1: The boundaries of commons must be clearly defined, with certainty about who can appropriate resource units and how many.

At present there is considerable disagreement (or at least confusion) about the boundary rules for who will participate in pooling and conserving PGRFA in the multilateral system, and who gets to benefit from the use of those pooled resources. On the one hand, the historically largest international suppliers of PGRFA in the multilateral system (Canada, a few European countries, and the CGIAR centres) appear to have adopted the stance that membership in the multilateral system is one thing, and the freedom to enjoy spillover benefits from that system is another. These organizations and countries have adopted policies to make pooled multilateral system available to non-parties, using the SMTA. This practice is offensive to a number of ITPGRFA state parties, some of whom have refused to place materials in collections that have the policy of distributing PGRFA to non-parties, or they have requested assurances that the material they deposit will be treated exceptionally (and not distributed to non-parties). There is some evidence that allowing non-Parties access to PGRFA pooled under the multilateral system is creating disincentives for them to join the Treaty with the result that their PGRFA is not being included in the common pool (Wang 2013). It is also logical that this approach would undermine the shared sense of purpose that would otherwise exist among those countries who feel that facilitated access should be limited to the member states (Halewood et al. 2013a).

The ITPGRFA is clear that, for the time being, natural and legal persons within contracting parties are entitled to enjoy spillover benefits in the form of access to samples of the pooled resources. However, the ITPGRFA (article 11.4) also schedules a review of this situation, with the possibility of its being reversed.

Design principle 2: There must be proportional equivalence between benefits and costs for those directly involved in the management of the commons.

At the present time, the single largest benefit to be obtained from the multilateral system is access to pooled germplasm and related information. Another potential benefit which attracts a great deal of attention is money from the international benefit sharing fund. Other benefits envisaged as part of the multilateral system, but concerning which there has not been much progress at the level of the governing body are: access to information through a global information facility (that does not yet exist), technology transfer, and capacity building.

One of the most widely discussed 'costs' to participating in the multilateral system is the germplasm that a country will be expected to provide. This is really a perceived forgone opportunity cost, based on the perception that it might be possible to makes deals which involve more benefits for the providing country, outside the context of the multilateral system, … if and when they are discovered to possess commercially valuable traits. This perceived cost is one of the biggest challenges facing national policy makers when they seek to create space and momentum for the national implementation of the multilateral system, and to lead exercises to clarify what PGRFA are automatically included in the multilateral system. It is an even more significant consideration for natural and legal persons, whose decision to place any material in the multilateral system is purely voluntary. Monetary benefits shared through the SMTA's benefit sharing formula are directed to the international benefit sharing fund (and not to 'includers' of materials in the multilateral system); so there is no built-in incentive (benefit) for natural and legal persons – including, very importantly, farmers – to offset the opportunity cost of voluntarily including the materials in the multilateral system.

Far more concrete costs for providers are those associated with actually conserving, characterizing, and evaluating PGRFA, including the costs of genebanks, cold storage, test fields, laboratories, and programs to support *in situ* conservation by farmers or protected areas. As far as the multilateral system of access and benefit sharing is concerned, these costs are, *de facto,* treated as contributions-in-kind from the countries that have opted to become members.[18]

The costs that commercial plant breeding organizations are most concerned about are those associated with receiving and using germplasm from the multilateral system. There is the possibility, if they 'trip' the relevant conditions, that they will be required to pay a royalty to the international benefit sharing fund. Given the nature of the benefit sharing formula, commercial plant breeding organizations hoping to avoid such obligations must bear the costs of scrupulous monitoring and record-keeping concerning how multilateral system germplasm is used in their breeding programs.

[18] The Global Crop Diversity Trust, which is 'an essential element of the funding strategy' of the ITPGRFA, provides financial and technical support for *ex situ* conservation of PGRFA. The administration of those funds however, is separate from the multilateral system *per se*.

In a number of ways, the multilateral system fails to contribute to equivalence between the benefits and costs involved for a number of the actors who should be participating more actively in the collective management of PGRFA through globally coordinated efforts. There are no rules regarding equivalency between the costs of making PGRFA available through the multilateral system and the benefits of either a) receiving materials through the system or b) receiving support from the benefit sharing fund. Conversely, once a country has ratified the Treaty, it may seek, as of right, facilitated access to PGRFA from other countries in the multilateral system and to apply for support from the fund ... even if it has not included PGRFA in the system,[19] or borne the costs of other forms of support for the conservation of the materials in the multilateral system, such as sharing responsibility for conserving, or regenerating or evaluating some portion of the pooled PGRFA.

The same situation prevails, at higher levels of granularity, for natural and legal persons within contracting parties. There is no equivalence in terms of the absence of costs borne, and high levels of benefits received, by natural and legal persons *vis-à-vis* the multilateral system.

Commercial plant breeders that exploit technical or legal restrictions in ways that could potentially 'trigger' the mandatory monetary benefit-sharing conditions complain that there is a lack of equivalence between the benefits they gain from access to the pooled germplasm, and the costs associated with monitoring their own uses of that germplasm, and the cost of the royalties they have to pay if they actually do 'trip' the benefit-sharing conditions.

Design principle 3: individuals affected by operational rules of the commons can participate in changing them to make the better fit circumstances, developments in the field, etc.

On the one hand, the multilateral system does provide flexibility to PGRFA users to tailor the rules, and the terms and conditions of their interactions, in response to changing circumstances. For example, a number of the CGIAR centres have created research consortia whereby they 'auction off' inbred parental lines to private sector bidders/consortia members on preferential, semi-exclusive bases (Lopez-Noriega et al. 2012). While such arrangements did not exist when the text of the Treaty was adopted, the system was nevertheless broad enough to accommodate this novel form of private ordering.[20]

[19] To know what PGRFA within countries is actually automatically or voluntarily included in the multilateral system, countries need to publish lists of the accessions, accompanied by passport and other data. Unfortunately, such publication is not legally required under the Treaty. So a country can be a state party, but not provide enough information to become a *de facto* provider.

[20] Pursuant to the ITPGRFA and the SMTA, providers of 'PGRFA under development' (improved PGRFA that incorporates multilateral system material, and that has not been released on the open commercial market) may add legal conditions to those in the SMTA, including restrictions on further transfers, royalty payments, intellectual property sharing and so on.

On the other hand, the system is not flexible enough to provide PGRFA users the ability to alter, on their own, some of the rules associated with the multilateral system discussed under design principle 2 above. Genebanks managers and breeders cannot create reciprocity rules where the ITPGRFA says (be default, through silence on the matter) that there are none. Similarly, commercial breeders and genebanks cannot agree to suspend the mandatory financial benefit sharing conditions in the SMTA.

As a creation of international law, only countries, through the mechanism of the governing body of the ITPGRFA, have the possibility of changing the formally established outer legal boundary rules of the multilateral system. However, countries are not PGRFA users; scientists, plant breeders, and farmers, hobbiests are. They have first-hand experience as participants/users of the multilateral system, but cannot participate in rule reformulation at the level of the governing body (except, perhaps, as observers at the meetings, or guest members on country delegations). This is an area of tension what frequently exists where private ordering and public ordering are mixed in the governance of a collectively managed resource. As Ostrom (2008) acknowledges, "[i]n most modern political economies, […] it is rare to find any resource systems that are governed *entirely* by participants without rules made by local, regional, national and international authorities also affecting key decisions."

Design principle 4: monitoring of compliance with should be done by appropriators of resources in the commons (or by people accountable to the appropriators).

Here again, the support that the multilateral system provides the global PGRFA commons is vulnerable to critique. Genebankers and plant breeders openly lament the fact that a number of countries with large PGRFA collections or rich in in situ diversity or well-funded crop improvement programs refuse to share those resources (Lopez-Noriega et al. 2012; Halewood et al. 2013b). Some CGIAR centres suspended their attempts to acquire new germplasm to include in their genebanks until the ITPGRFA negotiations were completed, in the hopes that the multilateral system would help providers overcome their reluctance (with respect to benefit-sharing in particular), and create transparency with respect to processes for requesting and adjudicating requests and monitoring performance overall (Halewood et al. 2013b). Nine years after it came into force many CGIAR scientists are still concerned that the Treaty has not had the hoped-for impact, and that many countries and organizations that were unwilling to share germplasm continue to be so. They are frustrated by the fact that there appears to be nothing they can do, and that the ITPGRFA is not providing an outlet for them to express concerns about their experiences.

While the genebankers, plant breeders, farmers are in the best position to observe non-compliance, they don't have ways of reporting, or initiating complaints in meaningful ways. The result is that many of the day-to-day users of the system feel disempowered and cut-off from the administration of the system of rules they are supposed to respect.

Design principle 5: sanctions are graduated, including the possibility of reducing access to the resource in question, and the sanctions are assessed by other resource users in the commons or by people accountable to them.

The ITPGRFA compliance rules do not include potentially serious sanctions, other than, indirectly, loss of country reputation. Again, it is not resource users, or anyone accountable to them who assesses and sets the sanctions, but a compliance committee made up of regional representatives and experts. Indeed, it could be argued that membership in the ITPGRFA reduces the sanctions that users have the option to invoke. For example, there is no provision in the ITPGRFA empowering a genebank to refuse to provide facilitated access to second genebank if the second has previously refused to provide facilitated access to the first. In theory, this relatively obvious form of 'tit-for-tat' sanction is replaced by the need of the national government in which genebank is located to initiate a complaint to the compliance committee.

Design principle 6: appropriators have access to low cost, efficient, local dispute resolution mechanisms.

The SMTA includes dispute resolution terms – amicable resolution, arbitration, legally binding arbitration – that are designed to be responsive to complaints that arise in day to day life of the PGRFA commons. But the SMTA is a contract only between individual providers and recipients, when they are actually providing and receiving materials. It does not apply to situations of non-compliance by should-be providers who are not taking steps to make PGRFA available through the multilateral system in the first place. Disputes over state parties' failures to provide facilitated access as envisaged by the ITPGRFA would need to be taken up pursuant to the compliance rules, which are slow, and centralized, and administered by an internationally appointed compliance committee.

Design principle 7: appropriators have a recognized minimum ability to devise their own institutions in ways that are not challenged by external, national authorities.

The multilateral system leaves considerable lee-way for how conservers and users of PGRFA organize themselves at local levels. This design principle does not highlight a significant vulnerability in terms of the support that the multilateral system provides for the PGRFA commons.

Design principle 8: for more widely dispersed resources, governance activities are organized in multiple layers of nested enterprises, allowing communal systems to be 'nested into a series of governance units the complement the organizational skills and knowledge of those involved in making collective-choice decisions in smaller units' (Ostrom 2008, 346–347).

On one hand, the multilateral system provides space, and support, for such nesting among some communities of PGRFA users. Genebankers can exchange germplasm and information amongst themselves, but at the same time, be informed by breeders as to the kinds of germplasm and information that they would find more useful. In this way, genebanks collecting, characterizing, evaluating, and pre-breeding activities can be informed by breeders. Not all genebanks work together as a single unit; instead those that are conserving germplasm of similar crops, linked to breeding programs with similar agroecological zones, will likely cooperate more closely together as a nested units. They will be linked to one another at 'higher' levels when it comes to addressing common issues, such as standards for storage, or getting financial support for conservation writ-large, or comparing experiences dealing with particular national agricultural research programs and governments.

However, as highlighted above, the multilateral system does not provide significant space or support for the local-level modular forms of PGRFA production in which farmers engage. Nor, by extension, does it support the 'nesting' of those local 'enterprises' within the broader scale modules that are better supported by the multilateral system (networked genebanks and breeders) or higher-level coordination focusing on conservation-through-use/evolution of *in situ* crop diversity. Farmers of course are free to voluntarily include germplasm in the multilateral system, or receive improved germplasm from breeders, but there is very little in place within the architecture of the multilateral system, or the ITPGRFA as a whole, to engage farmers *qua* diversity producers, and to support connections between farmers, breeders and genebanks.

The forgoing analysis suggests a number of options for reforms to the multilateral system, to make it more responsive to the incentives and disincentives of various actors, and ultimately, to achieve the objective of promoting broader participation and transparency and equity in globally-linked collective efforts to conserve, share and benefit from PGRFA.

- International organizations like the CGIAR centres, and national genebanks and other organizations within ITPGRFA member states, could be encouraged to discontinue their policies of making materials available to recipients in states that are not Treaty members.
- Member states could be required to make contributions to the multilateral system as a precondition for accessing any materials from it or receiving support from the benefit sharing fund. These contributions could take the form of a) providing accession level information about all PGRFA within the country that is in the multilateral system, b) sharing responsibilities for conserving, regenerating, characterizing, evaluating materials in the system, bearing in mind the different capacities and resources of the countries concerned.
- Along the same lines, natural and legal persons could be required to demonstrate some assumption of costs associated with the multilateral system as a condition precedent for continued facilitated access. This much at least is explicitly considered in the text of the ITPGRFA.

- The balances of costs and benefits for different participants in the multilateral system need to be revisited. For example, options for lowering transaction costs associated with the use of multilateral system material by commercial need to be investigated. One approach would be to require commercial users to make up-front user fees, thereby providing them access to all PGRFA in the multilateral system, without the felt need to monitor/record their uses of that material (to avoid benefit sharing costs that are triggered by actual incorporation of material received in new products).
- There need to be benefits to offset the perceived opportunity costs of making voluntary deposits of materials to the multilateral system. Rewarding depositors with reciprocal rights of facilitated access, as suggested above, would be one way. Another would be to devise a complementary set of incentives/benefits. One possibility would be direct a proportion of the benefit-sharing fund to depositors, or at least allow them to enter a lottery whereby a number of depositors could, by lottery, qualify for a windfall. Another possibility would be to set up a system of competitive bids for financial or in-kind support in return for deposits of 'new' PGRFA into the multilateral system. Yet another relatively simple incentive would be to publicly recognize the countries, organizations, communities, researchers or individual farmers who make deposits of PGRFA in the multilateral system. The governing body could issue certificates and the ITPGRFA website (as well as genebanks holding the deposited materials) could include information about the depositors.
- The insights drawn from principles 3–6, read together, suggest that mechanisms need to be developed to make space for participation of PGRFA users in monitoring compliance, making complaints, adjudicating complaints and devising appropriate sanctions. The compliance rules of the ITPGRFA are still under development, and there may be opportunities for some reforms in this direction. Of course, there are limitations, as highlighted above, due to the fact that the multilateral system is a creature of international law, and governed at the highest level by an intergovernmental body. Nonetheless the forgoing analysis highlights the importance of pushing further in this direction, exploring novel mechanisms and processes.

All of these reforms are focused on improving the multilateral system's institutional support for conservation and sustainable use of crop diversity. Given the critical importance of the ITPGRFA and the multilateral system, such an outcome would be extremely important, in its own right.

However, this paper has highlighted the fact that a more fully-balanced system would also provide institutional support for the development (or continued evolution) of crop genetic diversity. The most obvious solution – within the existing logic of the multilateral system – would be to get more money in the benefit sharing fund, to be used to support modular forms of innovation by farmers and breeders. Other very closely related approaches would be to substantially increase

the levels of technical and financial support, capacity building, partnerships, and higher level coordination related to on farm management of crop diversity, and plant breeding under articles of the ITPGRFA dealing with *in situ* conservation, sustainable use, farmers rights and international cooperation.

Perhaps as part of these exercises, the ITPGRFA's governing body could sponsor a bottom-up process of research and consultations with farmers groups to understand their perspectives, needs, and incentives, *vis-à-vis* active participation in the Global System, and to fashion supports that build on local institutions, practices and priorities, which promote more active engagement and partnerships with genebanks and breeders. As part of the exercise, there could be consideration of developing models of standardized terms and conditions for farmers' engagement in these partnerships, including the terms and conditions under which they would be willing to share germplasm with other farmers and organizations in the broader context of these initiatives. Such a harmonized system could be based on the underlying rights of control over the crop diversity they manage and control, just at the multilateral system as it currently exists is based on state's voluntary exercise of their underlying sovereign rights of control. Consideration of such options is beyond the scope of this paper.

5. Conclusions

This paper analyzed, through the lens of recent commons scholarship, the decades-long effort of the international community, under the auspices of the United Nations, to create an international system of PGRFA conservation and sustainable use. The paper asserts that a global PGRFA commons exists (or is coming into existence), and highlights how, as a hybrid of natural and human selection, PGRFA are distinct from both natural resources and digitalized information resources, with unique attributes and attendant social dilemmas requiring tailored institutional supports. The paper demonstrates the utility of using commons-concepts and frameworks of analysis to diagnose apparent weaknesses in the architecture of the ITPGRFA's multilateral system of access and benefit sharing. While page length has not allowed an exhaustive analysis of options for policy reforms, it has demonstrated the powerful potential of the extension of the commons narrative to provide insights into how globally-linked collective actions to generate, conserve and sustainable use PGRFA could be strengthened.

Literature cited

Andersen, R. and T. Winge. 2013. *Realising Farmers' Rights to Crop Genetic Resources: Success Stories and Best Practices*. Oxon: Routledge.

Aoki, K. 2008. *Seed Wars. Controversies and Cases on Plant Genetic Resources and Intellectual Property*. Durham: Carolina Academic Press.

Badstue, A. L. B., M. Bellon, J. Berthaud, X. Juarez, I. Rosas, A. M. Solano, and A. Ramirez. 2006. Examining the Role of Collective Action in an Informal Seed System: A Case Study from the Central Valleys of Oaxaca, Mexico. *Human Ecology* 34(2):249–273.

Badstue, A. L. B., J. Hellin, and J. Berthaud. 2012. Re-orienting Participatory Plant Breeding for Wider Impact. *African Journal of Agricultural Research* 7(4):523–533.

Bertacchini, E. 2012. Contractually-constructed Research Commons: A Critical Economic Appraisal. In *The Digital Public Domain: Foundations for an Open Culture,* eds. M. Dulong de Rosnay, and J. C. De Martin. Cambridge: OpenBookPublishers.

Bishaw, Z. and M. Turner. 2008. Linking Participatory Plant Breeding to the Seed Supply System. *Euphytica* 163(1):31–44.

Bollier, D. 2007. The Growth of the Commons Paradigm. In *Understanding Knowledge as a Commons. From Theory to Practice,* eds. C. Hess and E. Ostrom. Cambridge: MIT Press.

Byerlee, D. and H. J. Dubin. 2010. Crop Improvement in the CGIAR AS A Global Success Story of Open Access and International Collaboration. *International Journal of the Commons* 4(1):1–19.

Cabrera, J., F. Perron-Welch, and O. Rukundo. 2011. *Overview of National and Regional Measures on Access to Genetic Resources and Benefit-Sharing: Challenges and Opportunities in Implementing the Nagoya Protocol (First edition)*. Montreal: Centre for International Sustainable Development Law.

CGIAR. 2012. *In Trust for the International Community: Plan and Partnership for Managing and Sustaining CGIAR-held collections.* http://library.cgiar.org/bitstream/handle/10947/2567/Support_Center_Genebanks_proposal_2012.pdf?sequence=1 (last accessed 24 June 2013).

Crucible II Group. 2001. *Seeding Solutions. Volume 2. Options for National Laws Governing Control Over Genetic Resources and Biological Innovations.* Ottawa: International Development Research Centre. Rome: International Plant Genetic Resources Institute. Upsala: Dag Hammarskjold Foundation.

Dedeurwaerdere, T. 2010. The Contribution of Network Governance in Overcoming Frame Conflicts: Enabling Social Learning and Building Reflexive Abilities in Biodiversity Governance. In *Reflexive Governance. Redefining the Public Interest in a Pluralistic World,* eds. O. De Schutter and J. Lenoble. Oxford and Portland, Oregan: Hart Publishing.

Dedeurwaerdere, T. 2012. Design Principles of Successful Genetic-Resource Commons for Food and Agriculture. *International Journal of Ecological Economics and Statistics* 26(3):16–30.

Dedeurwaerdere, T. 2013. Institutionalizing Global Genetic Resource Commons for Food and Agriculture. In *Crop Genetic Resources as a Global Commons: Challenges in International Governance and Law,* eds. M. Halewood, I. Lopez Noriega, and S. Louafi. Oxon: Routledge.

Esquinas-Alcazar, J., A. Hilmi, and I. Lopez-Noriega. 2013. A Brief History of the Negotiations of the International Treaty on Plant Genetic Resources for Food and Agriculture. In *Crop Genetic Resources as a Global Commons: Challenges in International Governance and Law*, eds. Halewood, M., I. Lopez Noriega, and S. Louafi. Oxon: Routledge.

Falcon, W. and C. Fowler. 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.

FAO. 2010. *The Second Report on the State of the World's Plant Genetic Resources for Food and Agriculture.* Rome: FAO.

FAO. 2011. *Introduction to the International Treaty on Plant Genetic Resources for Food and Agriculture: Conservation and Sustainable Use under the International Treaty educational module.* Rome: FAO. http://www.planttreaty.org/sites/default/files/edm1_full_en.pdf (last accessed 24 June 2013).

FAO and IPGRI. 2001. *FAO/IPGRI Multi-Crop Passport Descriptors.* Rome: IPGRI. http://www.bioversityinternational.org/fileadmin/bioversity/publications/pdfs/124_FAOIPGRI_Multi-crop_passport_descriptors.pdf?cache=1371466913 (last accessed 24 June 2013).

Fowler, C. 1994. *Unnatural Selection: Technology, Politics and Plant Evolution.* Switzerland: Gordon and Breach Science Publishers.

Fowler, C. and Mooney, P. 1990. Shattering: Food, Politics, and the Loss of Genetic Diversity, University of Arizona Press, 1990, ISBN 0-8165-1181-0.

Fowler, C., M. Smale, and S. Gaiji. 2001. Unequal Exchange? Recent Transfers of Agricultural Resources and their Implications for Developing Countries. *Development Policy Review* 19(2):181–204.

Frison, C., F. Lopez, and J. T. Esquinas-Alcazar. 2011. *Plant Genetic Resources and Food Security: Stakeholder Perspectives on the International Treaty on Plant Genetic Resources for Food and Agriculture.* Oxon: Routledge. Rome: Bioversity International and FAO.

Gotor E., A. Alercia, V. Ramanatha Rao, J. Watts, and F. Caracciolo. 2008. The Scientific Information Activity of Bioversity International: The Descriptor Lists. *Genetic Resources Crop Evolution* 55(5):757–772.

Gulati, C. 2001. The "Tragedy of the Commons" in Plant Genetic Resources: The Need for a New International Regime Centered Around an International Biotechnology Patent Office. *Yale Human Rights and Development Law Journal* 4.

Halewood, M. 2010. Governing the Management and Use of Pooled Microbial Genetic Resources: Lessons from the Global Crop Commons. *International Journal of the Commons* 4(1):404–436.

Halewood, M. and K. Nnadozie. 2008. Giving Priority to the Commons: The International Treaty on Plant Genetic Resources for Food and Agriculture. In *The Future Control of Food: A Guide to International Negotiations and Rules*

on Intellectual Property, Biodiversity and Food Security, eds G. Tansey and T. Rajotte. London: Earthscan. Ottawa: International Development Research Centre.

Halewood, M., J. J. Cherfas, J. M. M. Engels, T. Hazekamp, T. Hodgkin, and J. Robinson. 2006. Farmers, Landraces, and Property Rights: Challenges to Allocating Sui Generis Intellectual Property Rights to Communities over their Varieties. In *Rights to Plant Genetic Resources and Traditional Knowledge: Basic Issues and Perspectives*, eds. S. Biber-Klemm and T. Cottier. Walingford, UK: CABI Publishing.

Halewood, M., I. Lopez Noriega, and S. Louafi. 2013a. The Global Crop Commons and Access and Benefit-Sharing Laws: Examining the Limits of International Policy Support for the Collective Pooling and Management of Plant Genetic Resources. In *Crop Genetic Resources as a Global Commons: Challenges in International Governance and Law*, eds. Halewood, M., I. Lopez Noriega, and S. Louafi. Oxon: Routledge.

Halewood, M., R. Sood, R. S. Hamilton, A. Amri, I. V. den Houwe, N, Roux, D. Dumet, J. Hanson, H. D. Upadhyaya, A. Jorge, and D. Tay. 2013b. Changing Rates of Acquisition of Plant Genetic Resources by International Genebanks: Setting the Scene to Monitor an Impact of the International Treaty. In *Crop Genetic Resources as a Global Commons: Challenges in International Governance and Law*, eds. Halewood, M., I. Lopez Noriega, and S. Louafi. Oxon: Routledge.

Hardin, G. 1968. The Tragedy of the Commons. *Science* 162:1243–1248.

Helfer, L. R. 2005. Using Intellectual Property Rights to Preserve the Global Genetic Commons: The International Treaty on Plant Genetic Resources for Food and Agriculture. In *International Public Goods and Transfer of Technology under a Globalized Intellectual Property Regime*, eds. J. H. Reichman and K. E. Maskus. Cambridge: Cambridge University Press.

Heller, M. A. 1998. The Tragedy of the Anticommons: Property in the Transition from Marx to Markets. *Harvard Law Review* 111:622.

Herdt, R. W. 1999. *Enclosing the Global Plant Genetic Commons.* Prepared for delivery at the China Center for Economic Research, 24 May 1999, based on a paper delivered at the Institute for International Studies, Stanford University, 14 January, 1999. New York: The Rockefeller Foundation. www.biotech-info.net/enclosing.pdf (last accessed 24 June 2013).

Hess, C. and E. Ostrom. 2006. A Framework for Analyzing the Microbiological Commons. *International Social Science Journal* 58:335–349.

Hess, C. and E. Ostrom, eds. 2007. *Understanding Knowledge as a Commons: From Theory to Practice.* Cambridge, MA: MIT Press.

Hodgkin, T., N. Demers, and E. Frison. 2013. The Evolving Global System of Conservation and Use of Plant Genetic Resources for Food and Agriculture: What is it, and where does the Treaty Fit in? In *Crop Genetic Resources as a Global Commons: Challenges in International Governance and Law*, eds. M. Halewood, I. Lopez Noriega, and S. Louafi. Oxon: Routledge.

Jinna, S. and S. Jungcourt. 2009. Could Access Requirements Stifle Your Research? *Science* 323:464.

Kanbur, R. 2002. *International Financial Institutions and International Public Goods: Operational Implications for the World Bank*. G-24 Discussion Paper No. 19. Geneva: United Nations Conference on Trade and Development.

Kaul, I. 2010. *Global Public Goods and Responsible Sovereignty: The Broker*. http://www.stwr.org/the-un-people-politics/collective-self-interest-global-public-goods-and-responsiblesovereignty.html (last accessed 5 June 2011).

Kingsbury, N. 2009. *Hybrid: The History and Science of Plant Breeding*. Chicago: University of Chicago Press.

Lopez-Noriega, I., G. Galluzzi, M. Halewood, R. Vernooy, E. Bertacchini, D. Gauchan, and E. Welch. 2012. *Flows Under Stress: Availability of Plant Genetic Resources in Times of Climate and Policy Change.* CCAFS Working Paper No. 18. Cali: CIAT. http://hdl.handle.net/10568/21225 (accessed 24 June 2013).

Louafi, S. 2013. Collective Action Challenges in the Implementation of the Multilateral System of The International Treaty: What Roles for the CGIAR Centres? In *Crop Genetic Resources as a Global Commons: Challenges in International Governance and Law*, eds. M. Halewood, I. Lopez Noriega, and S. Louafi. Oxon: Routledge.

Madison, M., B. Frischmann, and K. Strandburg. 2010. Constructing Commons in the Cultural Environment. *Cornell Law Review* 95:657.

Manzella, D. 2013. The Design and Mechanics of the Multilateral System of Access and Benefit Sharing. In *Crop Genetic Resources as a Global Commons: Challenges in International Governance and Law*, eds. M. Halewood, I. Lopez Noriega, and S. Louafi. Oxon: Routledge.

Meinzen-Dick, R. and P. Eyzaguirre. 2009. Non-Market Institutions for Agrobiodiversity Conservation. In *Agrobiodiversity Conservation and Economic Development*, eds. A. Kontoleon, U. Pascual, and M. Smale. Oxon: Routledge.

Moore, G. and W. Tymovski. 2005. *Explanatory Guide to the International Treaty on Plant Genetic Resources for Food and Agriculture.* IUCN Environmental Policy and Law Paper No. 57. Gland, Switzerland and Cambridge, UK: IUCN.

Narloch, U., A. Drucker, and U. Pascual. 2011. Payments for Agrobiodiversity Conservation Services for Sustained On-farm Utilization of Plant and Animal Genetic Resources. *Ecological Economics* 70(11):1837–1845.

Nijar, G. S., G. P. Fern, L. Y. Harn, and C. H. Yun. 2009. *Framework Study on Food Security and Access and Benefit-sharing for Genetic Resources for Food and Agriculture.* Background Study Paper No. 42 of the Commission on Genetic Resources for Food and Agriculture. Rome: FAO.

Ostrom, E. 1990. *Governing the Commons: The Evolution of Institutions for Collective Action*. New York: Cambridge University Press.

Ostrom, E. 2008. *The Danger of Prescribing Institutional Blueprints.* Discussion paper at "Which Governance for Which Environment? Institutions, Social

preferences, and Knowledge for Governing Environmental Issues" workshop, Institut d'Études Scientifiques de Cargès, France, 4–8 February 2008.
Pistorius, R. 1997. *Scientists, Plants and Politics: A History of Plant Genetic Movement*. Rome: International Plant Genetic Research Institute.
Richards, R. and G. Ruivenkamp. 1997. *Seeds and Survival: Crop Genetic Resources in War and Reconstruction in Africa.* Rome: International Plant Genetic Resources Institute.
Reid, W. V. 1993. *Biodiversity Prospecting: Using Genetic Resources for Sustainable Development*. Washington, DC: World Resources Institute.
Ruiz, M. and R. Vernooy. 2012. *The Custodians of Biodiversity: Sharing Access to and Benefits of Genetic Resources.* Ottawa: International Development Research Centre. Oxon: Earthscan.
Safrin, S. 2004. Hyperownership in a Time of Biotechnological Promise: The International Conflict to Control the Building Blocks of Life. *American Journal of International Law* 98:641.
Santilli, J. 2012. *Agrobiodiversity and the Law*. *Regulating Genetic Resources, Food Security and Cultural* Diversity. London: Routledge.
Sedjo, R. 1992. Property Rights, Genetic Resources and Biotechnological Change. *Journal of Law and Economics* 35(1):199–213.
Swanson, T. 2013. Technological Change and Diffusion in Agricultural Development. In *Intellectual Property Rights: Legal and Economic Challenges for Development*, eds. Cimoli Mario et al. Oxford: Oxford University Press.
System-wide Genetic Resources Programme (SGRP). 2011. CGIAR Centres' experience with the implementation of their Agreements with the Treaty's Governing Body, with particular reference to the use of the SMTA for Annex 1 and non-Annex 1 materials. IT/GB-4/11/Inf. 5. Rome: FAO. http://www.itpgrfa.net/International/sites/default/files/gb4i05e.pdf.
Tansey G. and T. Rajotte, eds. 2008. *The Future Control of Food: A Guide to International Negotiations and Rules on Intellectual Property, Biodiversity and Food Security,* London: Earthscan. Ottawa: International Development Research Centre.
Tsygaye, B. and T. Berg. 2007. Genetic Erosion of Ethiopian Tetraploid Wheat Landraces in Eastern Shewa, Central Ethiopia. *Genetic Resources and Crop Evolution* 54:715–726.
United Nations Environment Programme (UNEP). 2006. *Outcomes and Recommendations of the Meeting of 'Biodiversity: The Megascience in Focus'*, Doc. UNEP/CBD/COP/8/INF/46, http://www.cbd.int/doc/meetings/cop/cop-08/information/cop-08-inf-46-en.pdf (last accessed 24 June 2013).
Van den Wouw, M., C. Kik, T. van Hintum, R. van Treuren, and B. Visser. 2009. Genetic Erosion in Crops: Concept, Research Results and Challenges. *Plant Genetic Resources Characterization and Utilization* 8(1):1–15.
Van Etten, J. 2011. Crowdsourcing Crop Improvement in Sub-Saharan Africa: A Proposal for a Scalable and Inclusive Approach to Food Security. *IDS Bulletin*

42(4):102–110. http://dx.doi.org/10.1111/j.1759-5436.2011.00240.x (last accessed 24 June 2013).

Wang, F. 2013. Flows of Crop germplasm Resources into and Out of China. In *Crop Genetic Resources as a Global Commons: Challenges in International Law and Governance*, eds. M. Halewood, I. López Noriega, and S. Louafi. London: Routledge.

Wilkes, G. H. 1988. Plant Genetic Resources Over Ten Thousand Years: From a Handful of Seed to the Crop Specific Mega Genebank. In *1988 Seeds and Sovereignty: The Use and Control of Plant Genetic Resources,* ed. Kloppenberg, Jack. Chapel NC: Duke University Press.