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On the International Flow of Plant Genetic Resources

Forecasting the Impacts of an Evolving Legal Framework on CGIAR Genebanks

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Introduction

The CGIAR Research Programme on Policies, Institutions and Markets (PIM) has commissioned the Development Impact Unit (DIU) of Bioversity International the conduction of an Impact Assessment (IA) study on the revision of the Standard Material Transfer Agreement (SMTA) of the Multilateral System for Benefit Sharing (MLS-BS), now under discussion within the International Treaty on Plant Genetic Resources for Food and Agriculture (ITPGRFA) – or, more generally, the Plant Treaty. The SMTA revision represents the current effort of the Treaty Governing Body (GB) to increase incentives for users, in particular the seed industry, to access plant genenetic resources (PGR) under the MLS, enhancing the benefits distribution. The general distrust has been, in fact, the cause of a long history of implementation difficulties since the Treaty establishment in 2004. In this context, it is the CGIAR genebanks which hold the most part of MLS germplasm. From their perspective, some of the challenges encountered in genebanks' daily operations range from potential germplasm providers recluctance to provide access to their Plant Genetic Resources (PGR) collections, to users preferring to avoid CGIAR germplasm exchange channels because discouraged by the benefit sharing mechanism of the MLS. The difficult harmonization between national and international legislation in terms of PGR exchange has somehow kept the Plant Treaty provisions into a relatively low profile, lacking the desired political attention. While the CGIAR genebanks and centers' breeding programmes have so far made a remarkable contribution to agricultural research for development at a global scale, achievements are only a small part of what could effectively be done if stakeholders could be engaged in a more cooperative manner.

The continued and improved functioning of the ITPGRFA is critically important to the CGIAR, in that it provides the legal basis for CG Centers' transfers of genetic material to developing countries in pursuit of its objectives. Historically, the mission of the CGIAR evolved in a closely interwined way with the legal framework for genetic resources access and sharing, culminating with a strong overlap of objectives between the CG centers and the ITPGRFA. Their common ground was formally established in 1994 with the International Undertaking (IU) agreement between the CGIAR and FAO. By placing CGIAR germplasm collections under the auspices of FAO, freely available for the benefit of a global research effort, the 11 CGIAR genebanks have since then been actively engaging in the activities of the Plant Treaty (Noriega et al, 2019). These genebanks constitute the largest and most widely distributed collection of genetic diversity available under the MLS of the ITPGRFA. Over the first 10 years of operations under the Plant Treaty, CGIAR genebanks have distributed more than 4 million samples to plant breeders and crop researchers - representing 93% of the reported global germplasm distribution worldwide. The financial requirement for CGIAR genebanks operations and maintenance is estimated to be 15 $ millions per year[1] (Shands et al, 2011).

[1] The cited study includes aggregate costs for collections optimization and regeneration projects, raising the total costs to 21,028,960$. It also forecasts possible fluctuations due to inflation and capital investment needs (which are likely to increase as a result of additional international requirements for phytosanitary permits as well as the need to manage material transfer agreements and declarations on the presence of GMOs); and specific circumstances that will change the calculated "steady-state" level of financing as determined in the costing study (increases or decreases, depending on circumstances, local labour costs, productivity changes, changes in management structures and costs, and so on).

Table 1 Summary of CGIAR genebanks financial requirements for 2011, adjusted from Shands et al (2011)

Genebank	Collections	# SMTAs	# Samples	Timeframe	Estimated Costs ($)
AfricaRice	rice	483	46,440	2007 - 2017	342,515
Bioversity	Banana, plantain	386	6,109	2007 - 2016	970,932
CIAT	bean, cassava, tropical forages	2,547	246,650	2007 - 2017	2,394,585
CIMMYT	Maize, wheat	18,127	1,986,228	2007 - 2016	1,165,430
CIP	potato, sweetpotato, Andean root and tuber crops	560	15,391	2007 - 2017	3,231,248
ICARDA	barley, chickpea, faba bean, forages, lentil, wheat	12,977	779,390	2007 - 2016	1,299,908
ICRAF	Tree	154	679	2011 - 2016	NA[2]
ICRISAT	chickpea, groundnut, sorghum, millet, pigeonpea	3,885	159,362	2009 - 2017	2,464,419
IITA	cassava, cowpea, Musa, soya bean, yams, yam bean, maize	728	29,792	2007 - 2017	1,130,621
ILRI	forages	777	9,390	2007 - 2016	840,763
IRRI	Rice	7,186	635,090	2007 - 2017	1,393,625
TOTAL		47,810	3,908,412		15,234,045

Currently, the CGIAR conserve more than 700,000 accessions of crop, trees and forage germplasm, both in the centers' genebanks and in the Svalbald Global Seed Vault. These Ex Situ collections are actively regenerated and preserved in compliance to national and international phytosanitary regulatory requirements for international exchange. CG centers work to characterize, evaluate and improve PGRs, and engage in capacity building, knowledge sharing and technology transfers with farmers and scientists in developing countries to foster PGR sustainable use. CG centers actively participate the Plant Treaty meeting and negotiations. Ultimately, they contribute to identify strategies for resources mobilization for the functioning of the MLS. In 2006, the Crop Trust established by Bioversity International and the CGIAR was recognized as an essential element of the Funding Strategy of the Plant Treaty[3], in relation to the ex situ conservation and

2 In the cited study, ICRAF is not considered due to the different type of costs associated with preserving tree germplasm and its wild relatives.

[3] See the "Relationship agreement between the Global Crop Diversity Trust and the Governing Body of the ITPGRFA" signed on 16 June 2006.

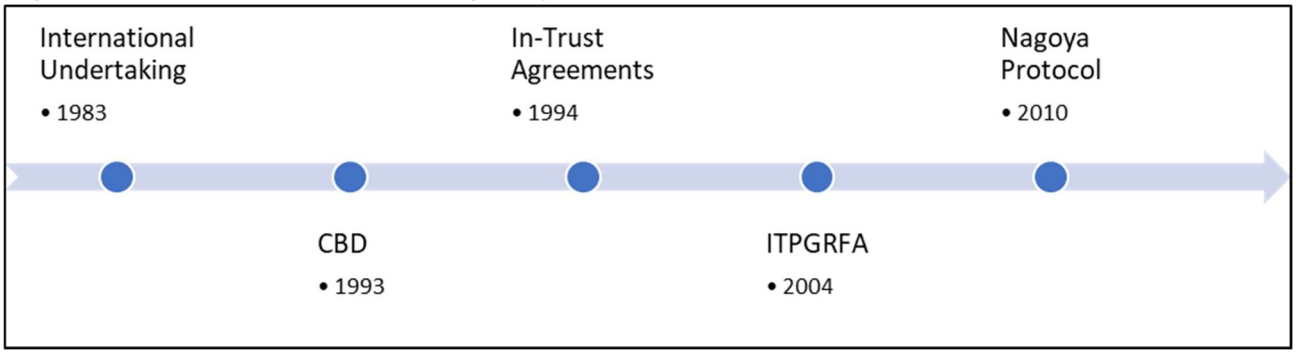
availability of plant genetic resources for food and agriculture. Following this line, in 2012 the Crop Trust and CGIAR entered into a five-year agreement to manage and sustain the world's international crop collections, and established the Genebank Research Programme to fulfill their legal obligation to conserve and make available accessions of crops and trees on behalf of the global community under the Plant Treaty.

In recognizing the linkages between the ITPGRFA and the CGIAR operations within the MLS, the present study aims at understanding the implications that the SMTA reform will have on the CG genebanks. To achieve its objective, the study starts by retracing the historical evolution of the legal framework guiding the international exchange of PGR. Then, it outlines the main features of the MLS reform processes currently being negotiated and identifies major challenges and sources of future uncertainties. By isolating those components relevant for CGIAR, the study constructs the different scenarios that might occur, and forecast the likelihood of different impacts and consequences for CG genebanks.

The Historical Path towards the Legal Framework for Access to Plant Genetic Resources

Over thousands of years, plant genetic resources (PGR) have been continuously exchanged across the world's regions, with our current global genetic heritage existing as the result of the phenomenon of geographical interdependence (Esquinas-Alcázar et al., 2013; Halewood, 2014). Nowadays, to varying degrees, all countries depend on PGRFA originated in other geographical regions (Galluzzi et al., 2016). The international policy framework that regulates the access, conservation and distribution of these resources is the complex result of a long series of historical events and political negotiations, which over the last 50 years has undergone and continues to undergo a constant process of change.

Figure 1: Historical evolution of the PGR regulatory framework



In the 1960s and 1970s, the attention of global agricultural development was focused on the so-called "Green Revolution", registering radical innovations in the use of technology in agriculture and the creation of improved plant varieties, boosting productivity and production. At the same time, the introduction of these new varieties accelerated a tendency to replace local and traditional varieties, contributing to the loss of genetic diversity (Esquinas-Alcázar et al., 2013). The emerging concern about the loss farmers' varieties, crop wild relatives and subsequent genetic erosion led the CGIAR group to establish, in 1974, the International Board for Plant Genetic Resources (IBPGR), an international centre hosted by the FAO. The mission of the IBPGR was to coordinate an international PGR programme and collecting missions to promote the building of new and the expansion of existing genebanks at the national, regional and international levels (Moore and Frison, 2011). The CGIAR made conservation and free availability of plant genetic material for research and plant improvement a significant part of its mission, in order to address food security and increase productivity (Gotor et al., 2010). Between 1975 and 1995, the IBPGR collected and conserved over 200,000 accessions from over 136 countries (Moore and Frison, 2011; Thormann, Engels and Halewood, 2019).

The same historical period faced growing tensions pertaining to the ownership and control of genetic resources (GR), also triggered by the emergence of new regulations on intellectual property rights that led to international agreements restricting access to PGFA, such as the establishment of the International Union for the Protection of New Varieties of Plants (UPOV) in 1961 (Esquinas-Alcázar et al., 2013). In the absence of formal recognition, the status of the CGIAR collections became the centre of a controversial situation. Developing countries, in particular, expressed concerns about the possible sovereignty loss of their genetic resources, while private companies based in developed countries accrued the monetary benefits derived from the

commercialisation of improved varieties generated from the use of the same plant genetic resources (PGR). In response to this situation, in 1979 the FAO Conference started the discussions that led, in 1983 (Resolution 8/83), to the creation of the Commission on Genetic Resources for Food and Agriculture (CGRFA) and the adoption of the International Undertaking on Plant Genetic Resources (IU) (Gotor et al., 2010). The IU was the first comprehensive international agreement recognizing the global relevance of plant genetic resources and the need for an international approach in order to "explore, preserve, evaluate and made these resources available for plant breeding and scientific purposes" (Resolution 8/83). The International Undertaking's underlying principle identified "Plant genetic resources for food and agriculture (PGRFA) as a common heritage of humankind", representing the first institutionalized attempt to create collective pooling and management to make PGR freely available without restrictions for the benefit of present and future generations, within an "internationally coordinated network of national, regional and international centres" (Halewood, 2014). However, the non-legally binding nature of the IU did not resolve the tensions between developed and developing countries over PGR, with the latter still manifesting concerns about increasing exploitation without any monetary compensation for the benefits generated from the use of the PGR resources collected within their territories. In addition, eight countries expressed reservations to the IU.

The "humankind heritage" principle started an intense debate that led to a different interpretation from the FAO Conference, that in 1989 recognized the primacy of plant breeders' rights (Resolution 4/89) and national sovereignty over PGR in 1991 (Resolution 3/91) (Thormann et al., 2019). The UPOV Convention revision, also in 1991, contributed to heightened IPRs protection (Halewood, 2014) that increased the concerns of developing countries. The major international policy promoting this paradigm shift was represented by the Convention of Biodiversity (CBD), which entered into force in 1993. The legally binding effects of the CBD stressed the principle of national sovereignty over all ecosystems, species and genetic resources, including PGRFA. The sole competence to grant access to PGR was subject to parties' Prior Informed Consent (PIC) and on Mutually Agreed Terms (MAT) to ensure an equitable sharing of the benefit flows derived from their use (Kate and Lase, 1997; Mekonnen and Spielman, 2018). Unlike the CGIAR operational regime, which promoted a multilateral mechanism of access to PGR, the CBD operated the exchange of germplasm through bilateral contracts, to preserve the member countries' individual rights over their natural resources.

This newly established legal framework was substantially opposed to the principle of free availability of germplasm as introduced by the International Undertaking, placing the International Agricultural Research Centres' (IARCs) collections, and the role of CGIAR itself, in a situation of serious instability (Gotor, et al., 2010). The major risk of germplasm privatization was that the hosting countries could claim rights to the accessions placed within their territory, hampering the activities of collection, conservation and distribution. In order to overcome this deadlock, after a long and intense process of negotiations on 26 October 1994, the IARCs of CGIAR signed trusteeship agreements with the FAO, formally placing their ex-situ PGRFA collections under the FAO's auspices to make them freely available for research, conservation and breeding purposes. According to the In-trust Agreements (ITAs), no intellectual property rights could be sought over the materials accessed through the ITAs and the related information. The influence of the ITAs on international germplasm exchange has been substantial; Gotor & Caracciolo's (2010) analysis of the acquisition and distribution of germplasm data held by the International Research Rice Institute (IRRI) provides evidence of a significant enhancement when comparing the period between the adoption of the CBD and the ITAs, and the one immediately after. The ITAs can therefore be considered a first attempt to create a formal multilateral system for germplasm conservation and use, paving the road for a legally binding framework in the same direction,

which was even more necessary after the adoption of the TRIPS agreements signed in 1994 (Gotor et al., 2010; Esquinas-Alcázar et al., 2013). The FAO Resolution 7/93 requested a forum for negotiating the revision of the International Undertaking in harmonization with the CBD, addressing the ex situ collection status and recognizing farmers' rights (Esquinas-Alcázar et al., 2013). The negotiations took 7 years to reach an agreement on the revision that was adopted on November 3, 2001 as the International Treaty on Plant Genetic Resources for Food and Agriculture (ITPGRFA) and entered into force in 2004 (Sauvé and Watts, 2003; Halewood, 2014).

The ITPGRFA represented a turning point in the global policy framework on PGR, providing a legally binding alternative approach to the CBD and recognizing the special nature of those resources important for global food security (Brahmi and Tyagi, 2017). The most significant development introduced by the Treaty was the establishment of a Multilateral System (MLS) of Access and Benefit-Sharing (ABS) granting unrestricted access to a pool of 64 food: (35) forage crops and (29) food crops for the sole purposes of "utilization and conservation for research, breading and training for food and agriculture" (FAO, 2010). As mentioned in Visser (2013) and Halewood (2014), the content of Annex 1 was the matter of heated debates, in which at the beginning of the negotiations the African proposal was to include only 9 food crops against the 287 advanced by the European Union. The final compromise was achieved with 64 crops considered to have extreme importance for global food security, together accounting for 80 percent of all human food consumption (Mekonnen and Spielman, 2018). The objective of the MLS is to facilitate access to the genetic resources, and their related information, stored in "local, national and international gene banks that are in the public domain and under the direct control of the Contracting Parties" (FAO, 2010). The CGIAR, represented by the International Plant Genetic Resources Institute (IBPGRI), within its technical and scientific expertise over the course of the negotiations, exerted significant influence on the outcome of the negotiations (Sauvé and Watts, 2003). The ITAs were embedded in the Treaty, recognizing the essential role of the CGIAR genebanks and their collections in the MLS (Articles 11 and 15).

In June 2006, during its first session, the ITPGRFA Governing Board adopted the Standard Material Transfer Agreement (SMTA), a contractual instrument providing a standardized mechanism of access to Annex 1 materials. The Treaty provides that all PGRFA transfers are to be made under the SMTA, in order to cut down both the transaction costs and negotiation time usually required by bilateral negotiations between breeders and genebanks (Halewood, 2014). The crops not included in Annex 1 are not subject to the SMTA and respond to PIC and MAT, as provided by the CBD. If the major added value of the ITPGRFA is clearly represented by the facilitated access to PGRFA, other significant benefits—to be distinguished between monetary and non-monetary—have also been provided. The non-monetary benefits consist of the exchange of information, the access to and transfer of technology, and the implementation of programmes for capacity building, especially dedicated to developing countries and countries with economies in transition (Brahmi and Tyagi, 2017). Under the Treaty, the recipients "shall not claim any intellectual property or other rights that limit the facilitated access to the material provided under this agreement, or its genetic parts or components, in the form received from the Multilateral System". If they commercialize products deriving or incorporating materials accessed through the SMTA, a fixed percentage of the sales shall be payed to the Benefit-Sharing Fund. The Benefit-Sharing Fund (BSF) was created in order "to share fairly and equitably" the monetary benefits arising from the commercialization of MLS materials and voluntary contributions (Brahmi and Tyagi, 2017). In addition, the ITPGRFA promotes Farmers' Right and their importance in conservation, selection and development of new varieties of PGRFA. The treaty calls on its member countries to implement the appropriate measures to

recognize and protect them through the preservation of traditional knowledge, and the right of farmers to equitably share benefits that result from their use and to participate in making decisions at national level on matters related to the conservation and sustainable use of PGRFA (FAO, 2010).

The emergence of this innovative legal framework introduced by ITPGRFA created the basis for updating the provision of the CBD, particularly regarding the ABS mechanisms. In 2004, the Seventh Conference of Conference of the Parties (COP) to the CBD mandated the Working Group on ABS to elaborate an international regime on access and benefit-sharing to genetic resources (FAO, 2010). This resulted in an additional international agreement, the Nagoya Protocol, signed at the Tenth COP to the CBD in 2010 and entered into force in 2014. The Nagoya Protocol recognizes the ITPGRFA's role in its preamble and within Article 4, stating that the Protocol "shall not affect the rights and obligations of any Party deriving from any existing international agreement". It has a wider scope than the Treaty, covering all genetic resources, but it still recognizes the special role of PGRFA for food security in Article 8. However, as highlighted in Halewood (2014), the Nagoya Protocol focus is entirely directed towards benefit-sharing, not on multilaterally constructed access mechanisms. The aim of the protocol is to set out a stronger and clearer ABS framework, by requiring the parties to adopt ad-hoc national legislation (Mekonnen and Spielman, 2018).

The ITPGRFA together with the CBD and the Nagoya Protocol represent the current policy framework regulating GR access and use. Despite their similarly aligned objectives—promoting the conservation and sustainable use of biological diversity and the equitable sharing of benefits derived from its use—their implementation tools and approach are extremely diverse (Halewood et al., 2013). The continuous progression and growing complexity of the framework have not been able to cease the political tensions around the international exchange and use of PGRFA, conversely the global scenario is still evolving and uncertain, slowing down the process of adoption of the provisions and the expected beneficial impacts. These issues will be discussed further explored in the following chapter.

Recent evolution and challenges

Despite the fact that the ITPGRFA represented an enormous breakthrough in the regulation of international PGRFA exchange, the implementation and harmonization of the current international policy framework has proven to be complex and cumbersome. The nature of PGR makes it difficult to consistently track the germplasm exchange across the world and the increasing complexity of regulation is hampering the process of creating a comprehensive and updated database (FAO, 2010). Over the years, several concerns on the functioning of the Treaty have emerged, led by the capacity of the current MLS and SMTA set up to attract the acquisition of new genetic material to be made available through the genebanks and to generate the expected monetary benefits through the Benefit-Sharing Fund (BSF) (Halewood et al., 2012; Galluzzi et al., 2016; Noriega et al., 2019). Recent studies have already attempted to assess the status of international germplasm exchange in terms of acquisition and distribution and how it has been influenced by the entry into force of the ITPGRFA. In Halewood et al. (2012), evidence shows that since the mid-1990s, the rate of acquisition of new genetic material by the CGIAR genebanks and the MLS have registered a significant downward trend. The authors stressed the need for more time for the Treaty to express its full potential, also considering that the parties have been slow in putting in place the necessary structures, processes and internal capacity building procedures in order to make the MLS operational. The same trends have been also highlighted by Galluzzi et al. (2016) and Mekonnen & Spielman (2018). The latter study analysed the different impact over the years of the adoption of the CBD and the ITPGRFA, registering mixed results that differ from crop to crop. Yet, the study findings confirmed that in general, after the adoption of the CBD, many countries have been more protective of their PGR, while those who also ratified the ITPGRFA showed better propensity to make their germplasm available through the genebanks.

However, it is the monetary benefit-sharing mechanism that represents the major source of debate and political tension among the Treaty's member countries. The performance of the Benefit-Sharing Fund is certainly one of the main concerns. Over the years, the mechanism of Benefit-Sharing of the MLS has revealed to be insufficient in attracting users with the potential to generate the obligatory contributions to the fund (Noriega et al., 2019). The primary recipients of the MLS genetic resources have been public sector organizations, mainly from developing countries (Galluzzi et al., 2016). Commercial companies that would potentially trigger the benefit-sharing monetary contributions have been reluctant to request germplasm from the MLS and consider the current payment rates too high to be competitive (Halewood et al., 2012). In order to avoid the benefit-sharing clauses and royalty, many private companies and commercial breeders have adopted SMTA-avoidance internal policies, preferring to acquire genetic material from elsewhere (Janick, 2015). Until now, the BSF has only received a single payment of 119.083 USD from a private company under the SMTA, whereas the rest of the financial resources were based on voluntary contributions from Contracting Parties and other International institutions. The slow implementation and low success of the monetary benefit-sharing mechanism represent a major source of uncertainty and distrust for the Treaty's parties, especially developing countries, with the result of reducing the incentive in making new genetic materials available through the Multilateral System (Halewood et al., 2012). Other significant factors contributing to this scenario include the reduction of international support for collecting missions, the difficulty in creating a consistent monitoring of the germplasm exchanges and the use of the SMTA – with the consequence that a large share of the transfers within the MLS remains still unreported – and the political tensions about the control, use and sharing of benefits that are still feeding the distrust among the parties, slowing down the process of a national implementation of the provisions of the Treaty (Halewood et al., 2012).

In order to respond to these major concerns and constraints to the MLS implementation, the ITPGRFA's Governing Body created the Ad Hoc Open-Ended Working Group to Enhance the Functioning of the MLS (Working Group) during its 5th Session in 2013, with the main objectives of developing measures to increase user-based payments and contributions to the BSF and enhancing the functioning of the Multilateral System. The Working Group met several times following its official establishment, and the 9th meeting held in Rome on 17-21 June 2019 represented a turning point of the MLS history and functioning (IISD, 2019). The main discussion topics the parties negotiated revolved around the 1) revision of the SMTA; 2) adaptation of coverage of MLS crops of Annex I; 3) genetic sequence data and 4) a growth plan for benefit sharing arising from the combined adoption of the revised SMTA and the expanded Annex I. While consensus was reached on several provisions, a lack of compromise on the most controversial topics – most notably, the genetic sequence data and the rates for benefit sharing payments - led to the supension of the meeting to allow for further negotiation before eight session of the Treaty Governing Body, which will be held in Rome in November, 2019. The emerging difficulties in the implementation at national level and its scarce capacity to trigger the monetary benefit-sharing mechanism have made the revision of the SMTA the central topic of the debate. Enhancing the general functioning of the MLS and expanding the list of the crops covered by Annex I is also a priority and considered a valid option to increase the MLS attractiveness. The parties are discussing the proposal of Switzerland to extend Annex I to all the PGR for food and agriculture "under the management and control of the Contracting Parties and in the public domain" (IISD, 2014). This could ideally simplify and resolve potential conflicts with the Nagoya Protocol (ITPGRFA, 2017). However, this topic still remains deeply contentious, a possible solution likely depends on a successful agreement regarding the SMTA revision process. Reaching a satisfactory compromise, especially for the enhancement of the benefit-sharing mechanism, would represent an important incentive for reluctant Parties to agree to make new crops and materials available to the MLS. It is also well recognized that the simplification of the SMTA and the reduction of the related administrative costs and payment rates would increase private users' involvement in the MLS. In this regard, the Working Group has been developing options to increase user-based payments to the BSF. One is the adoption of the Norwegian Model, following the example of Norway that since 2008 has been making annual voluntary contributions to the Benefit-sharing Fund equivalent to 0.1% of the seed commercialised in the country (ITPGRFA, 2009; Noriega et al., 2019). However, the negotiations are moving towards the adoption of a subscription system as an alternative to the current provisions in order to simplify administrative transaction costs and procedures and avoid PGR flow tracking[4]. Several commercial actors – those in the position to contribute to the BSF - have formally declared their commitment to contribute to the BSF if the establishment of a subscription system is approved (Seed Companies Declaration of Commitment, 2017). Pursuant to the subscription system, subscribers will make annual payments to the Plant Treaty's BSF, based on a fixed percentage of their annual seed sales[5]. They will agree to be subscribers for a minimum of 10 years. In return,

[4] It should be mentioned that, if the subscription system will reduce administrative burdens by avoiding the tracking of genetic resources flows, it remains unclear how such a reform would fit into the current debate at the World Intellectual Property Organization (WIPO) on the necessity of disclosing country of origin of the said material when applying – and enforcing – a patent upheld on a life form. Moreover, the wider framework of TRIPS, within the World Trade Organization (WTO), provides several prescriptions at odds with the Convention on Biological Diversity (CBD). These conflicts are particularly striking in terms of the recognition of property rights on life forms (allowed by TRIPS, subject to national authority in the CBD) and the share of benefits derived from patent protection (absent in the TRIPS, while allowed by the CBD).

[5] During the last Working Group meeting of June 2019, the sales rate proposed is of 0.015% for subscription; and between 0.2% and 2% for access recipient in regard to products that are not available without restriction for further research and breeding (Article 6.7) and products that are available without such restrictions (Article 6.8). The negotiations are ongoing, due to polarization of Northern countries and Seed Industry representatives (demanding a rate of 0.01%) and Southern countries, civil society and farmers' representative pushing for a higher rate of 0.3%. In particular, civil society pointed to the World Health Organization's

they will enjoy facilitated access to all PGRFA in the Plant Treaty's multilateral system, for free or for minimal administrative costs. Under discussion is the possibility of exemption of the system of payments for public institutions, small enterprises and family farmers. One of the major innovations introduced by the subscription system might be that payments would be calculated on final sales, instead of single sales of products incorporating material accessed from the MLS. As highlighted by Noriega (2019) this might represent an interesting solution to capture the "benefits realized by users from access to both material genetic resources and genomic sequence".

The Digital Sequence Information (DSI), or dematerialization, of genetic resources is an emerging topic of discussion in relation to the possible applicability of the Treaty's provisions on the use of this information. DSI can be used for characterization, breeding and genetic improvement, conservation and identification of PGRFA and the potential application of this massive quantity of data can be extremely valuable also for private users with commercial purposes (Marden, 2017). Originally, dematerialization was not included in the Working Group tasks, but the interest on its potential role in plant breeding and food security is opening a space for discussion in the negotiations (Noriega et al., 2019). Parties from the global South, strongly opposed by Northern countries, are expressing concerns on the public availability of this information and are calling for including the possible applications of benefit-sharing obligations on the use of DSI of PGRFA in the final revision of the MLS, since the Treaty does not explicitly address their role yet (IISD, 2019). However, identifying and tracking the use of this information is extremely difficult and the application of the SMTA provisions to the DSI would add another level complexity to the implementation of the MLS (Marden, 2017). Moreover, since the "dematerialized germplasm" can be used in lieu of the actual genetic resource, civil society organizations raised their fears of biopiracy if this information will not be explicitly part of the revised SMTA.

As evident from the outcome of the negotiations that took place in June 2019, the parties are still extremely divided on this topic and reaching a common agreement might require considerable time and negotiations (IISD, 2019). Indeed, when the Working Group met again in November 2019 during the 8th session of the Governing Body (GB 8) of the ITPGRFA, the fragile compromise reached in June 2019 collapsed. While all eventually concerted that benefit-sharing payments had to be compulsory, and consensus was emerging on the rates for such payments, the growing use of DSI in research and development was the trigger for the collapse of the negotiations. Developing countries wanted to ensure that benefit-sharing obligations extend to DSI use, while developed countries considered it premature to pose obstacles to this technological innovation.

Uncertainty prevailed on the way forward to bridge positions between the developed and the developing world on enhancing the Treaty's Multilateral System of ABS. Consequentially, during the GB 8 it was decided to convene a closed group, composed of two party representatives and two party observers per region, to discuss the main controversial items, such as benefit-sharing from DSI use, and specific payment rates for benefit-sharing. The closed group met from Wednesday evening to Saturday morning; and on Saturday afternoon was presented a proposed "package", including a resolution, a revised SMTA text, text for the amendment of Annex I of the Treaty, and terms for intersessional work.

Agreement, however, was nowhere to be found. Developing countries rejected the proposed "package", stressing it lacks balance with regard to fair and equitable benefit-sharing and it does not adequately address

Pandemic Influenza Preparedness framework, set to raise USD 200 million in payments over seven years, with an initial rate of just under 1% from an industry that is one-tenth of the size of the seed industry. He suggested a realistic rate would be 0.5 to 1%. During the Closing Plenary, a delegate from Brazil, speaking in a personal capacity, made a plea to find a solution for the rates issue.

genetic sequence data. In turn, developed countries opposed continuation of the Ad Hoc Open-ended Working Group on the MLS.

The GB took note of the need to take stock and evaluate future steps for further work on the Enhancement of the Multilateral System. However, the GB had different views on the way forward. Some Parties wanted the GB, at its Ninth Session, to consider how to carry out further work, considering outcomes of relevant debates under the Convention on Biological Diversity (CBD). Other Contracting Parties specified that they prefer to review the best way forward.

In conclusion, delegates could not reach consensus on continuing intersessional work on this issue during the next biennium. For this reason, the GB encouraged informal consultations among Contracting Parties and especially national consultations amongst sectors and relevant stakeholders.

The current debate for the MLS' revision has encouraged the ratifications of new countries, that by becoming members of the Treaty are gaining the opportunity to take part in the ongoing negotiations. When it entered into force in 2004, the Treaty was ratified by 57 countries and, after fifteen years, this number has increased to 145 (Table 2).

Table 2: Parties of CBD, ITPGRFA and Nagoya Protocol in numbers

CBD	***ITPGRFA***	***Nagoya Protocol***
196 parties • 88 countries in 1994, • 36 countries in 1995, • 35 countries in 1996 • The rest after 1996.	145 member countries • 57 countries ratified in 2004, • 14 countries in 2005, • 33 countries in 2007, • The rest in more recent years.	116 parties • 52 countries in 2014 • 49 countries between 2015 and 2017. • the rest after 2017

The ratification of the U.S. in 2017, the second largest international supplier of PGRFA samples in the world after the CGIAR centres (Halewood et al., 2012), could represents a turning point for the future of the Treaty, opening the space for new scenarios and bringing both new opportunities and risks (Thormann, Engels and Halewood, 2019). The U.S. placed over 500.000 accessions into the MLS from their National Plant Germplasm System (NPGS) collections. Before entering the ITPGRFA, the NPGS used to be a relevant alternative to the MLS, especially for those users interested in avoiding the MLS benefit-sharing conditions. The NPGS did not require the use of the SMTA and use to make the PGRFA available all over the world, at minimal conditions (Halewood et al., 2012). Marden (2017) analysed the potential role of the U.S. in the ITPGRFA and the possible risks. Surely, the ratification of the U.S. has the potential to be a significant opportunity to harmonize the benefit-sharing obligations and officially eliminate the major alternative source of germplasm to the MLS, especially for commercial companies. Furthermore, the ratification of the United States could potentially pave the road for the entry of other important international players, most notably China. This may lead to a further expansion of the MLS gene pool, but also to growing complexity in the negotiation process. The opportunities and risks of the new scenario have been extensively covered in Marden (2017).

However, the USA entry in the Treaty perpetuates notable concerns since it is still not clear how it will implement the ratification. It is important to mention that the U.S. Senate Report, accompanying the U.S. ratification of the Treaty, has declared that the U.S. interpretations of the SMTA obligations apply only to international transfers of PGRFA, maintaining "de-facto" the pre-ratification status for the domestic transfers.

This means that, if with the U.S. joining the Treaty, MLS access and benefit-sharing obligations have been extended to all the non-U.S. recipients requesting the NPGS's germplasm, the U.S. users will likely remain outside of the same provisions. This critical issue, as emphasized by Marden (2017), may potentially have a negative impact on the Treaty by creating more confusion on the application of the SMTA and especially increasing the distrust among of country members over the efficiency of the benefit-sharing mechanism.

Research Approach and Methodology

The research team will make use of a combination of qualitative and quantitative research approaches in order to construct and validate a range of scenarios on the possible future outcomes of the MLS reform. Qualitative information will be gathered through desk review and Key Informants Interviews (KIIs) with the aim of developing the scenarios. Then, quantitative data will be used to econometrically quantify the impacts of the scenarios. The information generated in the course of the study will flow in two different yet complementary analysis: an ex post evaluation of past germplasm flow, to be combined with an ex ante econometric model. The ex ante modelling exercise is used to forecast the predicted changes in genes flow based on assumptions of the possible, future scenarios. Specifically, the econometric model that we will employ aims to analyse the dynamics of germplasm exchange of at least two important CGIAR genebanks. Analytically, the relationship in question can be described for each *i*th crop germplasm sample sent (i.e., rice, wheat, maize, etc) and for each *j*th receiving institution type (i.e., commercial company, CGIAR centre, university, etc.,) imported in month *m* as:

$$SAMPLE_{ijm} = \alpha_0 + \mathbf{x_i}'\boldsymbol{\omega} + \mathbf{z_j}'\boldsymbol{\theta} + \alpha_4 SMTA_{im} + \beta_5 month_m + \sum_{i=1}^{N-1} \lambda_i (month_m \times crop_i) + \sum_{i=1}^{N-1} \gamma_i (month_m \times crop_i \times SMTA_{im}) + \varepsilon_{ijm}$$

where the dependent variable represents the count of samples distributed in the *m*th month for the *i*th crop to the *j*th receiving institution type. x_i matrix may include characteristics of the crop that may influence the exchange flow (i.e., those associated by the specific distribution center, level of improved materials) while z_j similarly may include characteristics of the recipient institution (i.e., those related to the hosting country of the institution). $SMTA_{im}$ will represent the share of the material distributed as SMTA for the specific crop in the specific month, while month and its interaction with the type of crop and with the SMTA will take into account the dynamics. Since the discrete nature of the dependent variable and the potential presence of zero flows, the model could be consistently estimated by a pseudo-Poisson Maximum Likelihood estimator (PPML). However, different specification will be assessed.

While the present study is still in the early stage of development, the research team has so far devoted its efforts to a series of preliminary activities aimed at better defining the study scope and building relationships with relevant stakeholders. The activities conducted by the Development Impact Unit (DIU) since May 2019 can be grouped as follows:

Desk review: to gather exhaustive literature on the topic and understand the historical processes that led to the ITPGRFA establishment, including the perspective of each stakeholder and the main past and present challenges of the MLS. A list of the scientific literature consulted is available in the reference list at the end of the present document. Table 3 below reports firstly the documentation made available during the FAO negotiations in Rome, June 2019. The research team notes and recrods from the meeting can be made available upon request.

Table 3 List of documents made available to participants to the 9th WG Meeting held at FAO from 17-21 June, 2019

Working and Information Documents – 9th meeting of the Ad Hoc Open Ended Working Group	
IT/OWG-EFMLS-9/19/3	Draft revised standart material transfer agreement: proposal by the working group, at its eight meeting
IT/OWG-EFMLS-9/19/4	Enchanhing the functioning of the MLS: note by the co-chairs
IT/OWG-EFMLS-9/19/4 add.1	Draft revised standard material transfer agreement – co-chairs' proposal to the 9th meeting of the working group
IT/OWG-EFMLS-9/19/4 add.2	Draft revised standard material transfer agreement – co-chairs' proposal to the 9th meeting of the working group: explanatory notes
IT/OWG-EFMLS-9/19/4 add.3	Adaptation of the coverage of the MLS: proposal by the co-chairs
IT/OWG-EFMLS-9/19/inf. 2	Note for participants
IT/OWG-EFMLS-9/19/inf.3	Submissions from contracting parties and stakeholders on matters to be discussed at the 9th meeting of the working group
IT/OWG-EFMLS-9/19/inf.3 add. 1	Submissions from contracting parties and stakeholders on matters to be discussed at the 9th meeting of the working group - addendum
IT/OWG-EFMLS-9/19/inf.4	Report of the standing group of legal experts: outcomes of the 4th meeting
IT/OWG-EFMLS-9/19/inf.5	Report on sales within the seed sector
IT/OWG-EFMLS-9/19/inf.6	Report on supportive measures to facilitate the implementation of the possible expansion of the coverage of the MLS

Capacity building and networking: we initiated a process of gradual stakeholder engagement with the assistance of the Policy Research and Support Unit. Resources have been allocated to enable the research team to participate to the Working Group (WG) negotiation that took place at FAO in June 2019, as well as the next WG meeting scheduled later in October and the ITPGRFA Governing Body meeting in November. As stated above, notes and records of the meetings can be made available upon request.

Disentangling data needs: the different qualitative and quantitative data sources to be combined have been established and the sources to collect them identified. Below, a summary of the data that will be made available under this grant:

a. *Qualitative Data*: semi-structured interviews with available genebank managers will be conducted between September and October 2019. The objective is to validate the scenario developed and eventually integrate them with further feedback based on managers' perception and experience;

b. *Quantitative Data*: gathering of existing and readily available datasets on digitalized SMTA, different for each scenario analysis:

i. Data on demand of accessions, regardless of the source of the request. The information to be extracted would regard the type of crop, year, type of recipient (including commercializes users, but also other entities), country. The ideal time coverage would be of 10 years, in order to understand long-term patterns;

ii. Data on demand of accessions specifically from commercial users (i.e for each user, identification of the company and frequency of requests). The time coverage would be the last 3-5 years.

These preliminary research activities resulted in the following outcomes:

Genebank Managers positively responded to the invitation to participate to the study: CGIAR genebanks' managers were contacted and, following their positive feedback on the research proposed, they were included early in the discussion and invited to actively participate in the dialogue to outline the scenario analysis. Email exchange resulted in a three hours Skype conference on the 28th of June. The table below indicates the focal points of each genebank that positively received the proposal to participate to the study.

Table 4 Genebank managers interested to participate to the study, their data availability, and their comments – explored in detail in the next chapter.

Genebank	*Collections*	*Teleconference Participant*	*Database Available*	*Comments*
AfricaRice	Marie-Noelle Ndjiondjop	No	NA	Awaiting further feedback
Bioversity	Nicolas Roux	Yes	Yes	Awaiting further feedback
CIAT	Carolina Roa	Yes	Yes	Highlights the importance to look at PGRFA under development
CIMMYT	Thomas Payne	No	Yes	
CIP	Noelle Anglin	Yes	Yes	Warns about possible misleading information regarding DSI generation from commercial companies
ICARDA	Mariana Yazbek	Yes	NA	
ICRAF	NA	No	NA	
ICRISAT	Vania Azevedo	Yes	No	Would require about 6 months to digitalize all the SMTAs of the past 10 years
IITA	Michael Abberton	Yes	NA	
ILRI	Alieu Sartie	Yes	NA	
IRRI	Venuprasad Ramaiah	Yes	Yes	

While most participants declared their data is readily available, a broader participation could be achieved in terms of data sharing with an extended timeframe. Some centers (es. ICRISAT) would need additional time and resources to digitalize the available data. Moreover, the several discussions conducted with the research team highlighted a number of issues, detailed in the next chapter.

Preparation of a Data Sharing and Confidentiality Agreement: Information on the recipients of materials (name of the entity, address, contact person) transferred by both genebanks and centers is normally considered confidential information. Although the Plant Treaty Secretariat receives and stores that information, it never discloses information about the identity of the recipients. It is considered information "commercial in confidence". Many private recipients and even public ones do not wish their identity to be disclosed to avoid open competition with other recipients of materials sent by CG Centers. Therefore, to access this type of data, the research team would need to treat such information as Confidential (like Personally Identifiable Information under the GDPR) and work with it and publish it in an anonymized way, to never reveal their identities. Because this is the nature of the information, we would likely be restricted to share results and with anybody else, including others CG centers. For this reason, the DIU is currently working to the development of a Data Sharing and Confidentiality Agreement in collaboration with genebank managers and their legal offices, in order to ensure their active participation as well as preserving the research team credibility and trustwhortiness.

Development of scenario: two scenarios on the MLS reform possible future impact have been outlined throught the research team review of literature, attendance to FAO working group meeting and, most notably, the group conference with genebank managers. Scenarios are summarized as follows:

a) **Scenario 1: Increase in the demand for CGIAR material:** The first hypothesis assumes that the MLS reform would result in increased payments to the BSF, which would lead to increased users' expectations and, consequentely, increased demand for PGR held by CGIAR genebanks. Once stakeholders, particularly (but not exclusively) from the private sector, commit to subscribe for a period of 10 years, they do commit to a stable and continuous flow of funding to the BFS based on their annual seed sales, and the payment rate to be defined in the coming months will range between 0.01% and 0.015%. Following the subscription, subscribers are entitled to access genebank material and related information[6] without restrictions in terms of germplasm typology and quantity. Three factors are considered of key importance to the likelihood of this hypothesis. The first one relates to the avoidance of tracking procedures and the consequent reduction of administrative workload. This is especially true when looking at what comes after an SMTA is signed, rather than the single agreement per se. Bureaucratic responsibility is often times referred as a burdern slowing down technological progress, particularly in terms of patent application processes within the TRIPS agrement[7] and the WIPO proposal to disclose country of origin of products for such applications[8]. With the subscription system in place, subscribers will not need to provide an SMTA for every accession they demand, in exchange for the agreed contribution to the Benefit Sharing Fund. The second factor follows the ratification of the ITPGRFA by the United States, as now the collection of the National Plant Germplasm System (NPGS), the largest ex situ collection of plant genetic resources, is part of the MLS. Prior to the US ratification of the Plant Treaty, the NPGS policy allowed for free and

[6] It remains to be negotiated wether DSI will be included into the notion of "related information" or not.
[7] As the TRIPS agreement allows for easier IPRs application on plant genetic resources, without explicitly requiring the share of derived monetary benefits.
[8] See for example, the document submitted by the US delegation to the WIPO Intergovernamental committee on IP and genetic resources, traditional knowledge and folklore entitled "US Concerns about proposals for new patent disclosure requirement", 2018.

unrestricted exchange of material for research, breeding and education to any requesting party, without any SMTA and no imposed restrictions to the pursuit of intellectual property. Thus, pre-ratification, any party could access the desired germplasm without incurring in benefit sharing obligation. Since 2016 this alternative channel, falling outside the scope of the Plat Treaty, does not exist anymore, making it more difficult to avoid such obligations and somehow compete with the MLS. Lastly, the third factor clearly emerges from the Declaration of Commitment signed by 20 seed companies representing the European, US and Asian seed industry, following an informal meeting held in Switzerland in August 2017. The signatories declare that they would opt for the subscription option provided that their conditions regarding the subscription scope, fee and general terms, rights and obligations, are met - such as the agreed payment rate and the expansion of Annex I to all PGRFA[9]. While there might be slight variations to the original proposal of the Seed Federation, all their conditions have been intensively discussed during the latest ITPGRA Working Group, and final negotiations are likely to take into high consideration the signatories' priorities. Overall, there is reason to expect the broader involvment of the private sector due to the growth of incentives in terms of procedures simplification and absence of alternative germplasm exchange channels. If on one hand this would result in an increased flow of resources to the BSF, it is likely that expectations on what can be accessed and under which terms, such as the quantity of material, its quality, and the frequency of requests, will grow simoultaneously. As a result, CGIAR genebanks will face growing operational and maintenance costs to keep up with the increased demand. The relevance of this change lies especially in the CGIAR ability to uphold to subscribers' expectations to a feasible, realistic extent, as the growing payment to the BSF might carry with them a sense of entitlement of subscribers, authorizing them to demand more germplasm.

b) **Scenario 2: Decrease in the Demand of CGIAR Material:** On the other extreme of the scenario explored in the above section is the possibility that the subscription system might, instead, create disincentives for commercial users of PGR to participate more actively to the MLS and contribute to the BSF. The companies which signed the Declaration of Committment in 2017 drew clear lines on what expectations they needed to be met if they were to become subscribers. Some of these expected clauses are being negotiated, and it remains to be seen what the contracting parties' final decision will be and how these are perceived by the private sector. In particular, the Seed Federation proposed a maximum subscription rate of 0.01% which might increase up to 0.015% in the next Working Group meeting. Seed companies might be hesitant to compromise on this rate. Even more controversial is the discussion around the Digital Sequence Information (DSI): even if one of the original aim of the proposed subscription system is to de facto dissolve the difference between digital information and the actual material being exchanged, tensions arose between developed and developing contries during the last Working Group meeting held in Rome in June 2019. Several ITPGRFA representatives from the global south expressed concerns regarding biopiracy and demanded an explicit and clear reference to the share of monetary benefits derived from DSI exchange. On the other hand, European and American representatives draw the attention to the limited flexibility they have to negotiate and make explicit reference to DSI monetary benefits. The evolution of the Working Group negotiations on specific provision of interest to commercial users might not only foster dissatisfaction from their side but, also, increase the general degree of distrust among the Plant Treaty contracting parties. The ratification of the United States could potentially result in more ambiguities than opportunities. In the US Senate report that accompanied the ratification, the new contracting party

specified that SMTA obligation will apply only “to international transfer of PGRFA”, and that “the SMTA is not applicable to transfers of PGRFA of a purely domestic nature”. In other words, the US role is narrowly interpreted and benefit sharing obligations are not foreseen for certain type of domestic transfers. The pre-ratification system alternative to the MLS will partially continue to exist, and the lack of clarity might be a relevant factor disincentivizing commercial users’ participation – being North America itself the largest and one of the fastest growing seed markets.

Draft Discussion: Understanding the Implications of the MLS-BS Reform on the CGIAR Centers

Clearly, CGIAR genebanks and their conservation and research activites are heavily influenced and supported by the Plant Treaty and the Multilateral System it governs. The correct functioning of the system is of vital importance to the CGIAR pursuit of its mission, in that it provides the legal framework for germplasm exchange. However, the persistent tensions among contracting parties over the share of PGR derived benefits severly undermine the functioning of the MLS. As a consequence, various forms of inefficiencies arise in the system which negatively reflect on the CGIAR ability to fully exploit its potential as a germplasm collector, curator and provider.

CGIAR genebanks daily operations encounter challenges ranging from recluctance from potential germplasm providers to provide access to their PGR collections (Noriega et al, 2019), to potential users preferring to avoid CGIAR germplasm exchange channels because discouraged by the benefit sharing mechanism of the MLS (Hammond, 2011; Marden, 2017). Furthermore, the difficult harmonization between national and international legislation in terms of PGR exchange has somehow kept the Plant Treaty provision into a relatively low profile, lacking sufficient political attention (Noriega et al, 2019). While the CGIAR genebanks have so far made a remarkable contribution to agricultural research for development at a global scale, past achievements are only a small part of what could effectively be done if stakeholders could be engaged in a more cooperative manner. Nonetheless, genebanks do incurr in noteworthy operations and maintenance costs, as well as expenses related to CGIAR Centers' R&D activities for the development and deployment of new, stress tolerant, crops and varieties. Due to their committment to the provision of agricultural public goods[10] and the prudent use of intellectual property rights to maximize the benefits of farmers in the global south, these genbanks costs are hard to recover through revenue derived from R&D activities.

The subscription system currently being discussed by contracting parties might represent a possible solution to increase the Treaty credibility throught the increase of a predictable, and stable, flow of resources into the Benefit Sharing Fund which might, in turn, ease the resource constraints of the CGIAR genebanks and their efforts to preserve and improve the germplasm in trust within the MLS. The aim of the BSF is, in fact, to deploy adequate resources for the Treaty implementation in the area of conservation and utilization of crop diversity, strenghtening food security and adapting to climate change. Genebanks, among others, are entitled to apply for funding in response to specific calls for proposals intended to benefit contracting parties in developing countries. Priority activities include 1) the characterizaion of traditional and wild crop genetic material for their stress resistant levels; 2) selection and breeding of high performing varieties adapted to specific local conditions; 3) making such material widely available to farmers; and 4) training farmers and other stakeholders (FAO, 2013). CGIAR representatives within the ITPGRFA Working Group discussions have been major proponents of this option, as a possible strategy to mobilize resources and, at the same time, solve the growing tensions among contracting parties around the Digital Sequence Information (DSI) of PGR being shared at a global scale[11].

[10] For further information, see the "CGIAR Principles on the Management of Intellectual Assets", 2012. The CGIAR is allowed to apply for strategic IP rights with the exclusive aim to incetivize downstream research, to incorporate technologies that are themselves subject to IPR, and to obtain some form of compensation in a context of uncertain donor support.
[11] As far as monetary benefits are concerned, the adoption of the subscription system would de facto dissolve the distinction between DSI and the material genetic resources.

The formalization of the subscription system within the MLS, combined with the extension of Annex I of the Plant Treaty, is expected to come to an end later in 2019 before the ITPGRFA Governing Body meeting scheduled for this November. Reaching an agreement on this reform might impact the CGIAR genebanks in several different and, arguably, opposing ways depending on stakeholders' priorities, attitudes, expectations and behaviours.

Preliminary Analysis of PGRFA exchange dynamics

CIP Accessions

Data regarding CIP genebank cover an 11-years period, from 2009 to 2019, during which a total of 32,181 accessions were distributed. The genebank embraces nine crops of which potatoes and sweet potatoes represent the main distributed crops with a percentage of distribution of 50.85% and 39.68% respectively (see Table 5). Other crops, such as achira, ahipa, arracacha, mashua, oca, ulluco and yacon, account less then 10% of the crops distributed.

Regarding the biological status of the crops distributed in the considered period, traditional cultivars are the leading typology. They represent more than the 65% of the distributed crops and almost 7% of this is part of the Standard Material Transfer Agreement (SMTA). The second most representative typology is composed of breeding with a percentage of distribution of less than 22%. Improved and wild typologies constitute the tail of the distributions.

CIP breeding programs and other CGIAR Centers form the main beneficiary institutions of the distributed accessions. Together they represent almost the 80% of the total (namely 53.49% and 24.74% respectively, as can be seen from Table 5). The other core group of institutions that requested the crops is made up of research institutions, more specifically the Advance Research Institute (ARI), Universities and the National Agricultural Research System (NARS). Other institutions that have accessed the crops in the genebank are commercial actors, farmers and non-governmental organizations (NGOs). Among the institutions considered, NARS had access to the highest percentage of crops that were part of the SMTA. Of all the crops received, the 4,31% was part of the SMTA.

Focusing on the distribution of accessionbs to the 44 countries involved, undoubtedly Peru stands out among them as it received 82.87% of the crops present in the genebank in the period considered. Among the developed countries, the United Kingdom, Sweden and United States stand out. An interesting aspect to note is that in most cases the crops distributed to these countries were not part of the SMTA.

Table 5 CIP Accessions.

Variables	*Distribution*	*Sample*	*SMTA*
Crops			
Potato	50.85%	54.20%	9.51%
Sweet Potato	39.68%	38.38%	1.78%
Others	9.47%	7.43%	1.45%
Biological Status			
Traditional	65.88%	56.52%	6.98%
Breeding	21.68%	32.45%	3.34%
Improved	6.24%	5.47%	1.11%
Wild	6.00%	4.65%	1.31%
Others	0.21%	0.92%	0.00%
Institutions			
CIP Genebank	53.49%	47.47%	0.44%
CGIAR Centers	24.74%	27.63%	0.03%
Advance Research Institute (ARI)	7.76%	7.49%	0.14%
University	5.16%	9.09%	3.96%
National Agricultural Research (NARS)	4.48%	4.94%	4.31%
Others	4.36%	3.38%	3.86%
Countries			
Peru	82.87%	79.59%	7.49%
United Kingdom	4.33%	3.93%	0.07%
Ghana	2.57%	2.68%	0.00%
Sweden	2.23%	2.41%	0.00%
United States	1.79%	5.58%	0.50%
Others	6.20%	5.80%	4.68%

From Fig.2 it is possible to observed that the trend of distribution of accessions has increased over time, with particular peaks in 2012 and 2018. By breaking down the graph for the different crops, it can be highlighted how the growing trend and the two aforementioned peaks mainly concern the potato (Fig.3). As previously stated, most of the distributed accessions concern traditional varieties. The analysis of the differentiated trend based on the level of improvement does not show particular differences between breeding and improved varities. However, a peak in 2017 is observed for wild varieties and a peak in 2018 for traditional varieties (Fig.4 and 5). Focusing on the distribution of accessions to the various institutions, a peak in distributions to ARI in 2017 and another to the CIP genebank in 2018 is evident (Fig.6 and 7). Most accessions concern developing countries (Fig. 8) and are not part of the SMTA (Fig. 9).

Figure 2. Distribution of accessions per year

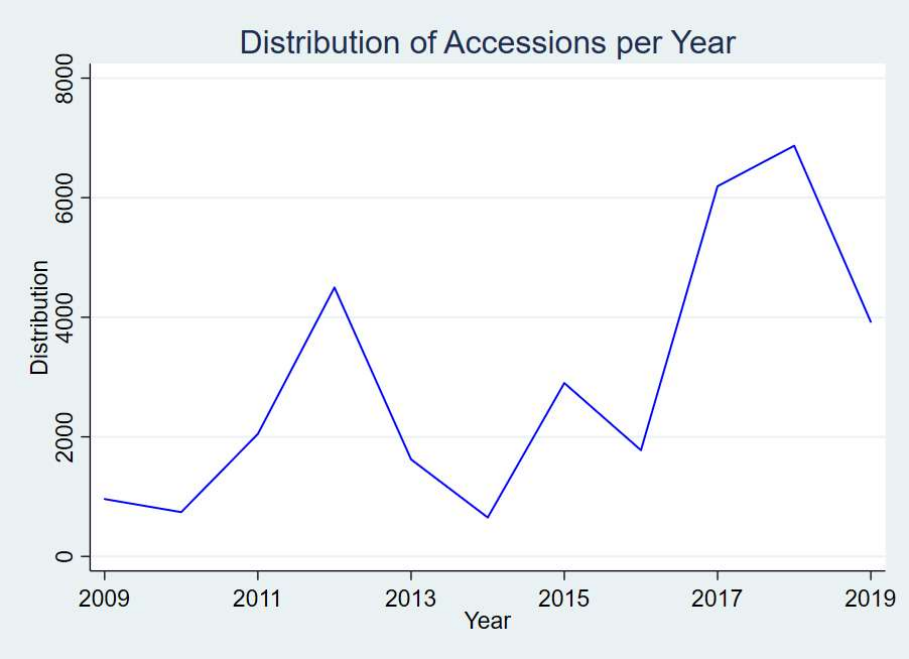


Figure 3. Distribution of accessions by crops per year

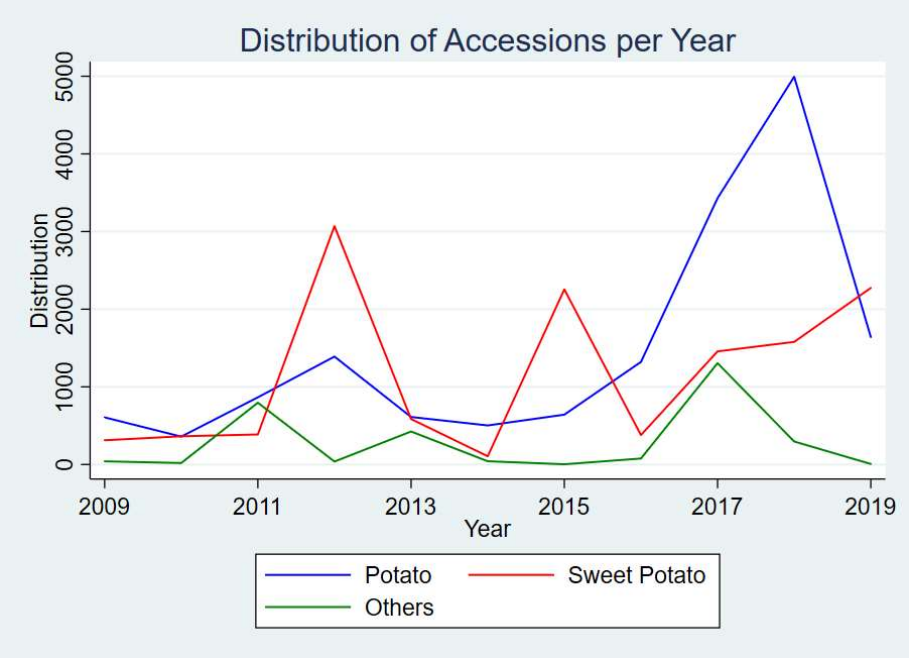


Figure 4. Distribution of traditional and breeding accessions per year

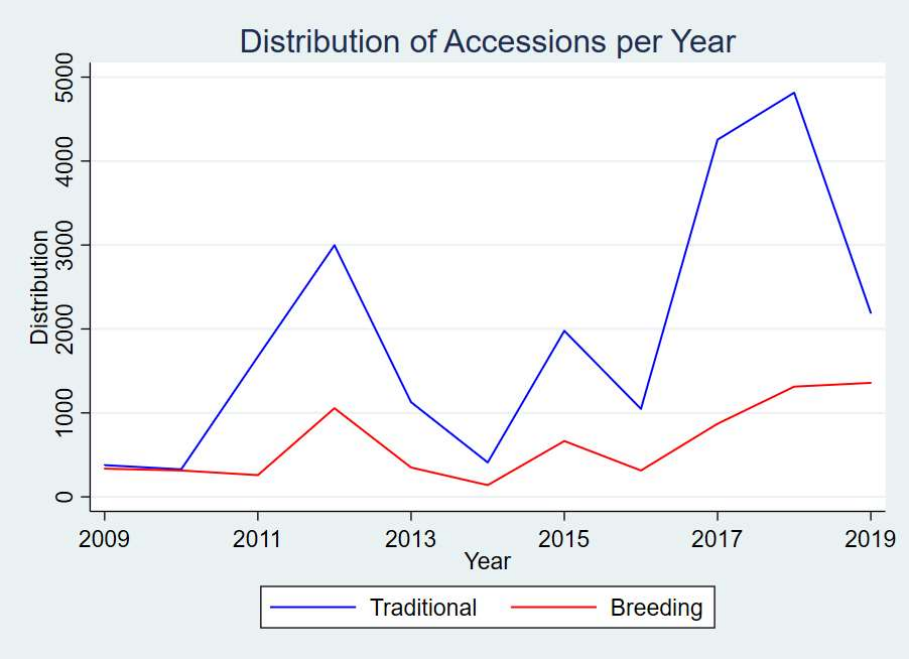


Figure 5. Distribution of improved and wild crops per year

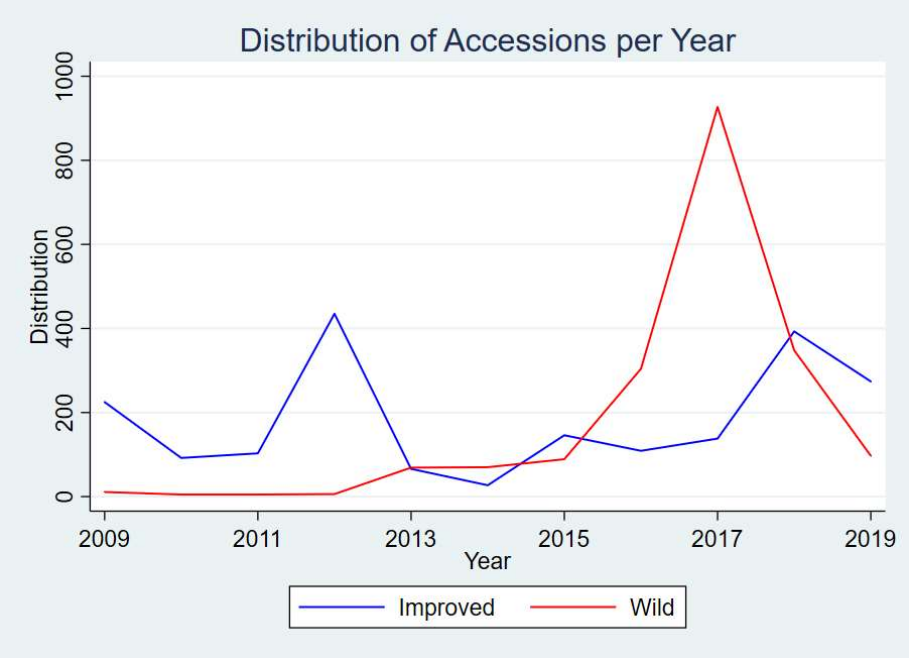


Figure 6 Distribution to Institutions per year

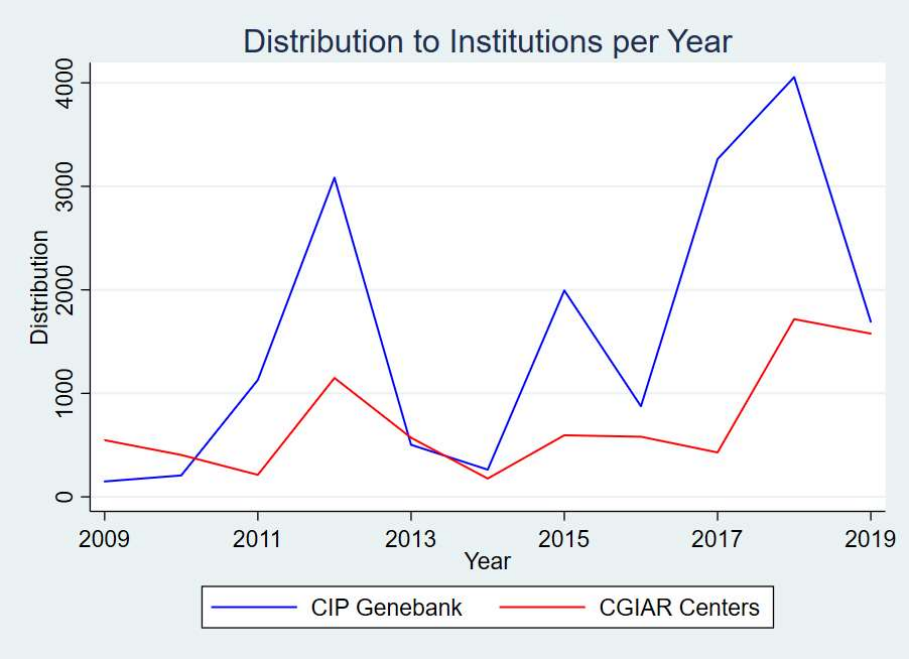


Figure 7. Distribution to Research Institutions per year

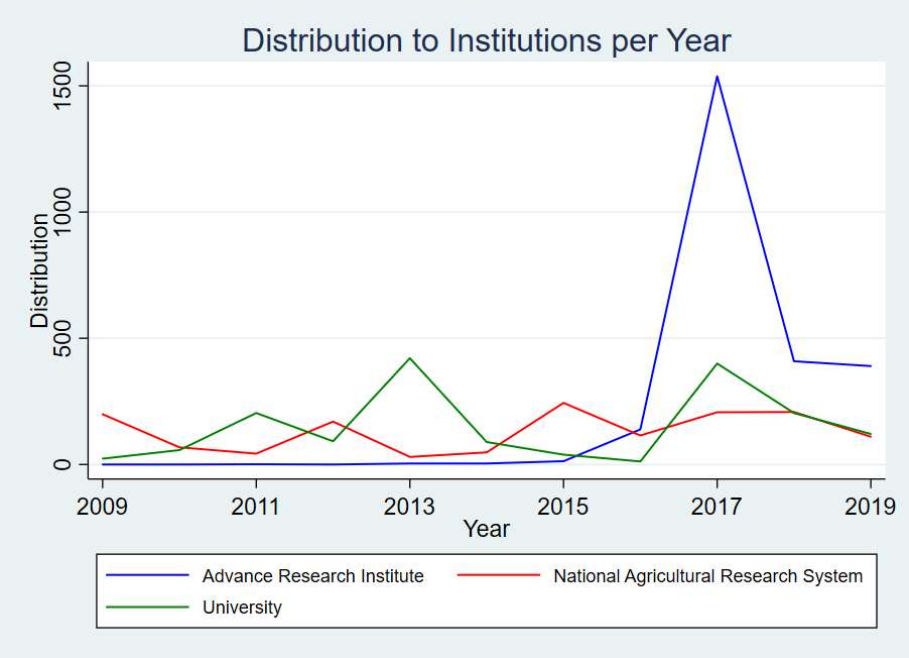


Figure 8. Distribution of accessions to Countries per Year

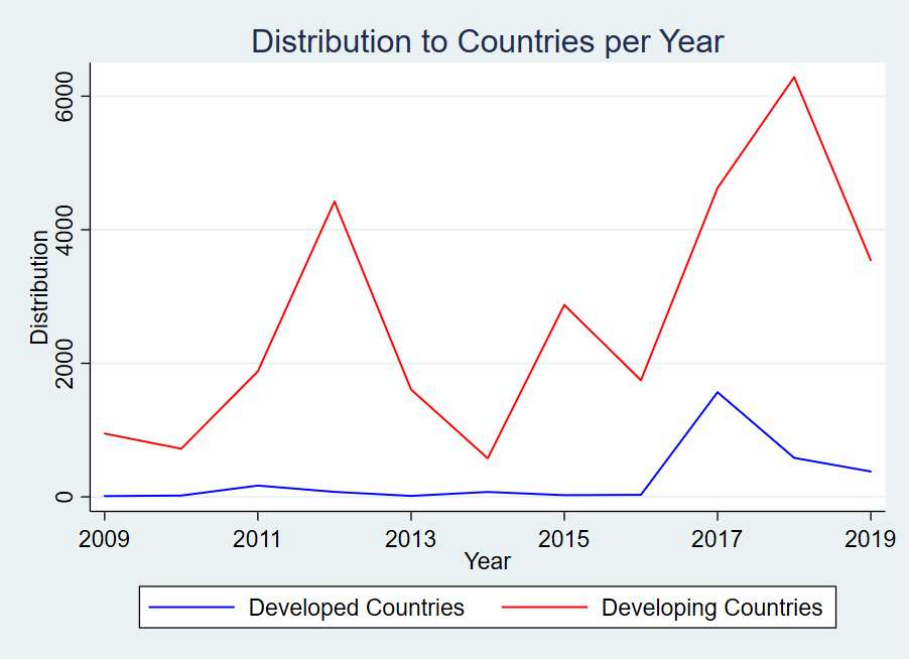
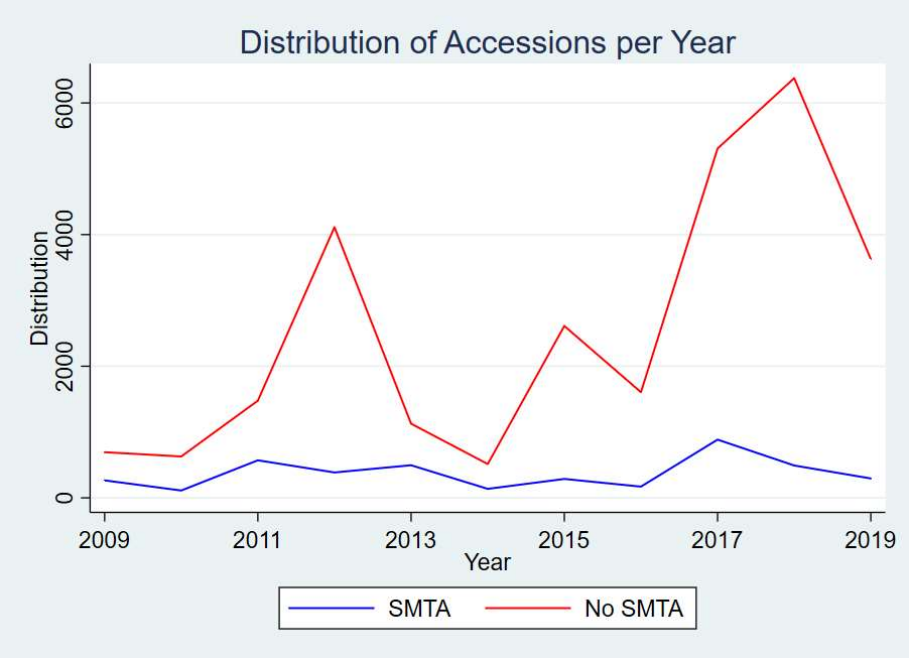


Figure 9. Distribution of SMTA accessions per year



Bioversity accessions

The banana genebank of Bioversity International contains more than 1,100 banana varieties. From 2009 to 2018, a total of 7,437 samples were distributed. Of these, just over 48% were covered by the SMTA. Banksii, Gros Michel, Calcutta 4, Pisang Mas and Mbwazirume form the main varieties distributed. Despite this, they represent only the 5.47% of the total varieties distributed in the period considered.

As can be seen from Table 6, more than 70% of the accessions distributed in the considered period are traditional cultivars. Improved varieties are the least represented typology. Only 9.32% of the bananas accessions distributed were improved varieties. The remaining varieties were wild (i.e. almost 20% of the total).

Focusing on the institutions that received the varieties present in the genebank, NARS represents the principal institution, with a percent of more than 25% of the total. Of this, more than 9% were part of the SMTA. Next, we find the Universities and ARI. These institutions received 21.27% and 21.08% of the total accessions respectively. Going further, 11.43% of the accessions distributed in the period considered were assigned to the CGIAR Centers, but less than 5% were part of the SMTA. Other institutions that have accessed to the genebank are commercial actors and regional organizations. Overall, ARI had access to the highest percentage of crops that were part of the SMTA. In particular, more than 13% of the samples received were part of the SMTA.

At the bottom of Table 6, information is provided on the distribution of accessions to the different countries. In the 10 years considered, 60 countries had access to the varieties present in the genebank. Belgium was the leading beneficiary, followed by China. The former received 12.71% of the varieties, while the second received 12.67% of the total. Moreover, we find France, The Czech Republic and Tanzania which respectively accessed 9.86%, 8.54% and 5.16% of the total varieties.

Table 6 Bioversity International accessions

Variables	***Distribution***	***SMTA***
Varieties		
Banksii	1.71%	0.59%
Gros Michel	1.05%	0.42%
Calcutta 4	1.04%	0.36%
Pisang Mas	0.85%	0.28%
Mbwazirume	0.83%	0.23%
Others	94.53%	46.44%
Biological Status		
Traditional	70.77%	35.66%
Improved	9.32%	3.63%
Wild	19.91%	9.04%
Institutions		
CGIAR Centers	11.43%	4.57%
Advance Research Institute (ARI)	21.08%	13.16%
National Agricultural Research (NARS)	25.35%	9.24%
University	21.27%	9.30%
International Agricultural Research Centers (IARC)	3.47%	1.65%
Others	17.40%	10.39%
Countries		
Belgium	12.71%	7.65%
China	12.67%	7.87%
France	9.86%	6.86%
The Czech Republic	8.54%	3.58%
Tanzania	5.16%	1.60%
Others	51.07%	20.77%

Focusing on the distribution of accessions per year (Fig.10), no predominant trend is observed, however there are several distribution peaks. In particular, in 2013 and 2015 there were years of particular distribution. From the analysis of the type of material distributed, it is observed that the peaks concern both traditional and wild but not improved (Fig.11). As for the receiving institutions, the trend observed for CGIAR and NARS is decreasing, while the others (ARI, University and IARC) are relatively constant (Fig.12 and 13). Going further, it is possible to observe a reversal of the trend towards the end of 2011 between developed and developing countries (Fig.14). A similar switch can be observed in Fig.15 regarding the accessions that were part of the SMTA.

Figure 10. Distribution of accessions per year

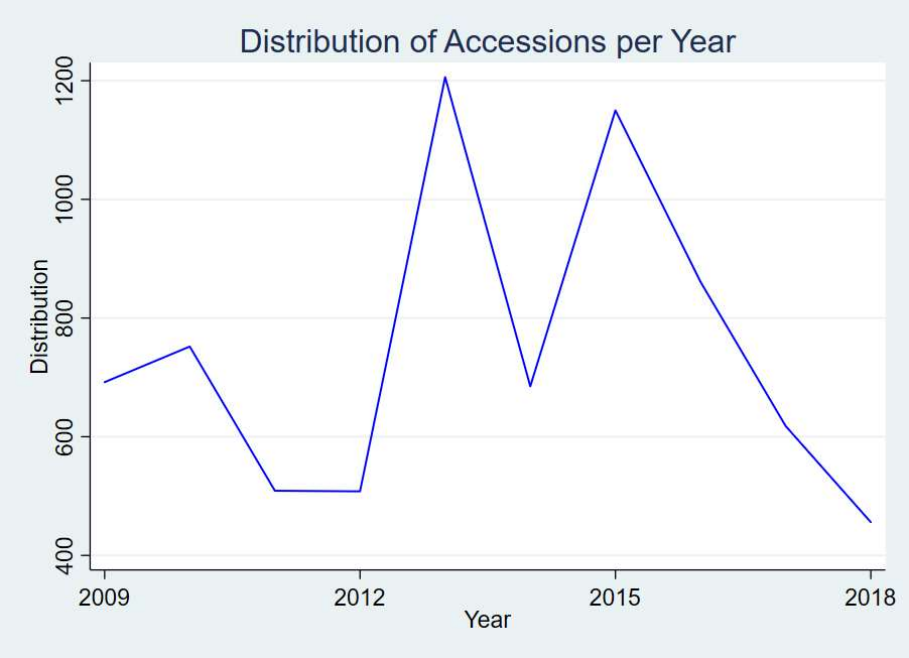


Figure 11. Distribution of traditional, improved and wild crops per year

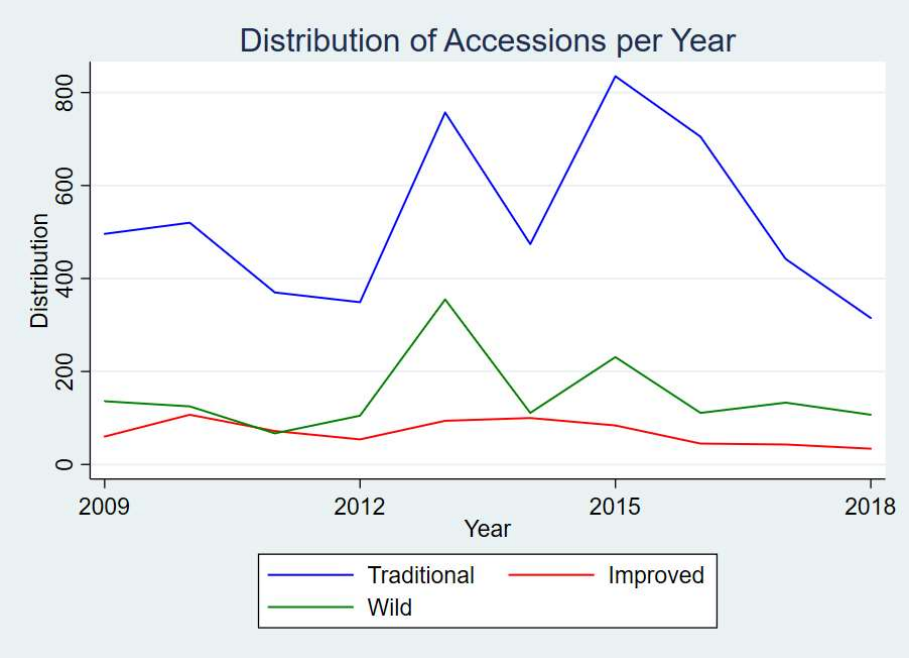


Figure 12. Distribution to CGIAR per year

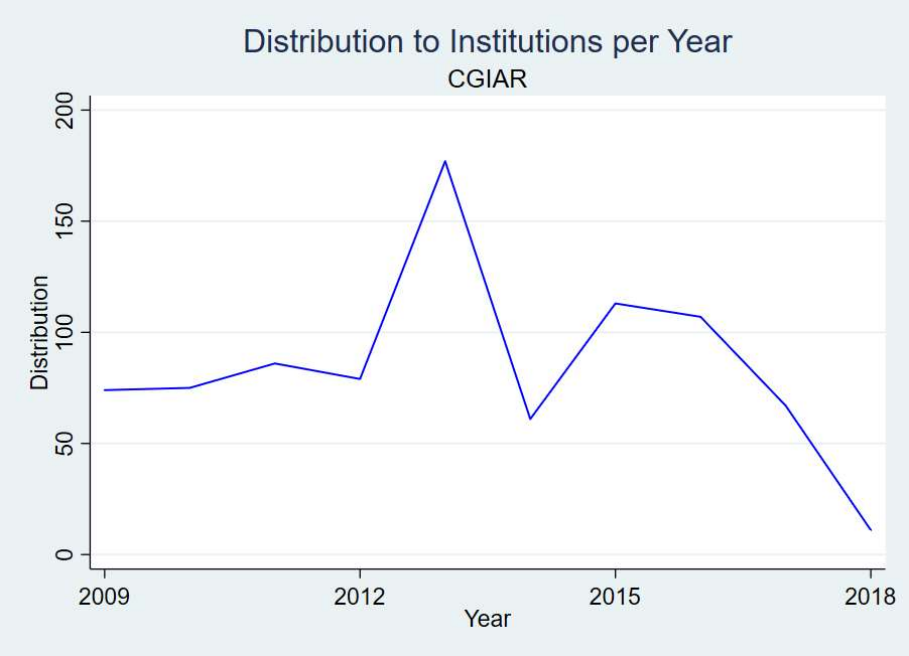


Figure 13. Distribution to Research Institutions per year

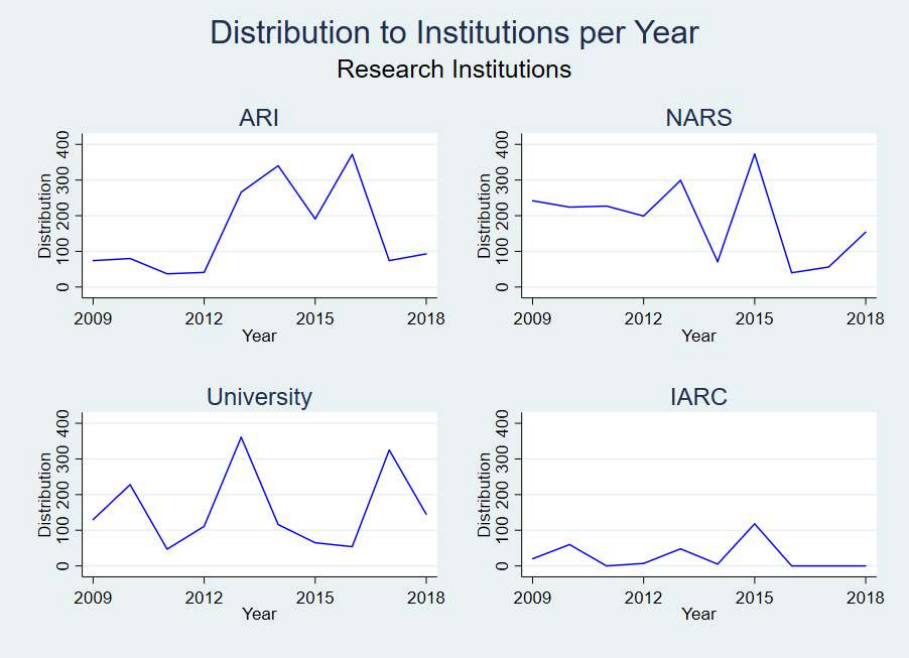


Figure 14. Distribution of crops to Countries per Year

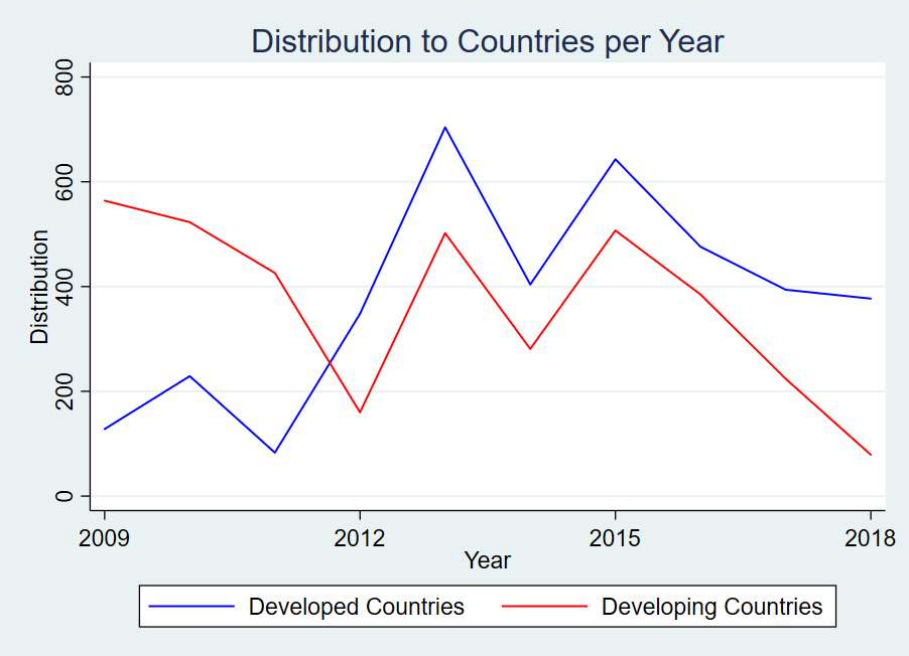
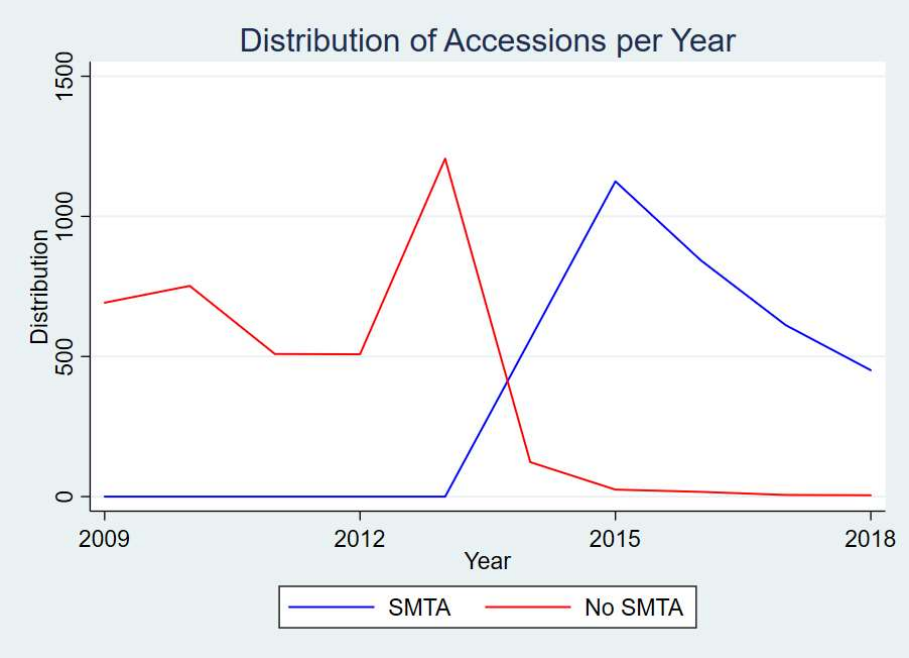


Figure 15. Distribution of SMTA bananas per year



Open Issues

The discussion held with genebank managers highlighted a number of issues which should be accounted for the further development of the study. Main findings show that:

Digital Sequence Information (DSI) emerged as a possible source of confusion: some centers apper to register information differently, as for example CIP is using SMTAs to send out germplasm to commercial companies with the intention of requesting their service to digitalize the germplasm that was sent. In other words, CIP is sending material off to commercial companies, paying for their services, and getting the data back - which is different to a commercial company requesting material for use. The case described was motivated by researchers within the organization to collect data through a commercial company. In the case of CIP distribution data, this can be checked out by looking at all the associated details within the request. However, discussion is ongoing on how to avoid the inclusion of this possibly misleading information in the data collected by other genebanks.

A comprehensive study would require the inclusion of data on PGRFA under development: Looking at the statistics of the transfers by the CGIAR Centers, the bulk of the materials transferred are what is called “PGRFA under development” (PuD). In the report of the CGIAR Centers to the last Governing Body meeting (GB7) in 2017, it appears that at least 80%, if not more, of the materials transferred are classified as PuD. These materials are the breeding materials coming out of breeding programs of the CGIAR Centers, not from the CG genebanks. Taking into account this aspect, the research team might consider including PuD materials as well. In that way, we are likely to find more private companies as recipients of PuD than as recipients of accessions from the genebank. Entities closer to using the materials for breeding to potentially release promissory materials as commercial varieties or lines are in general much more interested in PuD than in accessions from the genebank. An entity in general has to invest much more work and resources in genebank accessions to get to a stage of promissory materials for release than if they access and use already worked, tested, pre-bred materials.

Data Sources are fragmented: In terms of how the transfer of materials is handled at CG Centers, the research team found that in some Centers (for example CIMMYT) the management for all germplasm exchanged (that is, both out of the genebank and out of the breeding programs), is centralized. One unit or department at the Center handles everything that goes in and out and has a unique database with all the transfers information (i.e. genebank accessions and PuD materials are all in one database). Other Centers, such as CIAT, have multiple “outlets” managing the transfer of materials. The CIAT genebank handles only the genebank accessions and has a database for them alone, while each CIAT breeding program handles its own breeding materials and consequently handles its own database for it. Therefore, if we opt for the inclusion of PuD materials, the potential decentralization of information on transfers could be an issue to take into account.

Next Steps

The research team acknowledges that the project will continue until December 2021. The activities expected to be implemented in the coming months will focus on the finalization of the data collection and data processing. Specifically, the next steps can be ordered as follows:

1) **Identification of suitable genebanks for study participation:** Among those genebanks whose focal points expressed interest and willingness to participate to the study, it is most likely that the final choice will partially deviate from the original idea of selecting two centers' genebanks. Ultimately, such choice could fall on Bioversity International, CIP and CIAT due to the stronger ties currently in place with their focal points, and the consequent easiness of data comprehensiveness, timely availability and collection.
2) **Submission of Data Sharing and Confidentilaity Agreement:** With every genebank of choice, a specific letter of agreement for data use will be drawn up. A draft agreement is now finalized and has being shared with the genebanks focal point for further feedback and final approval.
3) **Collection of quantitative data:** Once the terms and conditions for data use are agreed upon, the research team will work in close collaboration with each selected center to gather the requested information in the form of a standardize dataset containing all the necessary variables for the econometric analysis.
4) **Schedule and conduction of Key Informants Interview for scenarios validation:** Throughout the time that the quantitative dataset is assembled, we plan to schedule qualitative interviews with Key Informants aimed at enriching and validating the scenarios developed so far. These interviews will not be limited to the genebanks focal points selected for the quantitative, econometric analysis. On the contrary, the research team believes that the involvement of as many CG genebanks as possible would ensure on one hand the representativeness of their inputs and, on the other, a more impartial evaluation of their opinion.

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