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Improving the global exchange of germplasm for crop breeding

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1 Introduction

Different norms, rules and practices (referred as institutions) organize the exchange of germplasm to address broader global challenges such as advancement of science and innovation, food security, sustainable agriculture and global equity. Some of these institutions are now embedded in various treaties and national regulations. This chapter demonstrates that these regulations are not as successful as they could be because they only partially integrate the complexity of the germplasm exchange environment. In order to better understand how germplasm exchange could be improved, it is important to go beyond the often-employed legalistic approach to examine the social contexts in which exchange takes place.

Increasing the mobilization of germplasm needed to address new global challenges requires collaborative initiatives made up of multiple actors. Yet, these global initiatives are often highly complex. For example, in research teams that include individuals who are close friends, germplasm exchange might be based on long-term obligations and norms of reciprocity, while in other newer teams, exchange must rely on explicit negotiated agreements. Additionally, exchange can occur among a set of actors organized as a club that concentrates resources, sets rules and provides access only to members. But it can also operate in open communities with a fluid membership that can set

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the conditions of exchange depending on the context. Exchange of germplasm can occur within homogenous groups of actors who share similar objectives, or within heterogeneous groups where substantive differences in capacity, knowledge and objectives lead to imbalances in learning, reputational and financial outcomes among actors. Importantly, the norms, rules and practices pertaining to property rights, benefit sharing and openness can also dictate collaboration structures that are more or less homogeneous, closed or equitable.

These examples demonstrate just few ways in which the policies are embedded in the social context of germplasm exchange can vary. Nevertheless, how policies are embedded in collaborative initiatives will likely significantly affect the exchange of germplasm by, for example, increasing trust or reducing transaction costs. This chapter aims to increase understanding about collaboration dynamics such that new approaches can reduce the 'institutional misalignment' between policies and practices to improve mobilization of genetic diversity across heterogeneous actors and contexts. In particular, we ask: How do collaborative teams manage germplasm access, exchange and use? What factors explain why exchange is facilitated or blocked in various collaborative settings? What biases frame germplasm exchange and what are the consequences?

This chapter is based on a literature review and empirical work conducted by the authors in various collaborative contexts and for various crops and resources. It is hoped that a better understanding of these factors could help the policy community to design more effective rules and regulations and the germplasm user community to develop institutions that improve mobilization of genetic diversity. The first section describes the importance of germplasm exchange and the central role of collaboration. The second section describes a framework that describes how different factors may impact exchange of germplasm. The third section examines the consequences of not including these factors and discusses possible ways forward.

2 Exchange of germplasm for crop breeding: what are we talking about?

The use of genetic diversity in crop breeding is an essential component of improved agricultural productivity through the development of new varieties. These new varieties are very often developed by reshuffling existing alleles within a subset of well-performing genetic material, as it is in general a costly and time-consuming process to develop less-advanced material to attain higher performance levels. However, in the context of rapidly changing environments, recourse to the genetic variability of landraces and/or crop wild relatives is often required. This germplasm can be used to introduce specific traits into breeding populations or for base-broadening activities, which usually require long time and efforts.

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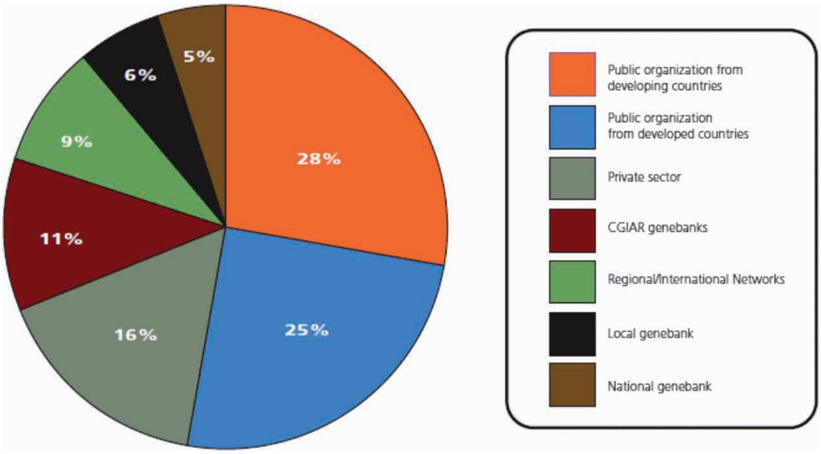

Figure 1 Sources of germplasm used by breeders in national breeding programs. Source: Food and Agriculture Organization of the United Nations. Reproduced with permission.

Breeders access germplasm from multiple sources: their own working collections, other germplasm pools managed by breeders, publicly available varieties, genebank collections, farmers' fields and the market (commercial seed and vegetative propagating material). The relative proportion of these different sources is difficult to determine as it may greatly vary depending on the crops, the type of breeder and regulatory considerations. One survey of breeders working in national programs in developing countries conducted in 2008 through the national information sharing mechanism on Global Plan of Action implementation of the FAO (2010, see Fig. 1) found that the main sources are public organizations[1] from developing or developed countries followed by private sector and genebanks from the Consultative Group of International Agronomic Research Centers (CGIAR). This diversity of sources is supported by other studies that have shown similar levels of distribution (Welch et al., 2017).

Flow of germplasm accessions from genebanks has been estimated to be several tens of thousands of transfers annually (FAO, 2010). However, most of that exchange is between genebanks for conservation and characterization purposes (Dulloo et al., 2010). Even though genebanks aim to facilitate exchange of material to advance research and breeding, there is little evidence that the material held in these collections is being used productively by breeding programs or farmers (Louafi and Manzella, 2018). From the perspective of breeders, only about one-fifth to one quarter of germplasm used in research comes from genebanks.

1 Within the category 'public organization', the survey does not differentiate whether the material comes from genebank or breeder's working collections.

The modalities for the exchange of germplasm depend on the crop and on the type of exchange partners. Over the years, many divergent views about ownership, control and access to germplasm have been expressed in varied policy forums (Tsoumani, 2020). Broadly speaking, starting from a common heritage of mankind, the Convention on Biological Diversity has introduced the concept of sovereign rights while recognizing some collective rights to indigenous people and local communities over their genetic resources and associated knowledge and know-how. The International Treaty on Plant Genetic Resources for Food and Agriculture (ITPGFRA) has developed a global public good approach while recognizing farmers' rights and intellectual property rights, and the International Union for the Protection of New Varieties of Plants (UPOV) and the World Trade Organization (WTO) recognized the granting of private rights through intellectual property rights[2]. Consequently, different approaches about germplasm ownership, control and access coexist, both in policy fora and are undertaken in practice by different groups.

International and national rules, regulations and laws have established increasing levels of control over the access, exchange and use of biological materials (Welch et al., 2013; Bretting, 2007; Sebastian and Payumo, 2006, ten Kate, 2002; Laird et al., 2020). These new institutions introduce new access and exchange procedures and obligations for managing and monitoring transfers to third parties such as memoranda of agreement, prior informed consent and material transfer agreements. The consequence of this proliferation of formal institutional norms is that breeders can no longer act according to their own set of preferred rules and norms when accessing genetic material. Since the signature of the Convention of Biological Diversity in Rio in 1992, they are increasingly expected to enter in complex, long and uncertain negotiation processes that go well beyond their own usual norms and practices. Although the regulations are intended to establish norms that facilitate international exchange and stimulate effective use of resources to solve complex problems while protecting the rights of multiple different stakeholders, they also increase transaction costs.

In the food and agriculture sector, the Multilateral System of Access and Benefit Sharing (MLS) of the ITPGRFA is a global expression of a collective management system for common pooling of genetic resources internationally (Girard & Frison, 2018; Louafi, 2012). Historically, crops and plant genetic resources (PGR) have been widely exchanged throughout the world, and many people in many different places have contributed in one way or another

2 The agricultural sector is characterized by the coexistence of at least two intellectual property systems: the patent system and the plant variety protection system. These two systems are harmonized at the international level by the World Trade Organization's (WTO) Trade-Related Intellectual Property Agreements (TRIPS) and the World Intellectual Property Organization's (WIPO's) affiliated UPOV Agreement. This later aims to find a balance between protection of innovations and free access to germplasm through the breeder's exemption which allows the subsequent use of an innovation protected by a plant variety certificate (PVP) for research purposes (Dutfield, 2011).

to the development of today's crop genetic diversity (Schloen et al., 2011). Consequently, current crop production relies significantly on the use of once-exotic species and all countries depend in part on genetic diversity that originated elsewhere (Khoury et al., 2016). The MLS is a reflection and recognition of this strong interdependency of countries and stakeholders regarding the material they hold. However, the extent to which the MLS has successfully enabled global exchange and use of agricultural genetic resources is unclear.

In part this is because the MLS and other global institutions such as the CBD often ignore the complex social context in which these legal and regulatory solutions are applied. The legal (laws, regulations, rules and contracts) and market-based (royalties from IPRs and benefit sharing agreements) policy approaches fit poorly with the broader set of motivations underlying movement of germplasm such as to increase knowledge, conserve biodiversity, combat climate change or reduce hunger. Germplasm exchange is also embedded in reputational, verification and reciprocity norms. Indeed, it has been shown that replicability of scientific findings (verifiability) and collegial expectations of two-way flow of resources over time (reciprocity) are important motivations for the conservation and exchange of genetic resources (Dedeurwaerdere et al., 2013). Additionally, germplasm exchange is seldom isolated from other shared resources such as technology, information, assistance and advice. Individual transactions are often part of longer term and broader collaboration relationship in which this broad set of resources is shared over time. These motivations and realities shape the exchange behavior of breeders and other researchers as much if not more than market and other rationales underlying many existing global policy solutions.

To provide evidence for the complexities of the exchange process, we present findings from a survey of FAO/CGRFA National focal points and GRFA stakeholders conducted by Louafi and Welch in 2017 for the Commission on Genetic Resources for Food and Agriculture (Louafi and Welch, 2018). Survey respondents were asked to indicate if their exchanges were generally embedded within a larger collaborative relationship or agreement. The results show that it is most often the case that respondents exchange as part of an established collaborative relationship. For example, in the plant sector, only 16% of exchanges are not part of an existing collaborative relationship (see Fig. 2). This is true for domestic and foreign exchanges alike and also across country groupings (OECD/non-OECD) and subsectors (Figs. 3 and 4).

To a large extent, these collaborative initiatives could be viewed as problem-oriented organizations designed to pool resources and knowledge, reduce transaction costs and enhance cooperation among a wide range of actors across different locations to create new knowledge and innovations while maximizing the benefits to all. Shaping these collaborative structures in a way that effectively organizes the complex institutional environment for germplasm access exchange and use could complement (or even sometimes substitute to) legal instruments or monetary incentives. The next section describes an analytical framework that provides a way to approach the substantial variations observed in these collaboration goals, structures and processes.

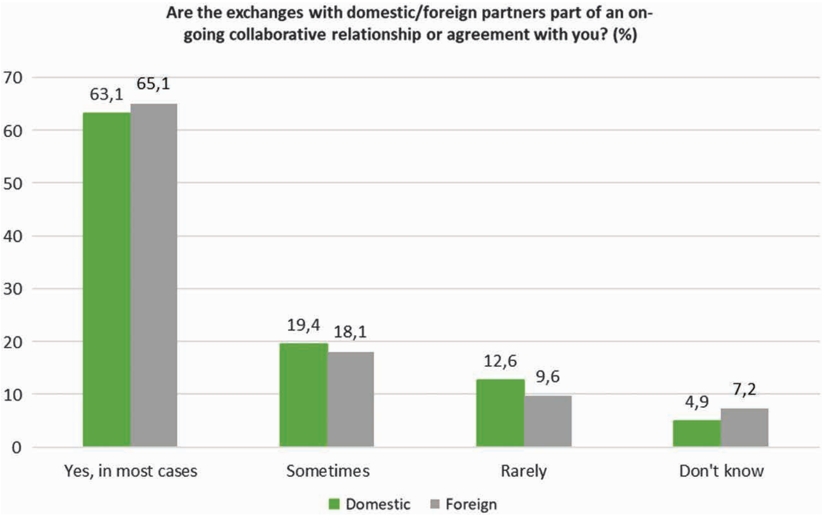

Figure 2 Collaboration pattern with domestic and foreign partners. Source: Food and Agriculture Organization of the United Nations. Reproduced with permission.

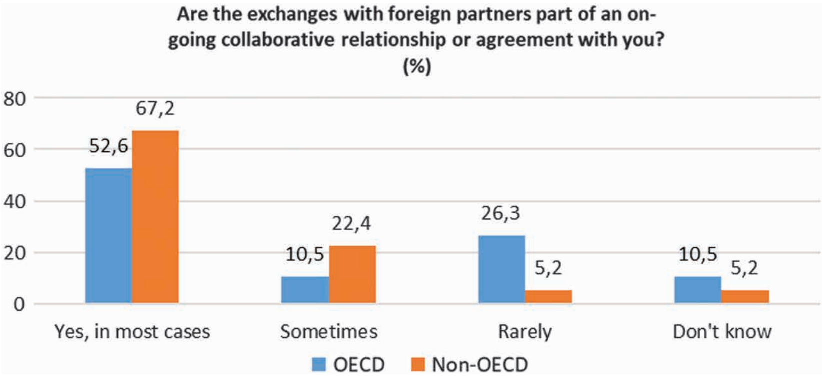

Figure 3 Collaboration pattern with foreign partners (OECD/non-OECD). Source: Food and Agriculture Organization of the United Nations. Reproduced with permission.

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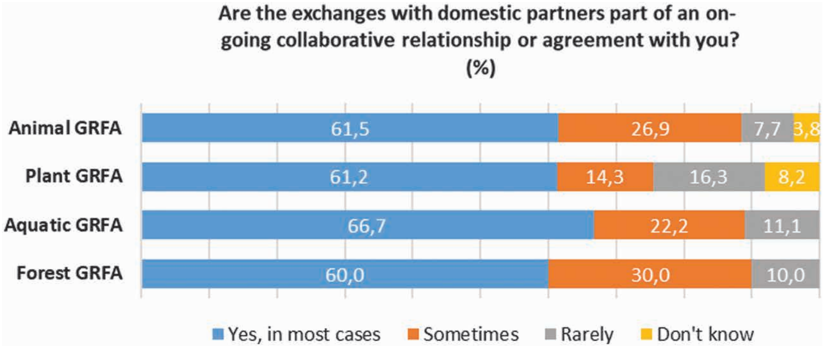

Figure 4 Collaboration pattern with domestic partners by subsectors. Source: Food and Agriculture Organization of the United Nations. Reproduced with permission.

3 Opening the black box of collaborations in plant genetic resources for food and agriculture

Collaboration implies a sustained relationship that involves a flow of different types of resources (technical, organizational, knowledge) among individuals and organizations with different capacities, objectives and perspectives about, for example, openness of science, equity and reciprocity. Because germplasm exchange between two or more entities often takes place within a collaborative context and includes multiple transactions over time, we propose an analytical framework that considers characteristics of resources, institutions, organizations, relationships and individual actors as determinants of germplasm exchange. Aspects of each of these factors can help explain why sometimes exchange is facilitated or blocked. Ultimately, a better understanding of these factors could help the policy community to design more effective rules and regulations. The following sections address each factor in turn.

3.1 Resources

Characteristics of resources affect exchange. First, not all species are equally valuable or equally available. Some species have higher value due to high market demand for new varieties (staple or major crops), low availability of genetic diversity or difficult conservation or complex reproduction. Besides, even different materials of same species are not equally valuable or equally available. For example, landraces with unique alleles or combinations of alleles may be more valuable and therefore more difficult to transfer or require substantial compensation to access. The ITPGRFA recognizes that all material is not equal. For example, the so-called 'Plant Genetic Resources for Food and Agriculture under Development' category gives to the provider the discretion to add additional terms and conditions to the standard material transfer agreement, such as restrictions on further distribution and use[3].

Additionally, germplasm is often only one of many resources used or exchanged through collaboration. Collaboration involves the pooling and management of multiple types of resources both as inputs and as outputs produced by research. A first set of resources includes genetic materials such as seeds or other propagation materials, plant material or DNA, genomic or phenotypic data, and other information associated with the material. Other resources play an important role in collaboration. These are technical resources such as equipment, software, scientific and technical human capital resources, organizational or administrative resources, such as conflict resolution services, institutional and governance resources such as material sharing standards, and social capital available through relations between individual collaborators.

Multiple dependencies exist among resources within a collaboration. The value of one particular resource may depend on its relationship to other shared resources. Additionally, new resources may be produced from combinations of different shared resource (Frischmann et al., 2014). This is for example the case of: the sharing of research results and information derived from the use of germplasm; the provision of access to technologies necessary for enhanced germplasm use; the creation of training and capacity building opportunities for increasing breeding capacities.

3.2 Institutions

Facilitating germplasm exchange is justified by the need to address higher societal goals such as food security and sustainable agriculture. Despite broad support of these goals by the global agricultural community, regulatory regimes and societal norms that govern germplasm exchange are fragmented and built upon different and often conflicting logics. The international treaty is one example of a regulatory regime that places high importance on the collective and equity logics that support germplasm exchange. These two logics value effective use of shared resources and reciprocity in order to strengthen the long-term cooperative capacities of stakeholders.

The collective logic stems from the high interdependence[4] on plant germplasm among countries that necessitates pooling of material and global collaboration to achieve global social objectives. The equity logic stems from the desire to accommodate and address differences in values, power and capacity across countries and stakeholders. Practically speaking, germplasm is

3 ITPGRFA, Article 12.3(e); SMTA, Article 6.5.

4 Interdependence is defined as when outcomes are based on a combination of parties' efforts. Interdependence involves mutual and complementary arrangements, reduces risks and encourages cooperation (Molm, 2003).

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held, valued and used by a broad range of stakeholders around the world. Each plays an indispensable role in conserving germplasm and making it available for use. Yet, no single actor has the capacity to conserve and provide all potentially useful germplasm. At the same time, not all countries or actors have the same ability to benefit from germplasm use. Tremendous inequalities exist in terms of human capacity, access to technology and access to information necessary to effectively manage and use germplasm.

Collaboration structures and the resources within them are governed by other logics besides the collective and equity ones. Multiple logics such as the conservation, safety, market, academic or the ethics logics underlie regulations, norms and standards that focus on some aspects of the material and some specific activities. Because diverse institutional logics are supported and emphasized by different stakeholders, conflicts can arise that may create barriers to access or increase transaction costs of germplasm exchange and use (Welch et al., 2019; López Noriega et al., 2013). In this context of germplasm exchange – conflicting logics, multiple stakeholders and fragmented governance – the context of has changed over time. The post-WWII era in which access to germplasm was centralized through genebanks and provided mainly on an informal basis has gone. It has been replaced by a more fragmented and opportunistic environment in which diverse groups across different countries exchange multiple resources under different conditions.

3.3 Organizations

Data and material come from a range of different mid-level organizations (e.g. teams, funded projects, and consortia), agreements and arrangements that provide varying levels of access to and discretion over exchange and use of germplasm for research (Reichman et al., 2016; Ulhir and Schröder, 2007).

In the genetic diversity and breeding sector, structure and composition of collaborative initiatives can take several forms: closely tied and homogenous teams, communities of practice, research organizations (NARS, universities, institutes, companies), inter-organizational initiatives (public-private partnerships, network, consortia), global collaborative initiatives of widely geographically spread organizations (programs, funded projects). Organizations may also differ in their level of specialization and concentration of resources, in whether the decision and control structure is hierarchical or distributed, and in the amount of discretion and control entities have for distribution, monitoring and tracking of exchange and use.

Collaboration and exchange complexity arises because individuals and organizations belong simultaneously to several collaborative initiatives each with its own goals, incentives and organizations. Management decisions taken at the level of these organizations could be collectively discussed and adapted to respond to the needs and goals of the collective. As such, they offer some flexibility in prioritizing institutional logics, interpreting policy rules and designing governance systems.

3.4 Relations

Flows of resource inputs to research occur within exchange networks that connect recipients and providers through different types of relationships, some of which are stronger and more trusted than others. Researchers who conduct research on a particular species are typically colleagues or friends: they usually know each other well. With the exception of few major crops, crop networks are often relatively small and the number of people engaged in germplasm exchange within these communities is even smaller. Collaborators within these communities may have the same disciplinary background, been trained at the same university, worked in the same organization or attended the same conferences.

Germplasm exchange is affected by the structure, composition and relations in collaboration and resource exchange networks, which may be composed of individuals, organizations or combinations of the two. Network structure includes network size and connectedness. For example, findings from a collaboration network analysis in cacao genetic resources reveals a cohesive community connected through central actors that have different and complementary profiles as resource and service providers (Louafi et al., 2017). In many cases, genebanks play a central role in the global collaborative structure because they are key providers, sometimes primary providers, of the germplasm. Network connectivity (e.g. density) can increase joint action, avoid resource conflicts and facilitate the development of common resource regulations (Bodin and Crona, 2009). In a global context, community building activities that generate greater connectedness can increase the exchange of information, knowledge and resources across diverse individuals and organizations (Fusi et al., 2018). For instance, the Association on the Study and Information on Coffee (ASIC) organizes a conference every two years for the global coffee research and innovation community. This conference offers the opportunity for information and expertise exchange but also for the development of greater global connectivity among coffee researchers. Similar association or initiatives exist for all kind of crops.

Collaboration and resource networks are composed of different types of actors that have different of capacities, backgrounds, types of expertise, perceptions and interests. Compositional diversity in the network will affect network cohesion such that divergent network composition would work against global collaboration creating instead (Louafi et al., 2017): (i) regional and biological divides, due to numerous factors such as regional specificity of pest and diseases, quality and flavor driving different markets, the existence of regional/national regulatory frameworks, or simply geographical distances; (ii) disciplinary divides and more particularly, the persistent division between conservation/diversity characterization, genomics, breeding and bio-informatics, each of which values different types of genetic material and associated information ; and (iii) market divides, specialty/high premium versus the bulk markets and, more generally, the private company strategies with regard to genetic resources-related research and partnerships.

Similarly, tie strength, measured as the frequency of interaction, duration of acquaintance, or emotional closeness (Wellmann, 1999; Krackhardt, 1992), is often associated with greater trust, longer term reciprocity and mutual confiding. These are important qualities of a resource exchange network. Individuals are more willing to exchange germplasm with close colleagues and friends due to higher trust and norms of reciprocity (Fusi et al., 2018; Cook and Whitmeyer, 1992). In fact, close colleagues may be more willing to exchange resources, even when the formal access is restricted by national regulations or industry competition (Shibayama and Baba, 2011). Similarly, researchers may be more likely to provide returns from the use of resources from close colleagues in order to maintain and build stronger collaborative relationships.

In sum, collaboration patterns can predict social processes, such as germplasm exchange and governance outcomes, including adaptive capacity. This section focused on network structure and composition. However, it is also equally relevant to assess attitudes and behavior at the level of the nodes, including the individual actors.

3.5 Actors

Attributes of actors may affect the way they engage in collaboration with each other and more specifically, their willingness to share resources. Attributes such as rank, discipline, sector and size of an individual's data or material collection, are likely to affect willingness to share or ability to easily access germplasm. In the context of genomic epidemiology network, Chokshi et al. (2006) have shown that lack of trust about what others will do with the data, discomfort with transparency, high costs of collection, first rights of primary researchers and students on the project, age, discipline and attitudes toward open science are all factors that explain data sharing.

Stakeholder groups holding and using germplasm include farmers, communities, associations and producers at the local level, public institutions at national and international levels, and private enterprises and farmers' and breeders' cooperatives at national and international levels as well as networks at local, national, regional and international level. They all fulfill different tasks in a complex network of actors, and are to various degrees involved in the maintenance and conservation of genetic diversity, the exchange and direct use of genetic material, and research and product development based upon genetic resources.

Individual attitudes toward germplasm sharing are formed through a socialization process and the incentive structure that conditions activity. Divergent of attitudes toward openness are usually observed between individuals from infrastructure science (e.g. genebanks), discovery science (e.g. breeders, geneticists) and bio-informatics. By contrast, scientists who are trained in research labs where there is a strong culture of 'open science', teamwork and sharing might be more likely to engage in resource sharing practices that promote this approach.

Similarly, the usual social and cultural norms of mutual assistance, reciprocity and solidarity associated to agrarian societies tend to encourage the free flow of seeds and germplasm between farmers or with farmers and other actors. In reality, many nuances have been introduced by several empirical studies to this perceived frictionless circulation of planting material (see Coomes et al., 2015 for a review of this literature). Findings from Kiptot et al. (2006) and Kawa et al. (2013) (cited by Coomes et al., 2015) showed, for example, that farmers with leadership positions and greater ethnobotanical knowledge (but not necessarily higher cultivar diversity) are found to be more likely to give out seeds than others.

4 The germplasm exchange fallacies

The different dimensions described in the previous section recognize a complex context of germplasm exchange in which tensions may arise between conflicting institutional logics, norms and values that are being expressed differently depending on the social and organizational context of exchange and the broader resource system in which germplasm is embedded.

This complex picture reveals at least three biases that limit germplasm exchange for research and breeding:

1 *Single-logic bias*. The existing regulatory framework focuses almost exclusively on access to germplasm based on legal status and monetary incentives to protect innovation or share benefits derived from germplasm. Such an approach fails to include other equally important determinants of exchange.
2 *Single-resource bias*. The exchange of germplasm tends to be addressed in isolation from other resources. Such an approach fails to maintain the integrity of the resource system in which germplasm is embedded and fails to account for the functional interdependence between the separate elements of the resource system.

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3 *Single-transactional bias*. Germplasm exchange tends to be approached as a single transaction that occurs between individual actors or organizations. Such approach fails to account for the broader social environment within which mutually beneficial relationships build norms of trust and reciprocity in collaboration and resource exchange networks.

4.1 The single-logic bias

The 'problem' of germplasm management has been traditionally framed at the global level as a conservation-based concern for crop diversity erosion linked to the genetic homogenization induced by the development of industrial forms of agriculture. In response, effort has sought to coordinate conservation activities to collect and conserve germplasm in ex situ-centralized genebanks and simultaneously stimulate use in research and breeding programs. Because regulatory frameworks have been designed based on conservation and innovation logics, they rely on technical solutions (ex situ conservation) and incentive structures (monetary through the granting of IPR to recoup the investment made in research and breeding) relevant for a small range of resources, actors and motivations. This way of framing the problem and designing solutions does not consider how and why people engage in producing more diverse new germplasm. It also ignores inequality in the capacity to use and produce diversity for their different needs and interests.

To be fair, some space has been carved out in existing policy frameworks that attempt to reconcile different institutional logics. As mentionned earlier, the Treaty recognizes specifically the collective dimension of innovation in breeding and the need for coordination between different communities. The Treaty recognizes 'that plant genetic resources for food and agriculture are a common concern of all countries' such that all countries largely depend on plant genetic resources for food and agriculture that originated elsewhere. The MLS of ABS is the expression of this need for collective action at the global level to manage a pool of common but distributed resources across multiples countries and entities (Louafi and Bhatti, 2012). It comprises a large number of plant genetic resources held by varied entities throughout the world, and aims 'both to facilitate access to plant genetic resources for food and agriculture, and to share, in a fair and equitable way, the benefits arising from the utilization of these resources, on a complementary and mutually reinforcing basis'.[5]

The facilitation of access and sharing of benefits is managed by agreeing collectively on standard conditions of access and benefit-sharing for all material included in the MLS and on establishing a Global Benefit Sharing Fund, which

5 Article 11.1 of Treaty.

disbursement is made according to procedures and priorities also agreed collectively. Besides, the pooling of benefits enables the realization of *collective* benefits independently of whether economic return is generated through the development of a particular variety or technology. Increasing knowledge, information and data produced through phenotyping, genotyping or evaluation are benefits that can be widely shared as many countries make use of the same species, establish similar production systems and struggle with the same biotic and abiotic stressors (Schloen et al., 2011). The Treaty also addresses equity beyond simply sharing of monetary benefits. It recognizes non-monetary benefits as important elements in the Treaty context to enable less-endowed actors to use the genetic diversity (i.e. have access to the benefit of 'facilitated access').

Even though the Treaty is to date the global framework that has managed to integrate the multiple logics, the process of Treaty implementation and its political dynamics still tend to often prioritize the legal and monetary logics over equity and collective logics. As a result, actors – individuals, groups, teams and countries – have engaged the Treaty opportunistically vis-à-vis other existing frameworks such as the UPOV and the Nagoya Protocol. This lack of shared commitment has negatively impacted the legal solution set up by the Treaty to facilitate exchange for research and innovation. Ultimately, no global framework has succeeded in integrating multiple logics in a functional way perceived as legitimate by all countries.

4.2 The single-resource bias

The more comprehensive picture provided by our framework also focuses attention on maintaining the integrity and functional interdependence of the resource system in which germplasm is embedded and avoiding the single resource bias that tends to structure the regulatory and legal approaches to facilitating germplasm exchange.

Resources may be subject to different property regimes across or within countries. It is indeed important to note that some resources may not be necessarily under the full control of the actual holder and that the regulatory and institutional controls are not necessarily uniform across countries. In this context, pooling various resources and agreeing on common rules within the collaboration provides one way to manage the complexity inherent to this system of interdependent resources (Kamau and Winter, 2013). Thus, facilitating germplasm exchange requires managing the resource system in which germplasm, as one resource unit, is embedded.

The Treaty does recognize information exchange, capacity building and access to technology for the good functioning of the multilateral system (as part of the so-called non-monetary benefit sharing components). However, no real operational mechanisms are in place to manage these components and

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germplasm in an integrated way. This gives the impression that the monetary and benefit sharing components can be managed separately or that they are secondary to germplasm, the main resource that the Treaty aims to regulate. Yet joint management is essential for both function and equity: facilitated access is only made possible as long as the necessary capacities, information or technology are also available. Making information available and strengthening the technical, knowledge and financial capacities of the various members is essential to increase the use of the material and information pooled (i.e. sharing the benefits of the facilitated access to germplasm offered by the Treaty).

4.3 The transaction bias

Germplasm exchange takes place within a complex organizational and relational context that determines how policies will be ultimately implemented. The production, management and exchange of germplasm is an inherently social phenomenon, taking place over a wide range of scales and within a complex, overlapping variety of supply channels. Organizations operate as hubs for organizing the complex and sometimes conflicting institutional environment related to germplasm. The level of internalization and integration of the different logics and policy constraints may vary greatly depending on the organization or network. The process of forging mutually beneficial relationships over a long period of time through repeated interactions and ongoing collaboration could be instrumental in facilitating exchange. Those relationships provide the social structure through which actors exchange materials, set expectations for compensation and manage regulatory constraints. López Noriega et al. (2013) noted that 'larger research projects, in which transfers of genetic materials are supportive of broader research objectives, can be instrumental. Scientists involved in international germplasm improvement networks noted that long-term co-operative links (for example, through the INGER network led by the IRRI) are less affected by the reduced willingness of countries to share germplasm'.

A typology of the various organizational models in response to the multiplicity of institutional logics and the constraints on access is difficult to draw given the complexity, interlinked and context-specific nature of collaborative initiatives in plant genetic resources (Fusi et al., 2018). From a broad perspective and from looking only at the way the trade-off between efficiency and inclusiveness is managed, initiatives tend to differ along a spectrum between the following two extremes:

- *Club approach*. A club is composed of a relatively homogeneous set of members who agree to centralized governance structures that set formal rules on access to and use of germplasm. High connectivity can facilitate exchange among members but lead to network closure that constrains exchange and collaboration between members and non-members, and with other clubs. This can lead to an overall decrease in the circulation of genetic diversity.

- *Inclusive approach*. An inclusive model encourages distributed organizational forms and capacities through a web of managed ties across which resources flow according to *ad hoc* procedures and rules, and greater informality based on trust and reciprocity. Actors invest in the technical capacity needed to ensure effective use of shared resources by connected stakeholder groups and countries that are less endowed. This model favors a stronger approach to ensuring an open system while managing interdependencies and creating greater recognition across all actors that exchange, research and innovation take place on equitable terms. The social diversity gathered will likely lead to more genetic diversity exchanged. Such model requires energetic and professional management to establish and sustain trust-building mechanisms and minimize opportunistic behavior.

Of course, these two ideal-type models are seldom found in reality. Eventually, the way the trade-offs and tensions are managed depends on joint commitment and management, which ultimately reconciles the fragmented institutional landscape.

5 Conclusion

This chapter offers a renewed perspective on the issue of germplasm exchange. Based on the increasing number of empirical studies, it describes the reasons why facilitation of exchange cannot be confined to a simple set of legal access rules. By developing an analytical framework that includes several dimensions beyond regulation, it sheds some light on the fallacies and biases surrounding the debate on the enhancement of germplasm exchange. It creates the foundation for a more comprehensive approach to governance of germplasm that recognizes the collaborative context and acts upon the relationship between germplasm and the diversity of institutional logics, germplasm and its resource system, and germplasm and its social environment.

Facilitating germplasm exchange starts by first recognizing that difficulties arise from the reconciliation of various institutional logics in relation to germplasm management, use and exchange. It also requires recognition the nature of the germplasm itself: human-made and shaped by the actors and their interactions. The multiplex interdependences across various resources must be carefully managed. Finally, it also requires action at the organizational and relational levels to manage regulatory constraints, reduce transaction costs and set expectations across members.

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Governance systems that recognize and address these complexities is particularly important in a context in which facilitating germplasm exchange is no longer devoted solely to breeding for yield improvement, but must also address the diversity of objectives depending on specific contexts and actors' needs and capacities. Achieving more sustainable agriculture requires not only more improved varieties, but also recognizing different production models and greater investment in human capacity across a more widely distributed innovation system that can address specific needs.

6 Where to look for further information

A good general overview to the International Treaty on Plant Genetic Resources for Food and Agriculture is Halewood, M., Lopez Noriega, I. and Louafi, S. (Eds), (2012), *Crop Genetic Resources as a Global Commons*. Earthscan Publications, London.

Two more recent reference books include:

- Tsioumani, E. (2020). *Fair and Equitable Benefit-Sharing in Agriculture: Reinventing Agrarian Justice* (p. 186). Taylor & Francis.
- Girard, F., & Frison, C. (Eds.). (2018). *The Commons, Plant Breeding and Agricultural Research: Challenges for Food Security and Agrobiodiversity*. Routledge.

More institutional resources about access and benefit sharing could be find at the following organizations:

- Convention on Biological Diversity, The access and benefit-sharing clearing-house: https://absch.cbd.int.
- International Treaty on Plant Genetic Resources for Food and agriculture: http://www.fao.org/plant-treaty/en/.
- UNDP/GEF, GLOBAL ABS Community: https://community.abs-sustainabledevelopment.net.
- IUCN, An explanatory guide to the Nagoya Protocol on access and benefit-sharing: https://www.iucn.org/content/explanatory-guide-nagoya-protocol-access-and-benefit-sharing.
- South Center: Genetic resources and TK: https://www.southcentre.int/category/issues/innovation-development/genetic-resources-tk/.
- The ABS Capacity Development Initiative, http://www.abs-initiative.info.
- Alliance Bioversity International and CIAT: https://www.bioversityinternational.org/research-portfolio/policies-for-plant-diversity-management/.

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