

Article

Conservation and Use of Genetic Resources of Underutilized Crops in the Americas—A Continental Analysis

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Abstract: Latin America is home to dramatically diverse agroecological regions which harbor a high concentration of underutilized plant species, whose genetic resources hold the potential to address challenges such as sustainable agricultural development, food security and sovereignty, and climate change. This paper examines the status of an expert-informed list of underutilized crops in Latin America and analyses how the most common features of underuse apply to these. The analysis pays special attention to if and how existing international policy and legal frameworks on biodiversity and plant genetic resources effectively support or not the conservation and sustainable use of underutilized crops. Results show that not all minor crops are affected by the same degree of neglect, and that the aspects under which any crop is underutilized vary greatly, calling for specific analyses and interventions. We also show that current international policy and legal instruments have so far provided limited stimulus and funding for the conservation and sustainable use of the genetic resources of these crops. Finally, the paper proposes an analytical framework for identifying and evaluating a crop's underutilization, in order to define the most appropriate type and levels of intervention (international, national, local) for improving its status.

Keywords: underutilized crops; NUS; genetic resources; Latin America; conservation and sustainable use; international policies

1. Introduction

In an increasingly globalized and interdependent world, eradicating hunger and poverty is not only an ethical imperative but an essential prerequisite for peace and world security. The challenge of feeding the expected 9 billion world population by 2050 in a sustainable manner can be met, among other measures, by rescuing and using more diversity in agricultural and food production systems, both in terms of crop as in terms of varieties within any given crop [1,2]. The human population today derives most of its calories from a very narrow set of crops, with only about 30 species providing 95% of the global food energy [3,4]. On the contrary, over 7,000 species are known as edible and are either partly or fully domesticated, suggesting that a large share of potential food sources is underutilized [5,6].

Latin America is home to a number of dramatically diverse agroecological regions which harbor a high concentration of crop diversity. This is particularly the case for the broadly defined diversity hotspots of Mesoamerica, the Andean region and the Amazon Basin, identified by Vavilov as key centers of plant domestication [7,8] and where genetic resources in traditional farming systems initially developed by indigenous people have undergone centuries of cultural and biological evolution. Some of the crops from those centers of origin and diversification have acquired global relevance (e.g., maize, potatoes, cassava), whereas others have retained a more local distribution. Early marginalization of some native crops may be traced back to the time of European colonization of Latin America; local species which were part of Pre-Columbian food systems were gradually substituted by crops from the Old World or local crops which attracted newcomers' attention [9]. More recent agricultural developments, particularly since the Green Revolution, deepened this marginalization by focusing on a package of staples (mostly wheat, maize and rice) on which a large percentage of the world population was already dependent for food security and to which priority investments were dedicated [10]. For these and other reasons, a number of Latin American edible plant species are nowadays considered minor, underutilized or neglected and, have joined a category of useful plant species often referred to as "NUS" (neglected and underutilized species). We will use the acronym as well as the adjectives listed above interchangeably throughout the study to refer to these crops.

Although a standard definition of NUS does not exist, a number of studies have described the typical features of NUS and the overriding issues affecting the conservation and use of their genetic resources [11–15]. In this paper, we aim to contribute to the discussion by critically analyzing the status of an expert-informed list of underutilized food crops in Latin America in light of the most commonly described features of underutilized crops. We also discuss the extent to which existing international policy and legal frameworks dealing with wild and cultivated biological diversity effectively support or not the conservation and sustainable use of underutilized crops' genetic resources.

2. Methods

In order to obtain an expert-informed list of crops which could be considered underutilized in Latin America, we prepared and circulated a survey to 120 experts involved in the conservation and use of plant genetic resources for food and agriculture (PGRFA) in 15 Latin American countries. In the survey, we asked them to list crops they considered underutilized in their country and to define their potential relevance, the limiting factors affecting their conservation in *ex situ* facilities, in the wild and on farm, and the effect of international biodiversity conventions on their conservation and sustainable

use (text of the survey is available in Annex 1). The list of crops emerging from the survey was used to test the features commonly attributed to an underutilized crop and to analyze the influence of selected international policy frameworks on the conservation and use of their genetic resources. The selection of the common features was guided by Padulosi *et al.* 2004 [15]: the authors identified a series of characteristics which are attributed to NUS and their work is often cited as a reference in this subject area. Table 1 shows the criteria and the relative sources of information, in addition to the surveyees answers, we used to evaluate the status of the crops in relation to each of the commonly attributed features considered.

Table 1. Criteria and relative sources of information for the evaluation of crops' status.

Feature Commonly Attributed to Underutilized Crops	Criteria and Sources of Information for Testing the Feature against the Listed Crops
Limited research efforts devoted to the species	Number of hits in Google Scholar [16], using the common name and the scientific name of each of the species ¹ . Google Scholar searches publications in scholarly literature of all disciplines.
Limited representation of the species in globally available <i>ex situ</i> collections	Number of accessions of the species in Genesys (the database of the collections held by the consortium of international agricultural research centers of the CGIAR, the Department of Agriculture of the United States of America, USDA and public research institutes of the European countries) [17], in the catalogue of CATIE (Centro Agronómico Tropical de Investigación y Enseñanza) [18] and the database of the genebank at the World Vegetable Center (AVDRC) [19].
Limited representation of the species in national <i>ex situ</i> collections	Number of accessions maintained in selected national genebanks (Bolivia, Brazil, Ecuador, Mexico, Peru) ² according to the information provided by the World Information and Early Warning System (WIEWS) [20] of the Food and Agriculture Organization of the United Nations (FAO) and the countries' reports [21] for the preparation of the <i>Second State of the World's Plant Genetic Resources for Food and Agriculture</i> [22].
Limited efforts in germplasm characterization	Availability of internationally developed descriptors, according to Bioversity International's list [23]
Limited knowledge of the species' distribution and production levels	Number of hits in the Global Biodiversity Information Facility (GBIF) [24] which contains species' occurrence data associated to samples deposited in a number of national and international institutions working with plants (genebanks, herbaria, botanical gardens, <i>etc.</i>) ³ . Presence/absence of each crop in FAOSTAT [25], the database maintained by the Statistics Division of FAO, which provides data relating to food and agriculture production for 200 countries.

¹ We used English, Spanish and Portuguese common names for each of the species. The search was limited to the title of the publications included in Google Scholar from 1970 to 2013. Patents and citations were excluded.

² These countries were selected because of the predominance of answers we received from experts working there, and as an attempt to cover albeit partially some of the main hotspots of the continent's diversity.

³ The search was restricted to Latin America and the Caribbean. Duplicates were removed and only georeferenced observations were retained, given that these are the only ones capable of providing direct, meaningful information on a species' distribution.

Table 1. Cont.

Feature Commonly Attributed to Underutilized Crops	Criteria and Sources of Information for Testing the Feature against the Listed Crops
Lack of plant breeding efforts and commercial varieties of the crop species	Number of long-term research and improvement programmes in selected countries (Bolivia, Brazil, Ecuador, Mexico, Peru) from the countries' reports for the preparation of the <i>Second State of the World's Plant Genetic Resources for Food and Agriculture</i> .
	Number of varieties in the Plant Variety Database (PLUTO) [26] of the Union for Protection of Plant Varieties (UPOV), which includes varieties registered in the national listings of varieties admitted for commercialization, varieties subject to plant breeders' rights and varieties subject to plant <i>sui generis</i> patents.

Table 2 shows the sources of information that we used to assess the impact of three selected international policy instruments on the conservation and use of the genetic resources of minor crops.

Table 2. Sources of information for the assessment of the influence of international policy instruments on the conservation and use of the genetic resources of minor crops.

International Instrument	Source of the Information and Methodology for Analysis
Convention on Biological Diversity	In the project data base of the Global Environmental Facility (GEF) [27] we performed a search of national and global projects dealing with agricultural biodiversity between 1991 and 2012, measured against the total funds disbursed in the biodiversity focal area.
International Treaty on Plant Genetic Resources for Food and Agriculture	We used the information on the Benefit Sharing Fund's webpage [28] to identify projects that deal with minor crops listed by the experts consulted in the survey. The share of efforts devoted to underutilized crops by the Global Crop Diversity Trust (GCDDT) was measured by checking the list of the technical support projects to <i>ex situ</i> collections which have been carried out [29].
Global Plan of Action for the Conservation and Sustainable Utilization of Plant Genetic Resources for Food and Agriculture (GPA)	We filtered information about NUS projects from the GPA project database [30] and the national reports submitted to FAO for the preparation of the <i>Second Report on the State of the World's Plant Genetic Resources for Food and Agriculture</i> . This analysis focused on Bolivia, Brazil, Ecuador, Mexico and Peru ¹ . The information obtained from these sources was complemented with data available on the websites of the largest public research organizations of these countries.

3. Results

3.1. An Expert-Informed List of Underutilized Crops in Latin America

We received 40 complete answers from researchers in 12 countries, resulting in a response rate of 30 per cent. Table 3 shows the respondents' field of expertise.

Although the response rate was relatively low, the number of crops listed as underutilized totalled 84 between genera and species (listed in Annex 2, Table A1). Species were more frequently reported, as requested in the survey, but in a few cases entire genera considered predominantly underutilized were also referred to (such as *Cucurbita*, *Carica*, *Xanthosoma* and *Passiflora*). We removed the three

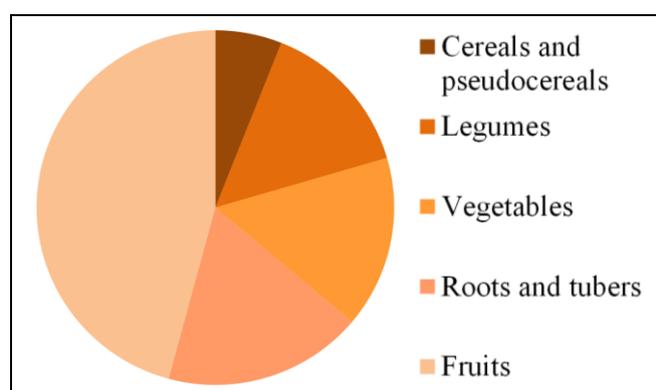
medicinal species which were reported, since the focus of the present article is on food crops. It is worth noting that 70% of the crops in our list are included in the list of Crops for the Future [31], an international organization with the mandate to document and promote research and awareness on underutilized species globally.

Table 3. Respondents' field of expertise. The total exceeds 100% because some respondents are involved in more than one field.

Respondents Field of Expertise	Percentages of Answers
<i>Ex situ</i> conservation	81.82
<i>In situ</i> conservation	27.27
Crop improvement	50
Policies	18.18
Other	34.09

Acknowledging this list in no way represents a neither exhaustive nor definitive picture, we considered it as an informative guide to orient our analyses and discussions. As shown in Figure 1, fruits were by far the category hosting the largest share of underutilized crops with 38 highlighted species, followed by roots and tubers with 15. All of the 38 fruit species are native to the continent, as well as all the 15 roots and tubers. Most of the species from other categories are also natives (88 per cent of the total), originating either in the Andean (e.g., grains and tubers), Mesoamerican (e.g., beans, sapotes) or Amazonian centers of diversity (cassava, peach palm, copuazú, among others).

Figure 1. Crop categories represented in the list of underutilized species resulting from the survey among Latin American experts.



When asked to describe the potential use and relevance of each listed species, respondents almost invariably (in 95% of the cases) selected more than one option, suggesting that underutilized crops have a multi-purpose potential. Nevertheless, the most frequent answer was dietary diversification, equaled by diversification of agricultural systems and followed by food security.

3.2. Testing NUS Features against the List of Latin American Underutilized Crops

This section presents the results of our testing of the common features attributed to neglected and underutilized crops against the list of species obtained from the survey, combined with the

respondents' perceptions. Some of the tested features have to do with research and conservation (Sections 3.2.1 and 3.2.2) whereas others are more related to use (Sections 3.2.3 and 3.2.4).

3.2.1. Limited Research Efforts Dedicated to the Species

Our survey revealed that the lack of research efforts only came third in the ranking of the main limiting factors affecting conservation and use of minor crops' genetic resources. When complementing this perception with an analysis of the degree of widely available scientific literature using Google Scholar searches performed in November 2013, we found that the average number of hits for our species was 1,954. Out of the 84 crops constituting our list, 67 species (*i.e.*, 79 per cent) have a lower than average number of hits, whereas the remaining 17 are above average. For an idea of scale, the score in literature hits for major cereals (rice, wheat and maize) with the same search criteria was just below 99,000, while for major vegetables (average between cabbage and tomato) it was 42,000. For chili pepper, common bean and potato (considered the major spice, legume and root/tuber of reference) we retrieved respectively 63,300, 31,600 and 67,400 hits. Average number of hits for three major fruit crops (pineapple, papaya and apple) was 25,540. All these values, as expected, largely exceed the average of hits retrieved for the crops treated here (Table 4).

Table 4. Comparison between literature hits in Google Scholar between the crops in the Latin American list of underutilized species and selected reference major crops.

NUS Categories	Average N. Hits		Average N. Hits	Major Crop of Reference
Cereals, pseudocereals	3,494	←→	98,967	Maize, wheat, rice
Fruits	1,056	←→	25,540	Apple, pineapple, pawpaw
Legumes	2,013	←→	31,600	Common bean
Roots and tubers	2,697	←→	67,400	Potato
Vegetables	1,768	←→	31,345	Cabbage, tomato

Species which feature in Google Scholar with a number of hits below the dataset's average (*i.e.*, less than 1,954 hits) are mostly crops natives to the continent (with only four exceptions, being exotic vegetables like verdolaga, winter melon, sponge gourd and lablab bean). Species at the top end of the range, with over 5,000 literature hits, are mostly crops of broad worldwide cultivation and commercial distribution (asparagus, sweet potato, cowpea, chilies and cassava).

3.2.2. Limited Representation in *ex situ* Collections

3.2.2.1. International Collections with Facilitated Access

It is often argued that a common feature of NUS is that they are conserved mostly on-farm and scarcely represented in *ex situ* collections [15], particularly in those collections which make their samples and the related documentation freely available for research and development purposes. Most PGRFA-based agricultural research in developing countries has been possible thanks to the germplasm conservation, documentation, characterisation and distribution services of the network of genebanks of the CGIAR [32]. Other institutions with vast, well documented and freely available collections which have been and still are instrumental in providing the genetic basis for breeding and improvement

programs of a number of crops are the European genebanks, and those of the USDA-ARS (Agricultural Research Service of the US Department of Agriculture), CATIE (Centro Agronómico Tropical de Investigación y Enseñanza) and AVRDC (The World Vegetable Center).

Of all the crops in the list, 17 (*i.e.*, 20%) have no accession in these genebanks and another 26 have less than 10 accessions, confirming that many of the species reported to be neglected are indeed poorly represented in international and regional collections. On the other hand, 22 of the crops listed as underutilized in the survey have between 100 and 5,000 accessions, countering the above mentioned negative picture. Crops which are absent or poorly represented are mostly fruit species (together with a root and two vegetables, all native); this is partly explained by the fact that most of the checked genebanks' mandate focuses on annual crops and partly by the difficulty and high cost of storing and maintaining perennials in field collections or *in vitro*. Even in the case of CATIE, with its extensive field collection in Costa Rica, fruit trees still occupy the lower end of the range in terms of numbers of accessions, with the notable exception of peach palm (*Bactris gasipaes* with over 600 samples). At the opposite end of the range of representation in the surveyed genebanks are crops such as sweet potato, cassava, cowpea, pigeon pea and squashes, which are the only ones in our list with collections exceeding 5,000 accessions.

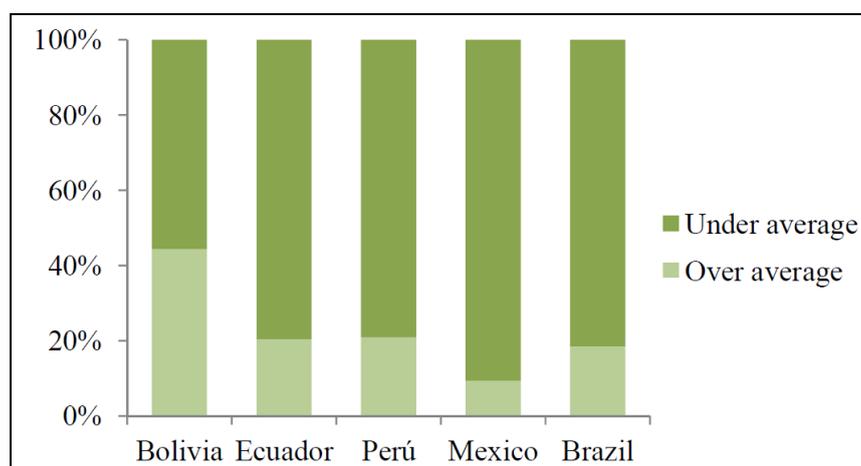
3.2.2.2. National *ex situ* Collections

In our survey, regional experts from Latin America did not rank *ex situ* conservation high among the critical areas of neglect for the species they listed. Our analyses show that, for many underutilized species in selected countries, there is a good level of representation in national genebanks (Annex 3). Collections of national agricultural research organizations in Bolivia, Ecuador and Peru (Table A2 of Annex 3) contain on average 38 of the underutilized species reported in the survey with an average 270 accessions each. Brazilian collections (Table A3 of Annex 3) store a wealth of tropical fruit trees and horticultural plants native to the continent, containing 27 of the species reported here (represented by an average 647 accessions); in Central America, the Mexican network of germplasm collections includes 53 of the crops reported in the survey, with average accession number of 365 (Table A4 of Annex 3).

However, when measuring the size of each species' collection against the average size of all underutilized crops' collections in each country, it appears that most underutilized species in national genebanks are conserved by a lower than average number of accessions (Figure 2), with a few champions contributing to the relatively high average number recorded. Underutilized species whose collections are well above average in the Andean region are mostly native grains and tubers. Quinoa collections reach 4,000 and 1,980 accessions in Bolivian and Peruvian collections, together with 487 and 2,217 accessions of oca (*Oxalis tuberosa*); over 2,000 accessions of South American lupin are conserved in Peru; native potatoes (a different set of species than the common potato) are represented by 1,760 accessions in Bolivia. In Brazil, the species whose collections greatly exceed average are legumes (*Phaseolus lunatus* with 2,673 accessions, *Vigna* with 1,787 accessions) and squashes (5,675 entries) and the large Passifloraceas fruit family. Only three crops in the Mexican genebanks have collections with more than average accessions, namely those of amaranth, chilli peppers and squashes.

A commonly observed trend in all countries is the tendency of most fruits species to occupy the lowest end of the collection size ranges, for likely the same reasons described for international collections.

Figure 2. Percentage of underutilized species conserved in national gene banks whose collections are represented by a lower than average number of accessions (light green), and percentage of those which are above average (dark green).

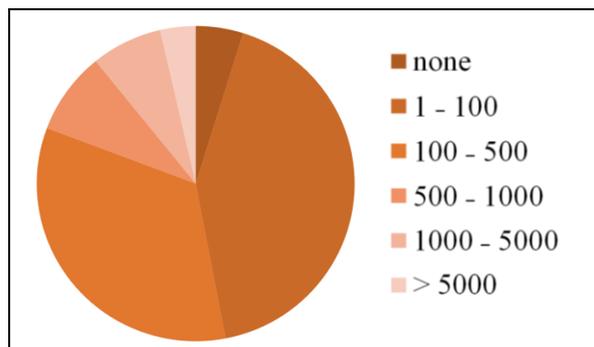


However, number of accessions per se is not a sufficient indicator of a species' status of *ex situ* conservation. Quality of the material in terms of viability and availability of accurate passport and/or characterization and evaluation data is an additional, essential measure of a collection's conservation status, since availability of this data is a precondition for using the genetic material in breeding or research. Survey respondents pointed to the technical and financial limitations to maintaining collections in good shape. Crop descriptors, which provide unambiguous guidelines for the documentation of accessions, have been developed at international level and made publicly available for only 22 of the 87 crops listed here. For one (a palm species from southern Brazil, *Butia odorata*) descriptors are currently under preparation thanks to a collaboration between Bioversity International and Brazilian experts. This of course does not exclude the likelihood of scientists using locally developed descriptors in their daily work, but this approach may limit broader sharing and comparison of their results.

3.2.3. Limited Knowledge on the Species' Distribution and Production

The lack of efforts in on-farm conservation was considered to be the most serious limiting factor to the enhancement of minor crops and, in turn, their use within farming systems by 75 per cent of the surveyed experts in the Americas. An important step towards improving the on-farm conservation of any species is having data about its current (and potential) distribution and cultivation. In addition to individuals' knowledge on these aspects, publicly available georeferenced data is a powerful starting point for studies on a crop's agroecological potential and adaptive capacity which in turn are useful for planning *in situ* conservation initiatives [33–35]. Searches performed in the data portal of the GBIF resulted in retrieval of georeferenced data for almost all the species. There is great variation in the number of observations across our dataset, ranging from no points (for only three species, all fruits) to over 2,000 for bean species (*Phaseolus lunatus* and *Phaseolus coccineus*), sweet potato and chili peppers (the latter considered as whole genus); cassava still totaled almost 5,000 observation points. Observation points for each species were spread across an average of nine countries within Latin America. Half of the species are represented by a lower than average number of observations, most often less than 500 (Figure 3). It is interesting to observe that half of the species with less than 50 observations are fruits and roots and tubers.

Figure 3. Number of observations recorded in GBIF for the species listed in our survey. Most species are recorded with less than 500 georeferenced observation points.



In terms of publicly available information on the production levels of our crops, the FAOSTAT database, which gathers and elaborates national statistics from FAO member countries, covers only 11 of our underutilized species, plus 7 generic categories which are likely to include them (such as “tropical fruits” and “roots and tubers”), over the 156 crop or crop categories represented. FAOSTAT’s section on methods and standards acknowledges that generally, production data relates to plantation crops or orchard crops grown mainly for sale, excluding many minor crops which are conserved for self-consumption or sale through local, informal channels. In particular, it is flagged that statistics on some species, particularly tropical fruits, are unavailable in many countries, and where reported often lack uniformity. We were able to access public agricultural statistics data only for Brazil [36], Mexico [37] and Peru [38]. While Brazilian statistics only mentioned major crops already covered in FAOSTAT, the Mexican and Peruvian databases allowed consulting information on some of the underutilized crops listed by our respondents (but only an additional seven in each country).

3.2.4. Lack of Plant Breeding Efforts and Commercial Varieties

A varying number of underutilized crops among those highlighted in the survey are object of institutional, longer term research and improvement programmes (see Tables 5 and 6).

These lists are likely not to be complete, but highlight significant attention to minor crops in Andean countries and to a certain extent in Mexico and Brazil (this may also depend on the smaller number of answers received from these countries and thus the smaller representation of their NUS in our list). It is important to recall that species which have been somewhat neglected by breeding are likely to harbor significant levels of genetic diversity, which not only makes them of great conservation value may also be allowing their continued adaptation to marginal environments and small-scale, low-input farming systems [39]. Therefore, breeding approaches which strive for maintaining a broad genetic basis while achieving the needed improvements in agronomic performance, product uniformity or other important aspects may be particularly relevant. The approaches commonly used in participatory plant breeding frequently aim at striking such a balance and encouraging the maintenance of diversity [40]. Curiously, in participatory breeding (PPB) programs in the Americas, underutilized crops are rarely represented: we are aware only of experiences of participatory variety selection only in the Andes on native potatoes [41,42] and of an interest and willingness to expand the maize and bean-based activities carried out in a number of Central American countries under the umbrella of the Mesoamerican Programme on Participatory Breeding to minor crops [43,44].

Table 5. Underutilized crops for which a public breeding or evaluation program exists in selected Andean countries.

Crop		Country		
		Peru	Ecuador	Bolivia
Amaranth	<i>Amaranthus caudatus</i>	✓	✓	
Chirimoya	<i>Annona cherimola</i>	✓	✓	
Soursop	<i>Annona muricata</i>		✓	
Borojó	<i>Borojoa patinoi</i>		✓	
Pigeon pea	<i>Cajanus cajan</i>	✓		
Chili pepper	<i>Capsicum</i> spp.	✓		
Papayas	<i>Carica/Vasconcellea</i> spp.	✓	✓	
Cañihua	<i>Chenopodium pallidicaule</i>	✓		✓
Quinoa	<i>Chenopodium quinoa</i>	✓	✓	✓
Squashes	<i>Cucurbita</i> spp.	✓		
Tree tomato	<i>Cyphomandra betacea</i>		✓	
Arazá	<i>Eugenia stipitata</i>	✓	✓	
Sweet potato	<i>Ipomoea batatas</i>	✓		
Andean lupin	<i>Lupinus mutabilis</i>		✓	
Cassava	<i>Manihot esculenta</i>	✓		
Camu camu	<i>Myrciaria dubia</i>	✓		
Maracuyá	<i>Passiflora edulis</i>	✓	✓	
Granadilla	<i>Passiflora ligularis</i>	✓		
Avocado	<i>Persea americana</i>	✓	✓	
Lima bean	<i>Phaseolus lunatus</i>	✓		
Inca berry	<i>Physalis peruviana</i>	✓	✓	
Lúcuma	<i>Pouteria lucuma</i>	✓		
Guava	<i>Psidium guajava</i>		✓	
Sapote	<i>Puteria sapota</i>	✓	✓	
Andean berries	<i>Rubus</i> spp.		✓	
Lulo	<i>Solanum quitoense</i>		✓	
Native potatoes	<i>Solanum tuberosum</i> ssp. <i>andigenum</i>	✓	✓	✓
Pitaya	<i>Stenocereus</i> spp.	✓	✓	
Copuazú	<i>Theobroma grandiflorum</i>		✓	
Cowpea	<i>Vigna unguiculata</i>	✓	✓	

Commercialization of seed of varieties resulting from breeding efforts is often preceded by a series of procedures aimed at officially evaluating and releasing the plant variety in the country where its commercialization is sought. Officially released plant varieties are commonly listed in national registers of commercial varieties. The presence of minor species in such registers can therefore be taken as an indication of, first, public and private organizations' breeding work on such species and, second, their interest in the commercialization of seed of improved varieties of the species, which suggests, in turn, that there is a demand for such species among farmers. The same can be said about species included in the national and international catalogues of varieties subject to plant breeders' rights. The Union for the Protection of Plant Varieties maintains a database of plant varieties included in the registers of commercial varieties and in the catalogues of varieties protected by plant breeders'

rights or plant patents in UPOV member countries. According to the information in this database, out of the 84 crops in our list, 37 have at least one variety registered in national listings or protected by plant breeder's rights or plant patents, representing around 43% of the total. The number of registered varieties however is highly variable, ranging from one as in the case of Andean fruit *Physalis peruviana* to over 500 as for asparagus. The species with no registered varieties under UPOV's database are in the great majority fruits and roots and tubers. Only 13 of the fruits species out of 38 reported by experts have commercially registered varieties, the average being five varieties; of the 15 roots and tubers searched in UPOV's database, only five have commercial varieties, the average being nine (including cassava which alone has over 17 varieties). For comparison, major staples such as wheat and maize, have 39,000 and 89,000 registered commercial varieties, whereas major fruit species such as apple and avocado have over 3,000 and over 100 respectively.

Table 6. Underutilized crops for which a public breeding or evaluation program exists in Brazil (left) and Mexico (right).

Brazil		Mexico	
Crop		Crop	
Copuazu	<i>Theobroma grandiflorum</i>	Chili peppers	<i>Capsicum</i> spp.
Cassava	<i>Manihot esculenta</i>	Amaranth	<i>Amaranthus caudatus</i>
Agraz	<i>Vaccinium</i> spp.	Squashes	<i>Cucurbita</i> spp.
Peach palm	<i>Bactris gasipaes</i>	Papayas	<i>Carica/Vasconcellea</i> spp.
Chili pepper	<i>Capsicum</i> spp.	Prickly pear	<i>Opuntia ficus-indica</i>
Squashes	<i>Cucurbita</i> spp.	Avocado	<i>Persea americana</i>
Quinoa	<i>Chenopodium quinoa</i>	Chirimoya	<i>Annona cherimola</i>
Passifloras	<i>Passiflora</i> spp.	Chayote	<i>Sechium edule</i>
Surinam Cherry	<i>Eugenia uniflora</i>	Pitaya	<i>Stenocereus</i> spp.
Feijoa	<i>Acca sellowiana</i>	Chili pepper	<i>Capsicum</i> spp.
Jelly Palm	<i>Butia capitata</i>	Amaranth	<i>Amaranthus caudatus</i>
Rio Grande Cherry	<i>Eugenia involucrata</i>	Squashes	<i>Cucurbita</i> spp.

3.3. The Influence of International Biodiversity Conventions and Programs on the Conservation and Use of Genetic Resources of Underutilized Crops in the Americas

In the last decade, the attention paid to minor crops by international policy making has increased considerably. As international conventions, programs, initiatives and projects dealing with the conservation and use of wild and domesticated biodiversity and food security have proliferated, the interest in underutilized species as key examples of the genetic diversity under threat and as potential contributors to food security has grown. However, to what extent do these international instruments have an influence on countries' management of NUS' genetic resources? Have they been able to effectively improve their conservation and sustainable use? In this section, based on data from Latin America, we critically analyze the commitments related to minor crops assumed by parties to two international conventions and one international plan of action that represent the most relevant international instruments in the area of plant diversity conservation and sustainable use.

3.3.1. The Convention on Biological Diversity

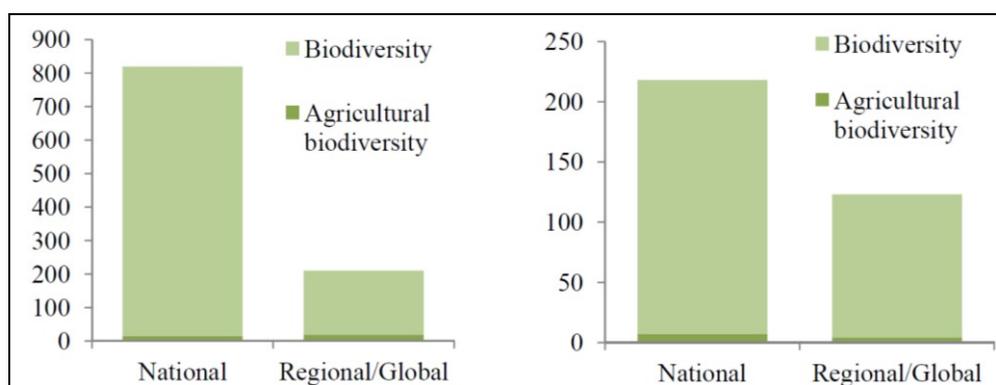
The Convention on Biological Diversity (CBD) was the first international instrument to address conservation, sustainable use and equitable sharing of benefits derived from the utilization of all biological diversity. All Latin American countries are members of the CBD. Since its entry into force in 1993, the parties to the CBD have agreed on an innumerable amount of strategies and programmes that translate the general obligations stated in the convention's text into concrete measures to be adopted at the local, national and regional levels. Some of these are more relevant than others for the conservation and use of domesticated species. In 2002, the member countries of the CBD agreed to put in place a Global Strategy for Plant Conservation (Annex to decision VI/9) with the ultimate goal to halt the continuing loss of plant diversity. It includes 16 outcome targets to be met by 2010, target 9 being the most relevant for cultivated species: "70 per cent of the genetic diversity of crops and other socioeconomically valuable is plant species conserved, and associated indigenous and local knowledge maintained". The CBD's program on agricultural biodiversity (established with Decision VI/5 of the Conference of the Parties in 2000) includes an initiative on biodiversity for food and nutrition which explicitly calls for "identification and promotion of species currently underutilized or of potential value to human food and nutrition, including those important in times of crisis, and their conservation and sustainable use" [45].

Around 20 per cent of the respondents to the survey acknowledged that increased attention had been devoted to *in situ* conservation of biological diversity, after the entry into force of the CBD in 1993. However, 60 per cent of respondents pointed that due to the convention's focus on wild biodiversity conservation and the fact that its implementation resides in the hands of Ministries of the Environment, the consideration of crop and agricultural issues is relatively weak within this framework. Interventions in the field of agricultural genetic resources directly supported by the CBD's financial mechanism are much less far-reaching than those in the field of wild biodiversity conservation. The Global Environment Facility (GEF) has been functioning since 1996 as the institutional structure to operate the financial mechanism of the Convention, providing countries and institutions with funds for carrying out conservation and sustainable use initiatives. From 1992 to 2012, agricultural biodiversity projects in the Americas received only 1.8% of the overall GEF funds disbursed at national level in the biodiversity focal area, spread out over seven projects out of 211. These seven projects (in Argentina, Bolivia, Chile, Colombia, Cuba, Ecuador and Peru) include at least some minor crops among their target portfolio, the greatest emphasis being observed in the Andean region with a focus on grains, roots and tubers and a few fruit species. In terms of GEF funds for regional or global projects including a Latin American country, agricultural biodiversity projects received a greater share of funds, reaching 9.5 per cent of the total biodiversity budget, spread over four projects out of 43 of the biodiversity focal area. Three of these include at least a partial focus on underutilized species. Figure 4 shows the small share of agro-biodiversity projects within the overall funding of the GEF.

The CBD recognized countries' sovereign rights over the genetic resources within their territories, and introduces an obligation for users of such resources to share the benefits arising from their utilization with the countries where the resources were obtained. The international recognition of countries' fundamental rights and obligations in relation to the access to, and use of genetic resources (commonly referred to as access and benefit-sharing or ABS) was brought up to avoid appropriation of

plant genetic resources from developing countries, by commercial actors usually operating in developed countries, with no benefit or involvement of the provider [46,47]. In 2010, the Conference of the Parties to the CBD adopted the Nagoya Protocol on Access to Genetic Resources and the Fair and Equitable Sharing of Benefits Arising from their Utilization, which elaborates the rights and obligations of the parties to the Convention in relation to ABS. The Nagoya Protocol has not entered into force yet. The complexity of the ABS procedures developed in many countries and the limited capacity to implement them at national level are often cited as major limitations to research on any country's biodiversity, including agricultural biodiversity and native crops [48–50]. The results of our survey point to the same direction: a strong point raised by 40 per cent of respondents when surveyed on the effect of the CBD on conservation and use of neglected crops' germplasm, resides in access and benefit sharing rules. This area of influence of the CBD was the only one in which a specific (negative) effect was detected in particular on minor species, conserved both in and *ex situ*. Perhaps the most loudly voiced concerns about access, emerging from our survey and confirmed in literature, have to do with the effects of the Andean Decision 391, directly or through derived legislation, on the Andean Community of Nations (Bolivia, Colombia, Ecuador, and Peru). Difficulties with the Brazilian and Mexican laws have also been reported [51]. Since the main scope of these legislations is *in situ* material [52], those genetic resources of minor crops which are mostly conserved on-farm rather than in genebanks fall under these usually complex and lengthy legal arrangements. Although some countries developed somewhat simplified procedures for access to material from genebanks (mostly through the design of institutional material transfer agreements, MTAs), the unclear legal scenario created around genetic resources is perceived to have affected the ease with which genebank curators grant access to their collections, for fear of infringing national law and the country's sovereign rights, particularly when the object are collections of their native crops. Data from Peru exemplify this uncertainty: the national genebank sent out genetic material under 35 MTAs for research purposes over the 2001–2009 time period but rejected applications which upfront mentioned a commercial development [53]. Respondents to the survey from other countries confirmed this tendency, in which fears of not complying with the national ABS legislation and thus exposing the nation's genetic heritage to misappropriation, combined with limited negotiation capacities of the competent authorities, make rejection a common reaction to a number of germplasm requests.

Figure 4. Share of Global Environmental Facility (GEF) funds (in million US dollars) and of GEF projects (numbers) dedicated to biodiversity and agricultural biodiversity within the overall funding strategy.



3.3.2. The International Treaty on Plant Genetic Resources for Food and Agriculture

The International Treaty (ITPGRFA) operates in harmony with the CBD, sharing the objectives of conservation, sustainable use and equitable benefit-sharing but with a narrower focus on plant genetic resources for food and agriculture, in recognition of their “special nature [...], [...] distinctive characteristics and problems, which require specific solutions” (Decision II-15 of the International Undertaking on PGRFA, Jakarta 1995). After seven years of negotiations under the auspices of FAO, the ITPGRFA was adopted in 2001, and entered into force in 2004. At the time we write this article (November 2013), 16 out of the 26 countries in Latin America are parties to the ITPGRFA.

The ITPGRFA creates a multilateral system of access and benefit sharing in which parties provide facilitated access to plant genetic resources for research, breeding, conservation and training, and commit to contribute part of the monetary benefits which may arise from the use of such resources to a common fund managed by the Governing Body of the Treaty (the Benefit Sharing Fund). The genetic resources subject to the multilateral system of the Treaty are those of species listed in the Annex 1 of the Treaty (35 globally relevant crops and 29 forages [54]), which are under the management and control of the Treaty parties and in the public domain; hosted in international *ex situ* collections like the ones of the CGIAR centers and institutions like CATIE in Latin America (according to the Treaty’s Article 15 which deals with the agreements established between the Treaty’s Governing Body and International Agricultural Research Centers, with regard to their *ex situ* collections); and those voluntarily included by other national and international organizations or individuals, for example companies or private collectors. The ITPGRFA’s multilateral system offers an alternative to bilateral ABS agreements inspired by the CBD, for an important subset of the world’s biodiversity. The text of the Treaty explicitly mentions the importance of conserving “those PGR that are under threat or are of potential use” [54] (Article 5b) and promoting the use of “local and locally adapted crops, varieties and underutilized species” [54] (Article 6.2e). Through an entire section on farmers’ rights [54] (Article 9), the Treaty also calls for protection of the rights of small scale farmers and for recognition of their traditional production systems, which provides additional space for initiatives enhancing conservation and use of minor crops and traditional varieties.

Almost all respondents to the survey (average 66 per cent) feel that the ITPGRFA has not determined significant changes in the status of conservation and use of underutilized crops; this perception of a lack of influence on minor species is particularly felt in terms of their on-farm conservation (80 per cent of respondents) *versus ex situ* conservation. The fewer respondents which did feel the ITPGRFA had a somewhat differentiated effect depending on the species, reported that germplasm distribution (30 per cent), breeding (29 per cent) and international funding (36 per cent) had improved only for major, globally distributed staples.

The correlation between countries’ obligations under the ITPGRFA and their efforts to conserve and promote the sustainable utilization of minor crops in Latin American countries is not easy to measure. The number of projects targeting NUS which have been funded by the two financial mechanisms of the ITPGRFA may be used as a tentative measure of the Treaty’s influence. One of these mechanisms is the Global Crop Diversity Trust (GCDDT), which makes funds available for improving and upgrading the status of *ex situ* collections included in the multilateral system, and the second one is the benefit sharing fund, which supports actions covering all aspects of PGRFA management. Underutilized species in the Americas have only partially benefitted from the GCDDT’s

funds. Over the three rounds of funding released to date (2008 to 2010) only few of the minor crops listed by our experts, namely Peruvian and Argentinian sweet potato collections and Mexican collections of common bean, lima bean and cowpea, have been targeted by evaluation projects. No collection project has been funded in Latin America in the 2010 round of funding. In terms of regeneration, funds from the Trust have allowed securing vulnerable accessions of 22 priority crops, including cassava, cowpea, taro, pigeon pea, sweet potato and yam among those listed here. The Trust has also launched a project in partnership with the Millennium Seed Bank of the Royal Botanic Gardens in Kew which will safeguard and use the wild relatives of 29 crops of major importance to food security, of which only four coincide with species in our list (cowpea, lima bean, pigeon pea, sweet potato). One of the explanations for this low coverage of crops from our list in the GCDT's portfolio is that its operational strategy, which is independent from the Treaty's Funding Strategy, explicitly prioritizes *ex situ* collections of species listed in the Annex 1 of the Treaty, *i.e.*, major species of global importance and distribution. Furthermore, even if exceptions are made to this Annex 1 preference, the Trust funding mechanism also requires that the target collections be effectively exchanged according to the rules of the multilateral system of access and benefit-sharing, *i.e.*, be placed within the MLS. These conditions are seen by some respondents as a limitation to the possibility of obtaining funds for the conservation of those underutilized crops which parties are not necessarily willing to put in the multilateral system and prefer keeping under the CBD-inspired access and benefit sharing mechanism in place. It is anyhow important to acknowledge that the Trust has also supported broader initiatives such as the drafting of the Hemispheric Strategy for the Americas [55], which aimed at assessing the most important crops and collections in the hemisphere and providing recommendations for their continued *ex situ* conservation. Forty-nine of the total 85 species in the Hemispheric Strategy's list overlap with those highlighted in the present survey.

The benefit sharing fund of the Treaty, whose priorities are informed by the Treaty's Funding Strategy (adopted by the Governing Body of the Treaty at its first session, Resolution 1/2006) and its Annexes on eligibility criteria and funding priorities (adopted by the Governing Body at its Second Session in 2007), does not have a formally declared intention to focus on specific crop categories. Admittedly, a requirement to focus on Annex 1 crops was introduced in one of the two windows which made up the second call for proposals (released in 2010), making roughly half of the funding portfolio unavailable to most NUS in that cycle. Overall, out of the nine projects awarded funding in Latin America, only two explicitly target underutilized crops from our list. Another three include underutilized species among the portfolio of target crops (see Table 7 for details).

The creation of the Treaty's multilateral system of access and benefit sharing has not until now addressed the shortcomings of CBD-inspired ABS rules in Latin America due to a great extent to the very modest level of implementation of the system in most of the ITPGRFA member countries [56]. The only Latin American country that has officially notified the national *ex situ* collections included in the multilateral system is Brazil with rice, maize, bean and cassava collections held by Embrapa. Except for Embrapa's cassava collection, no national collection of any minor crop among those listed here has been included in the multilateral system. However, even under the best-case scenario of a well implemented multilateral system, many underutilized crops are likely not to be covered by its scope: only 14 (16%) of the species reported as underutilized here are in the Annex 1 of the ITPGRFA (although parties are free to place non-Annex 1 collections in the system), and most of the genetic

resources of those species are found on-farm, for which the application of the rights and obligations of the Treaty's multilateral system is unclear. Only three of the 22 respondents who expressed and motivated their opinion on the possible benefits of the Treaty's implementation to conservation and use of NUS germplasm, mentioned they did not see any benefits; the other experts feel there is scope for ITPGRFA-driven improvements in minor crops' status.

Table 7. Projects supported by the Treaty's Benefit Sharing Fund in its current two rounds of funding and coverage of underutilized crops.

	Title	Targeted country or countries	Focus on underutilized crops
First round projects	Identification of useful potato germplasm adapted to biotic and abiotic stresses caused by global climate change	Costa Rica	no
	Rescue, conservation and sustainable management of teocintle in Nicaragua (<i>Zea nicaraguensis</i> Iltis & Benz) in the Apacunca Genetic Reserve	Nicaragua	no
	Contribution of traditional methods for the <i>in situ</i> conservation and management of maize (<i>Zea mays</i> L.) and bean (<i>Phaseolus</i> spp.) to the food security of farming families in Cuba	Cuba	no
	Conservation and Sustainable Use of Native Potato Diversity in the "Potato Park"; Cusco, Peru	Peru	yes
	Broadening of potato (<i>Solanum tuberosum</i>) genetic basis through introgression of local wild species, <i>Solanum commersonii</i>	Uruguay	no
Second round projects	Participatory and science-based formulation of a Strategic Action Plan to strengthen the conservation of plant genetic resources and their enhanced use in adapting to climate change in Mesoamerica	Guatemala, Belize, El Salvador, Honduras, Nicaragua, Costa Rica, Panama, Mexico	partial
	Shared management and use of (agro)biodiversity by indigenous and the traditional communities from the semi-arid region of Minas Gerais State as a strategy for food security and to reduce climate risks	Brazil with partner applicants in: Costa Rica, Nicaragua, Guatemala, Cuba, Haiti, Mozambique	partial
	Conservación y manejo sostenible del germoplasma de papas nativas en las comunidades campesinas de la Provincia de Andahuaylas	Peru	yes
	Establecimiento de una red preliminar de bancos comunitarios de semillas, en regiones vulnerables del país, para disponer de semillas en caso de desastres naturales	Guatemala	partial

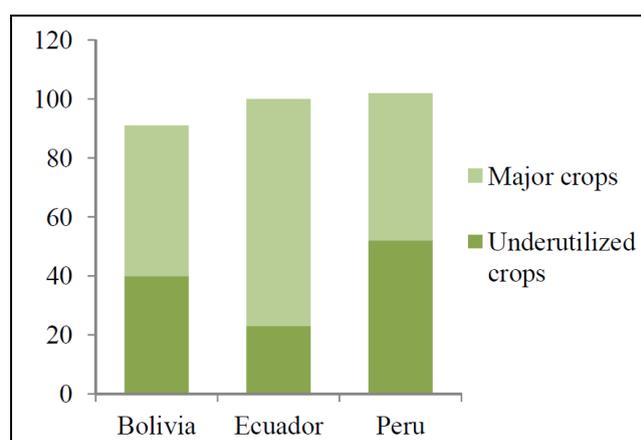
3.3.3. The Global Plan of Action for the Conservation and Sustainable Use of Plant Genetic Resources for Food and Agriculture

The Global Plan of Action for the Conservation and Sustainable Utilization of Plant Genetic Resources for Food and Agriculture (GPA) is a set of recommendations developed by the Commission

on Genetic Resources for Food and Agriculture of FAO, and based on the Report on the State of the World's Plant Genetic Resources for Food and Agriculture. The GPA was adopted by 150 countries in 1996, and renewed in 2011, and is intended as a framework, guide and catalyst for action at community, national, regional and international levels. Unlike the CBD and the ITPGRFA, the GPA does not spell out member countries' rights and obligations but rather 20 priority activity areas grouped into four thematic sections: *in situ* conservation and development; *ex situ* conservation; utilization of plant genetic resources and institutions and capacity building. Although most activity areas of the plan are relevant for the conservation and sustainable use of minor and underutilized plant species, activity area 12 deals explicitly with minor species, encouraging actions to “identify underused species, develop sustainable management practices, develop post-harvest and marketing methods, and promote policies for the development and use of under-utilized species”, based on their “potential for wider contributions to food security, agricultural diversification and income generation”.

According to their reports to FAO under the GPA, Andean countries have directed 39% of their total *ex situ* projects to underutilized species as defined in the survey. Peru has the highest ratio, with 51% of projects being on minor crop collections (covering 28 of the species resulting from the survey). Bolivia has been giving high priority to quinoa, Ecuador to Andean fruit species such as cherimoya (*Annona cherimola*) and naranjilla (*Solanum quitoense*), while Peru has largely focused on Andean tubers [57–59], as exemplified in Figure 5. Respondents from the Andean region noted that although there had been some degree of national research and development efforts on NUS, they tended to focus on a narrow set of crops, especially those with increasing demand on national and international markets; this is the case of Andean grains, spearheaded by quinoa. Brazil's report to FAO (no information is available through the GPA portal) highlights significant investments in the upgrading and improvement of decentralized *ex situ* collections of cucurbits in the North East and fruit tree collections elsewhere. Among these, most work focuses on Passifloraceae, peach palm (*Bactris gasipaes*), Surinam cherry (*Eugenia uniflora*), feijoa (*Acca sellowiana*), guabiju (*Myrcianthes pungens*), jelly palm (*Butia capitata*) and Rio Grande cherry (*Eugenia involucrata*) [60].

Figure 5. Balance between *ex situ* projects dedicated to underutilized (darker green) versus major crops (light green) in Andean countries.

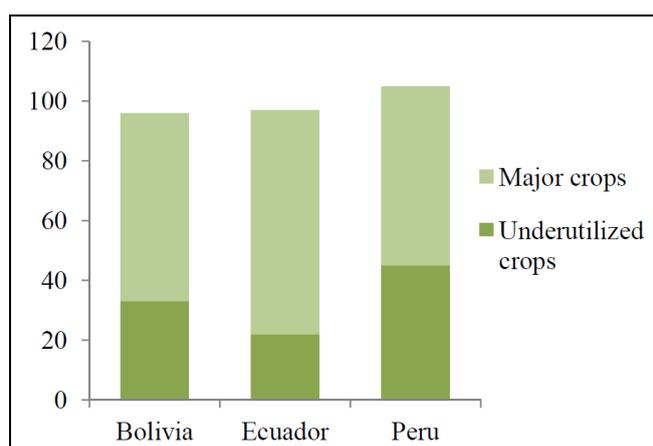


Notwithstanding admirable progress, countries' reports to FAO still highlight a worrying limitation in the funds available, both in amount and regularity. All countries report greater financial shortcomings

for species whose conservation is not through seed but *in vitro* or, even more, as field collections, which is the case for most fruit species and is clearly reflected in the numbers presented above.

Within the projects reported under the GPA *in situ* priority activities, an average 28% of conservation projects in selected countries are dedicated to underutilized species figuring in our list. Top percentages were reached in Peru (43%), covering 22 underutilized crops as defined in our survey (Figure 6). Crops in which most effort has been placed are Andean grains (particularly quinoa in Bolivia) and tubers (highest effort being in Peru), followed by specific fruit families (Passifloraceae, Caricaceae and Annonceae).

Figure 6. Balance between *in situ* projects dedicated to underutilized (darker green) versus major crops (light green) in Andean countries.



In these countries, many of the projects have focused on registering and documenting on-farm crop diversity and its associated traditional knowledge at local levels. In Peru these efforts have led to the identification of specially managed areas of agricultural biodiversity such as the well-known Potato Park [61]. In Bolivia, ten micro-centers of crop diversity have been identified across six departments and special initiatives such as inventories of on-farm agricultural biodiversity and traditional knowledge, seed fairs and repatriation of native varieties from genebanks have been carried out there [57]. In Ecuador, initiatives ranged from the local establishment of conservation gardens for Andean roots and tubers in farmers' fields to characterization and on-farm conservation projects on fruit species, particularly papayas and cherimoyas [58]. The Brazilian Ministry of Environment, in collaboration with research institutions (such as national research organization Embrapa and the Amazon National Research Institute, INPA) led the identification and the mapping of landraces and wild relatives of some of the main crops grown in Brazil. Seven subprojects involve two of the species here listed as underutilized (cucurbits and peach palm). A number of public institutions often in collaboration with NGOs and the civil society have been active in recovering and documenting local crop landraces, and reintroducing them in cultivation among small scale farmers. However, most initiatives have focused on major staples, namely maize and beans [60]. In Mexico, national surveys of the flora were conducted to establish a baseline of the conservation status for future monitoring: of the 62 plant families prioritized, 19 included food crops, only few of which correspond to those listed here, namely species of the *Opuntia* genus, squashes, beans and chilli (*Capsicum chinense*) [62].

4. Discussion and Conclusions

The first part of the study confirmed the complexity of defining neglect and underutilization and the great variation which exists among NUS species: not all of the common assumptions hold true for different species, each of which may suffer more under some aspects than others. This makes a univocal definition of NUS a challenging endeavor, which, in the words of regional experts, also affects the possibility of well-grounded priority setting exercises for improving the conservation and sustainable use of the genetic resources of minor crops at regional level. A way to address this issue could be to adopt a framework for the analysis of any crop's status based on the number of the typical features of neglect and underuse which affect it, and the degree to which each such features limit its development. We chose the following approach to somehow validate and quantify our crops' status by checking if they met at least three among the following thresholds, which were established on the basis of the results of our analyses:

- be relatively neglected by scientific research (here, we chose the average number of Google Scholar hits across our sample set of species as a threshold, *i.e.*, species with less than 1,954 hits are neglected in this aspect)
- be under-represented in the publicly available dataset of the GBIF (here, less than 126 georeferenced observations in Latin America, the average across our sample set, is the threshold)
- be not represented in FAOSTAT
- have a low number of registered varieties, a proxy of scarce plant breeding and seed commercialization (less than 20 registered commercial varieties, with this threshold corresponding to the average number of varieties registered in national catalogues of commercial plant varieties and in the national lists of plant varieties protected by plant breeders' rights and plant patents for the species from our list)
- be under-represented in globally accessible germplasm collections (by less than 320 accessions, the threshold corresponding to the average accession number of the species considered here in such collections)

The application of the above filtering criteria and thresholds (calculations were performed in R [63]) retained 74 of the crops (*i.e.*, those for which more than three typical features of neglect and underuse held true), while the ten species listed in Table 8 did not qualify as (fully) neglected or underutilized.

The top three crops in Table 8 are globally distributed and consumed, likely explaining why they retain none of the features commonly related to neglect and/or underuse. Other crops have a more intermediate status: cassava (*Manihot esculenta*), albeit not seriously neglected by research and conservation efforts, is still relatively underused partially because of the limited availability of commercial varieties for larger scale cultivation. The presence of quinoa (*Chenopodium quinoa*), often referred to as a typical NUS, in Table 8, suggests it is not as seriously overlooked as other Andean native crops, particularly in terms of research, but that it still suffers from limitations in terms of accessibility of germplasm and of conservation-relevant data. On the other hand, the absence of fruit species and most roots and tubers from Table 8 confirms that the majority (often all) of NUS features hold true for the two most numerous categories of NUS reported in the survey. Most of these species appear to be both neglected by research and conservation efforts as well as underused in commercial

production, because of the limited availability of agricultural statistics and of commercial varieties. The non-staple, non-commodity nature of fruit species, the generally limited long-term storability of their products and the inherent complexities of conserving and breeding species with vegetative propagation are probably the main reasons for their status. For promoting these species, efforts are required all along the conservation-to-use realm. In particular, a focus on on-farm conservation may be particularly appropriate given the difficulties of conserving fruit trees, roots and tubers *ex situ*; engagement of farmers in collaborative research projects for improving agronomic and processing aspects would provide incentives for the continued on-farm conservation of these species' genetic resources, enhancing their use potential; awareness raising efforts to highlight the role of these crops in diets and health, will be crucial to foster consumer demand and in turn, enhance commercial use.

Table 8. Crops which were not validated as underutilized according to the pilot framework proposed here.

Crop	Common Name	Origin	Aspects in which Underutilized (<3)
<i>Capsicum</i> spp.	Chili peppers	native	None
<i>Ipomoea batatas</i>	Sweet potato	native	None
<i>Phaseolus vulgaris</i>	Common bean	native	None
<i>Cajanus cajan</i>	Pigeon pea	introduced	Lack of widely available distribution data (GBIF)
<i>Fagopyrum esculentum</i>	Buckwheat	introduced	Lack of widely available distribution data (GBIF)
<i>Manihot esculenta</i>	Cassava	native	Limited commercial varieties available
<i>Vigna unguiculata</i>	Cowpea	introduced	Lack of widely available distribution data (GBIF)
<i>Chenopodium quinoa</i>	Quinoa	native	Low number of accessions in international genebanks and lack of widely available distribution data (GBIF)
<i>Cucurbita</i> spp.	Squashes	native	Not represented in FAOSTAT and no international descriptors available
<i>Phaseolus coccineus</i>	Runner bean	native	Limited representation in literature and not represented in FAOSTAT

While local, context-dependent expert knowledge and perceptions remain essential to assessing the possibly underexploited potential of any species, the availability of a validation method may provide for a more systematic definition of the extent to which crops present features of neglect and/or underuse and highlight where the major limitations and opportunities for improvement lie (e.g., if in research or conservation efforts, or in options for increased commercial use). This may better support the identification and prioritization of species or categories affected by similar constraints and planning for specific interventions to strengthen different areas along the conservation-use realm. Naturally, different threshold values and a different number of minimum conditions to be fulfilled can be tested, adapting the approach flexibly in consultation with experts' and depending on different contexts and time frames.

International frameworks aimed at conservation and use of plant genetic resources have had mixed, sometimes conflicting effects on the conservation and use of neglected crops. The GPA has probably helped to channel national and international funds to projects which meet its goals, allowing them to gain visibility, but the extent to which it has been the actual driver of these initiatives is not clear, among others because it lacks a financial scheme. While the Convention on Biological Diversity and

the Treaty on Plant Genetic Resources for Food and Agriculture have contributed to overall international awareness of the importance of agricultural biodiversity, their translation into practical measures for the conservation and sustainable use of minor crops at national levels has been limited. Important areas of influence of the CBD and the Treaty on minor crops are perceived to be those of access and benefit sharing, and experts have highlighted the importance of addressing the widespread lack of harmonized implementation of ABS mechanisms in countries which are Parties to both conventions, particularly when they harbor native, underutilized crops. Such harmonization is crucial for promoting the mobilization of genetic diversity of these species and encouraging research and development while ensuring equitable participation of all relevant actors.

The financial mechanisms of these two international instruments have provided very modest funds to the conservation, characterization and use of genetic resources of NUS to date. The relative dilution of agricultural biodiversity and NUS projects within the GEF's funding on biodiversity is somewhat understandable considering the broad mandate of the CBD (which encompasses all biodiversity) and the quantity of proposals focused on wild biodiversity conservation submitted to the GEF by organizations working in a mega-diverse region such as Latin America. The relatively limited coverage of NUS by the projects supported by the Treaty's benefit sharing fund may be due to a combination of factors, among which the partial reduction in scope in the latest BSF's call, the limited funds yet available through this funding mechanisms, and possibly the lack of NUS-based proposals received from applicants. If the latter hypothesis were the case, it may in turn reflect limited capacity, interest or resources at national level for participating in the competitive tender with NUS-based proposals, or a perception that this framework is not entirely appropriate for conservation and use of minor crops. Results of our survey suggest that the latter hypothesis may be at least partly true; there appears to be a widespread perception that the mechanisms and provisions of the Treaty are tailored exclusively around the Annex 1 list of crops, *i.e.*, mostly major species. While an Annex 1 focus (which is a matter of prioritization rather than exclusivity) is correct for the functioning of the MLS and the Trust's disbursements, we have explained how the benefit sharing fund has only partially restricted, in one of its funding windows, its scope to Annex 1 crops and therefore still promises to be an important opportunity for NUS-centred projects to receive support. It would be important to confirm if this somewhat narrow interpretation of the Treaty is indeed in place, and in that case, address it through capacity building and awareness raising in developing countries. Efforts in this direction should cover other important sections of the Treaty, such as [54] Article 6 on the sustainable use of PGRFA, and [54] Article 9 on farmers' rights, which also constitute very appropriate umbrellas for non-project based initiatives targeting NUS. A certain lack of awareness around the potential for NUS of these provisions may be the result of their rather general nature, which leaves it up to countries to devise relevant national measures. In order for these Treaty provisions to translate into national-level measures favourable to conservation and use of minor species parties may need more guidance on what types of interventions would be relevant. Some advances in this direction have been made in relation to [54] Article 9 on farmers' rights: recommendations to the Treaty's Governing Body on means for recognizing and implementing such rights have included an emphasis on participatory plant breeding [64,65] and other approaches to conservation and use that rely on farmers' participation, such as community seed banks and local seed production [66]. Given the fact that a considerable amount of the genetic resources of minor crops and of the knowledge about their diversity resides in farmers'

fields, adopting such community-based and participatory approaches may be particularly advantageous for meeting the combined goal of recognizing farmers' rights and halting genetic erosion.

It is important to acknowledge that other drivers are likely to be far more influential in defining countries' priority crops and research and development strategies. Market demand is likely one of the most powerful; increasing customer demand on national and international markets for specialty products from a number of minor crops may already be an important incentive for moving forward national level research and development (and to a certain extent conservation through use), becoming more powerful than any international instrument or funding scheme. Although markets have been quite extensively analyzed for their sometimes controversial effects leading to erosion of diversity and unequal participation [67,68], their potentially positive driving role in the conservation and sustainable use of PGRFA has also been recognized [69–73].

As expressed by the experts in Latin America, the contribution of international frameworks has so far remained mostly at the level of rhetorical discourse; however, these instruments do have a potential to better contribute to improving minor crops' status, by raising worldwide awareness and funds for the conservation and sustainable utilization of their genetic resources. At the same time, they cannot replace national efforts: initiatives at national and local levels are necessary to prioritize, define and implement practical measures that can effectively address the diversity of issues affecting each particular species. Our results allow a better appreciation of the complex nuances which characterize the status of crops commonly bulked under the NUS label; we show how different crops or crop categories are underutilized to very different degrees and in different aspects and suggest practical means to quantify these differences. We believe the application of an analytical approach such as the one presented here provides a basis for informing more targeted, case-specific measures in the field of minor crops' genetic resource management. Finally, in addition to better targeted interventions in the genetic resource conservation and use area, to truly leverage the role of these species, it will be important to link up with national and international initiatives in the fields of sustainable agriculture, food security and sovereignty [74], health [75,76], and adaptation to climate change [77], as minor crops can substantially contribute to the achievement of these objectives.

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Author Contributions

Galluzzi, G. designed and undertook data collection and analyses. López Noriega, I. provided substantial contributions to the survey design and the section on international policies, both in terms of analyses and writing.

Conflicts of Interest

The authors declare no conflict of interest.

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Appendix

Annex 1. Regional survey on underutilized crops of the Americas and the influence of international policies on biodiversity and plant genetic resources

Background and Assumptions

Over the last 20 years, significant political developments have changed the regulatory landscape governing the access to, sharing and use of plant genetic resources, especially with the adoption of the Convention on Biological Diversity (CBD) and the International Treaty on Plant Genetic Resources for Food and Agriculture (ITPGRFA).

However, simplification of agricultural landscapes and practices is causing food production to increasingly rely on a small number of globally distributed crops, to the detriment of a variety of local or regional species. Many of these are threatened by socio-economic and cultural factors and neglected by research and development (hence their definition as “NUS, Neglected and Underutilized Species”).

Some representatives of the international scientific community have expressed concern about the potential negative effect that policy frameworks could have on NUS, further undermining the recognized role these species can play in diversification, sustainability and resilience of agro-ecosystems as well as their contribution to income, health and nutrition of the poor.

One concern is related to the effects of the concept of national sovereignty over genetic resources, formalized by the CBD. It is perceived that the flow of germplasm may have suffered restrictions, especially in native crops—many of which are NUS—out of some countries’ fear of misappropriation of the genetic resources on their territory by a third party.

Another concern lies in the perception that the ITPGRFA is failing to recognize the importance of NUS, by designing its mechanism of access, benefit sharing and funding around a limited number of crops (listed in the Annex 1 of the Treaty, http://www.planttreaty.org/training/annex1_en.htm) selected based on their global importance and countries’ interdependence.

While acknowledging the difficulty of isolating effects of political and legal frameworks from economic, social and cultural issues affecting the conservation and use of NUS, we believe that gathering opinions and experiences from regional experts is extremely important for better understanding the relative influence of the different factors and developing a research agenda that will contribute to better conservation and use of NUS in the region.

Respondent Information

Q1

Please indicate your name and position/institute your work for. These data are useful for analyzing responses and necessary for following up and involving you in subsequent steps of the study on NUS.

Q2

Within the PGRFA theme, which are your areas of main expertise/interest? Please tick where relevant.

<i>ex situ</i> conservation	
<i>in situ</i> conservation	
breeding	
policies	
Other (please specify)	

NUS and Policies

Q3

Please list the crops in your collection/context of work/country which can be considered NUS (please provide scientific names).

Note: For general information on the definition of NUS, please consult http://www.underutilised-species.org/spotlight/what_are_underutilised_species.asp.

For the purpose of this survey, we invite you to refer to those crop species with under-exploited potential to contribute to food security, ecosystem and nutritional diversification.

Q4

In what area do you consider the NUS indicated above to have the greatest potential? Please insert the name of the species in the most relevant spaces.

For example, it could be “quinoa” in the box corresponding to “Food Security”.

Climate change mitigation	
Climate change adaptation	
Breeding	
Food security	
Dietary Diversity	
High value products (potential for niche markets)	
Agro-ecosystem diversification	
Other	

Note: The contribution to mitigation derives from an increased sequestration (mostly perennials) or a decreased emission of carbon dioxide (less chemical inputs required). The contribution to adaptation derives from greater resistance to droughts, floods or other extreme events, or from constituting a food or income generating alternative for farmers faced with increasing climate risks.

Q5

Please indicate (by ticking the box) the effect of each of the following limiting factors on conservation, distribution and use of NUS.

	No effect	Limited effect only in a few NUS	Limited effect common to most NUS	Strong effect in only a few NUS	Strong effect common to most NUS
Low number of accessions conserved in genebanks					
Poor regeneration status of <i>ex situ</i> material					
Poor documentation on <i>ex situ</i> material					
Complex regulations for access and distribution of material					
Lack of funding for <i>ex situ</i> conservation/management					
Lack of funding for <i>in situ</i> conservation/management					
Decreasing on farm conservation/loss of traditional knowledge on use					
Lack of attention by research and development					

Please expand your comments and views on the above or other limiting factors.

Q6

Based on your knowledge of the Convention on Biological Diversity (CBD), please indicate its effects in your working context and—most importantly—if it has influenced NUS and other crops differently over the past 20 years.

Note: Please consider the support granted by the CDB to conservation projects and initiatives through the Global Environmental Facility (GEF), which serves as the CBD's financial mechanism.

	Positive, stronger in NUS	Positive, stronger in other crops	Negative, stronger in NUS	Negative, stronger in other crops	Positive trend in all crops	Negative trend in all crops	No significant effect
Germplasm acquisition (<i>ex situ</i>)							
Germplasm characterization and evaluation (<i>ex situ</i>)							
Germplasm distribution							
<i>In situ</i> /on farm conservation							
Breeding and crop improvement							
Availability of national funds (for conservation, use, research)							
Availability of international funds (for conservation, use, research)							

Please explain how this policy framework can have affected or may in the future affect the status of NUS in your working context.

Q7

Based on your knowledge of the International Treaty on Plant Genetic Resources for Food and Agriculture (ITPGRFA), please indicate its effects in your working context and—most importantly—if it has influenced NUS and other crops differently since its entry into force.

Note: Please keep in mind the support granted by the Treaty to *ex situ* conservation initiatives/projects through its financial mechanisms, the Global Crop Diversity Trust (GCDDT).

	Positive, stronger in NUS	Positive, stronger in other crops	Negative, stronger in NUS	Negative, stronger in other crops	Positive trend in all crops	Negative trend in all crops	No significant effect
Germplasm acquisition (<i>ex situ</i>)							
Germplasm characterization and evaluation (<i>ex situ</i>)							
Germplasm distribution							
<i>In situ</i> /on farm conservation							
Breeding and crop improvement							
Availability of national funds (for conservation, use, research)							
Availability of international funds (for conservation, use, research)							

Please explain how this policy framework can have affected or may in the future affect the status of NUS in your working context.

Q8

Do you believe that conservation, management and use of NUS can benefit from the participation of your country in the International Treaty on Plant Genetic Resources for Food and Agriculture? Please explain how. If not, please give reasons.

Annex 2. List of NUS emerging from the survey

Table A1. List of crops reported as underutilized by plant genetic resource experts in Latin America.

Scientific name	Common name in Spanish or local language	English name	Origin
<i>Acca sellowiana</i>	Guayabo del país - feijoa	Feijoa	native
<i>Amaranthus caudatus</i>	Amaranto - kiwicha - achita	Amaranth	native
<i>Amaranthus quitensis</i>	Ataco - sangorache	Amaranth	native
<i>Anacardium occidentale</i>	Marañón	Cashew	native
<i>Annona cherimola</i>	Chirimoyo	Cherimoya	native
<i>Annona muricata</i>	Guanábana	Soursop	native
<i>Aristotelia chilensis</i>	Maqui	Chilean Wineberry	native
<i>Arracacia xanthorrhiza</i>	Arracacha	White carrot	native
<i>Asparagus officinalis</i>	Espárrago	Asparagus	introduced
<i>Bactris gasipaes</i>	Pejibaye - chontaduro	Peach palm	native
<i>Benincasa hispida</i>	Calabaza china	Winter melon	introduced
<i>Berberis</i> spp.	Berberis sp.	Barberry	native
<i>Borojoa patinoi</i>	Borojó	Borojó	native
<i>Butia capitata</i>	Butiá	Jelly palm	native
<i>Cajanus cajan</i>	Guandul	Pigeon pea	introduced
<i>Calathea allouia</i>	Dale dale	Guinea arrow root	native
<i>Canavalia ensiformis</i>	Canavalia	Jack bean	native
<i>Canna edulis</i>	Achira	Achira	native
<i>Capsicum</i> spp.	Ajíes	Chili	native
<i>Chamaedorea tepejilote</i>	Pacaya	Pacaya palm	native
<i>Chenopodium pallidicaule</i>	Cañihua	Cañihua	native
<i>Chenopodium quinoa</i>	Quinoa	Quinoa	native
<i>Chrysobalanus icaco</i>	icaco	Cocoplum	native
<i>Cnidoscolus chayamansa</i>	Chaya	Tree spinach	native
<i>Colocasia esculenta</i>	Pituca	Taro	native
<i>Cucurbita</i> spp.	Calabazas - zapallos	Pumpkins	native
<i>Curcuma longa</i>	Cúrcuma	Turmeric	introduced
<i>Cyclanthera pedata</i>	Achocha or cayhua	Stuffing cucumber	native
<i>Cynara scolymus</i>	Alcaucil	Artichoke	introduced
<i>Cyphomandra betacea</i>	Tomate de árbol	Tree tomato	native
<i>Dioscorea trifida</i>	Sacha papa	Indian yam	native
<i>Eugenia aggregata</i>	Cereza de Río grande	Rio Grande cherry	native
<i>Eugenia stipitata</i>	Arazá	Arazá	native
<i>Eugenia uniflora</i>	Grosella - pitanga - cereza de Cayenna	Suriname cherry	native
<i>Fagopyrum esculentum</i>	Trigo sarraceno	Buckwheat	introduced
<i>Fernaldia pandurata</i>	Loroco	Loroco	native
<i>Fragaria chiloensis</i>	Frutilla chilena - fresa chilena o frutilla blanca	Chiloé strawberry	native
<i>Frantzia tacaco</i>	Tacaco	Tacaco	native
<i>Hexachlamis edulis</i>	Ubajay	Ubajay	native
<i>Inga feuillei</i>	Pacay	Pacay or ice-cream bean	native
<i>Ipomoea batatas</i>	Batata - papa dulce - camote	Sweet potato	native

Table A1. Cont.

Scientific name	Common name in Spanish or local language	English name	Origin
<i>Lablab purpureus</i>	Zarandaja, frijol trepador	Hyacinth bean	introduced
<i>Luffa cylindrica</i>	Estropajo	Sponge gourd	introduced
<i>Lupinus mutabilis</i>	Tarwi	South American Lupin	native
<i>Mammea americana</i>	Mamey	Mamey	native
<i>Manihot esculenta</i>	Yuca	Cassava	native
<i>Maranta arundinacea</i>	Jamachipeke	Arrowroot	native
<i>Mirabilis expansa</i>	Chago	Pepper weed	native
<i>Myrcianthes pungens</i>	Guaviyú	Guaviyú	native
<i>Myrciaria dubia</i>	Camu Camu	Camu Camu	native
<i>Opuntia ficus indica</i>	Tuna	Prickly pear	native
<i>Oxalis tuberosa</i>	Oca	Oca	native
<i>Pachyrhizus ahipa</i>	Ashipa - ajipa	Andean yam bean	native
<i>Pachyrhizus erosus</i>	Jicama	Yam bean	native
<i>Passiflora ligularis</i>	Granadilla	Sweet granadilla	native
<i>Passiflora mollissima</i>	Tumbo - curuba	Banana passionfruit	native
<i>Paullinia cupana</i>	Guaraná	Guaraná	native
<i>Persea schiedeana</i>	Aguacate silvestre	-	native
<i>Phaseolus acutifolius</i>	Frijoles "comunes"	-	native
<i>Phaseolus coccineus</i>	Ayocote	Runner bean	native
<i>Phaseolus dumosus</i>	Frijol cache	-	native
<i>Phaseolus lunatus</i>	Pallar - frijol Lima	Lima bean	native
<i>Phaseolus vulgaris</i>	Frijol ñuña	Popping beans	native
<i>Physalis peruviana</i>	Aguaymanto - Uchuva o Uvilla	Inca berry	native
<i>Plukenetia volubilis</i>	Sacha inchi	Sacha inchi, Sacha peanut	native
<i>Portulaca oleracea</i>	Verdolaga	Pigweed	introduced
<i>Pouteria obovata</i>	Lúcuma	Lucuma	native
<i>Pouteria sapota</i>	Zapote	Sapote	native
<i>Psidium guajava</i>	Guayaba	Guava	native
<i>Rubus glaucus</i>	Mora de Castilla	Andes berry	native
<i>Sechium edule</i>	Chayote	Pear squash, vegetable pear	native
<i>Smallanthus sonchifolius</i>	Yacón	Yacón	native
<i>Solanum muricatum</i>	Pepino dulce	Pepino melon or melon pear	native
<i>Solanum quitoense</i>	Lulo	Lulo	native
<i>Solanum andigenum</i>	Papas nativas	Native potatoes	native
<i>Spondias</i> spp.	Spondiaceas	Mombins	native
<i>Stenocereus</i> spp.	Pitaya	Pitaya	native
<i>Theobroma grandiflorum</i>	Copoazú	Copoazú	native
<i>Tropaeolum tuberosum</i>	Mashua - Isaño	Mashua	native
<i>Ullucus tuberosus</i>	Olluco - Ulluco - Papalisa	Olluco	native
<i>Vaccinium meridionale</i>	Agraz - mortiño	-	native
<i>Vasconcella</i> spp.	Papaya de altura	Highland papaya	native
<i>Vigna unguiculata</i>	Caupí	Cowpea	introduced
<i>Xanthosoma</i> spp.	Malanga - quequisque - Walusa	Tannia, yautia	native

Annex 3. The *ex situ* conservation status of NUS in selected countries**Table A2.** Number of accessions of selected underutilized species, conserved in genebanks of Andean countries. Source: country report to FAO and WIEWS.

Crop	No. Accessions	Holding Institutions
<i>Ipomoea batatas</i>	8	Vallecito Bolivia
<i>Xanthosoma sagittifolium</i>	11	INIAF Bolivia
<i>Lupinus mutabilis</i>	12	INIAF Bolivia
<i>Canna edulis</i>	17	INIAF Bolivia
<i>Pachyrhizus ahipa</i>	18	INIAF Bolivia
<i>Amaranthus caudatus</i>	19	CIBREF-FCAP-UTO Bolivia
<i>Pachyrhizus tuberosus</i>	22	INIAF Bolivia
<i>Annona cherimola</i>	29	INIAF Bolivia
<i>Manihot esculenta</i>	38	Vallecito Bolivia
<i>Arracacia xanthorrhiza</i>	41	INIAF Bolivia
<i>Smallanthus sonchifolius</i>	43	INIAF Bolivia
<i>Passiflora</i> spp.	49	INIAF Bolivia
<i>Amaranthus caudatus</i>	51	INIAF Bolivia
<i>Tropaeolum tuberosum</i>	79	INIAF Bolivia
<i>Lupinus mutabilis</i>	105	INIAF Bolivia
<i>Amaranthus caudatus</i>	134	INIAF Bolivia
<i>Ullucus tuberosus</i>	197	INIAF Bolivia
<i>Phaseolus</i>	326	INIAF Bolivia
<i>Solanum</i> sp.	350	CIBREF-FCAP-UTO Bolivia
<i>Capsicum</i> spp.	447	INIAF Bolivia
<i>Chenopodium pallidicaule</i>	448	CIBREF-FCAP-UTO Bolivia
<i>Cucurbita</i> spp.	450	INIAF Bolivia
<i>Oxalis tuberosa</i>	487	INIAF Bolivia
<i>Chenopodium pallidicaule</i>	801	INIAF Bolivia
<i>Chenopodium quinoa</i>	1,700	CIBREF-FCAP-UTO Bolivia
<i>Solanum</i> spp. *	1,760	INIAF Bolivia
<i>Chenopodium quinoa</i>	3,121	INIAF Bolivia
<i>Dioscorea</i> spp.	1	DENAREF-INIAP Ecuador
<i>Opuntia</i> spp.	1	DENAREF-INIAP Ecuador
<i>Spondias dulcis</i>	1	DENAREF-INIAP Ecuador
<i>Myrciaria dubia</i>	1	Station Napo Payamino - INIAP Ecuador
<i>Annona cherimola</i>	1	Station Napo Payamino - INIAP Ecuador
<i>Theobroma grandiflorum</i>	1	Station Napo Payamino - INIAP Ecuador
<i>Annona muricata</i>	1	Station Napo Payamino - INIAP Ecuador
<i>Eugenia stipitata</i>	1	Station Napo Payamino - INIAP Ecuador
<i>Spondias purpurea</i>	1	Station Napo Payamino - INIAP Ecuador
<i>Annona cherimola</i>	1	Station Portoviejo - INIAP Ecuador
<i>Annona muricata</i>	1	Station Portoviejo - INIAP Ecuador
<i>Annona cherimola</i>	2	DENAREF-INIAP Ecuador
<i>Annona muricata</i>	2	DENAREF-INIAP Ecuador
<i>Vigna unguiculata</i>	2	DENAREF-INIAP Ecuador

Table A2. Cont.

Crop	No. Accessions	Holding Institutions
<i>Chenopodium pallidicaule</i>	3	DENAREF-INIAP Ecuador
<i>Passiflora</i> spp.	3	Station Napo Payamino - INIAP Ecuador
<i>Amaranthus hybridus</i>	5	DENAREF-INIAP Ecuador
<i>Pachyrhizus erosus</i>	13	DENAREF-INIAP Ecuador
<i>Eugenia stipitata</i>	15	Station Portoviejo - INIAP Ecuador
<i>Pachyrhizus ahipa</i>	17	DENAREF-INIAP Ecuador
<i>Vaccinium</i> spp.	29	DENAREF-INIAP Ecuador
<i>Borojoa patinoi</i>	30	Station Napo Payamino - INIAP Ecuador
<i>Cyclanthera pedata</i>	33	DENAREF-INIAP Ecuador
<i>Ipomoea batata</i>	33	DENAREF-INIAP Ecuador
<i>Cyphomandra betacea</i>	38	DENAREF-INIAP Ecuador
<i>Pachyrhizus tuberosus</i>	39	DENAREF-INIAP Ecuador
<i>Vasconcella pentagona</i>	47	UNL Ecuador
<i>Amaranthus caudatus</i>	54	DENAREF-INIAP Ecuador
<i>Physalis peruviana</i>	64	DENAREF-INIAP Ecuador
<i>Rubus</i> spp.	79	DENAREF-INIAP Ecuador
<i>Carica</i>	113	DENAREF-INIAP Ecuador
<i>Bactris gasipaes</i>	145	Station Napo Payamino - INIAP Ecuador
<i>Cucurbita</i> spp.	147	DENAREF-INIAP Ecuador
<i>Solanum quitoense</i>	163	UNL Ecuador
<i>Solanum quitoense</i>	168	DENAREF-INIAP Ecuador
<i>Solanum tuberosum</i> (incl. ssp. <i>andigena</i>)	237	DENAREF-INIAP Ecuador
<i>Passiflora</i> spp.	239	DENAREF-INIAP Ecuador
<i>Carica</i> sp.	336	UNL Ecuador
<i>Capsicum annuum</i>	355	UNL Ecuador
<i>Capsicum</i> spp.	370	DENAREF-INIAP Ecuador
<i>Lupinus mutabilis</i>	396	DENAREF-INIAP Ecuador
<i>Chenopodium quinua</i>	672	DENAREF-INIAP Ecuador
<i>Annona cherimola</i>	961	UNL Ecuador
<i>Phaseolus</i> spp.	3,100	DENAREF-INIAP Ecuador
<i>Dioscorea alata</i>	1	INIA SURDIGEB Peru
<i>Eugenia uniflora</i>	1	INIA SURDIGEB Peru
<i>Passiflora edulis</i>	1	INIA SURDIGEB Peru
<i>Spondias</i> spp.	1	INIA SURDIGEB Peru
<i>Theobroma grandiflora</i>	1	INIA SURDIGEB Peru
<i>Carica pubescens</i>	2	INIA SURDIGEB Peru
<i>Annona muricata</i>	3	INIA SURDIGEB Peru
<i>Physalis peruviana</i>	3	INIA SURDIGEB Peru
<i>Pachyrrhizus ahipa</i>	4	INIA SURDIGEB Peru
<i>Xanthosoma sagittifolium</i>	4	INIA SURDIGEB Peru
<i>Colocasia esculenta</i>	6	INIA SURDIGEB Peru
<i>Calathea allouia</i>	8	INIA SURDIGEB Peru
<i>Amaranthus hybridus</i>	12	INIA SURDIGEB Peru
<i>Anacardium occidentale</i>	12	INIA SURDIGEB Peru

Table A2. Cont.

Crop	No. Accessions	Holding Institutions
<i>Cucurbita</i> spp.	14	INIA SURDIGEB Peru
<i>Dioscorea trifida</i>	15	INIA SURDIGEB Peru
<i>Mirabilis expansa</i>	19	INIA SURDIGEB Peru
<i>Lepidium meyenii</i>	21	INIA SURDIGEB Peru
<i>Canna indica</i>	25	INIA SURDIGEB Peru
<i>Plukenetia volubilis</i>	42	INIA SURDIGEB Peru
<i>Camu camu</i>	43	INIA SURDIGEB Peru
<i>Cyclanthera pedata</i>	46	INIA SURDIGEB Peru
<i>Phaseolus lunatus</i>	47	INIA SURDIGEB Peru
<i>Lucuma obovata</i>	95	INIA SURDIGEB Peru
<i>Phaseolus vulgaris</i> (ñuña)	98	INIA SURDIGEB Peru
<i>Capsicum</i> spp.	105	INIA SURDIGEB Peru
<i>Bactris gasipaes</i>	113	INIA SURDIGEB Peru
<i>Vigna unguiculata</i>	114	INIA SURDIGEB Peru
<i>Smallanthus sonchifolius</i>	136	INIA SURDIGEB Peru
<i>Passiflora</i> spp.	158	INIA SURDIGEB Peru
<i>Arracacia xanthorrhiza</i>	174	INIA SURDIGEB Peru
<i>Opuntia ficus indica</i>	176	INIA SURDIGEB Peru
<i>Cyphomandra betacaea</i>	193	INIA SURDIGEB Peru
<i>Capsicum pubescens</i>	200	INIA SURDIGEB Peru
<i>Chenopodium pallidicaule</i>	267	INIA SURDIGEB Peru
<i>Tropaeolum tuberosum</i>	310	INIA SURDIGEB Peru
<i>Annona cherimola</i>	383	INIA SURDIGEB Peru
<i>Amaranthus caudatus</i>	486	INIA SURDIGEB Peru
<i>Ullucus tuberosus</i>	702	INIA SURDIGEB Peru
<i>Manihot esculenta</i>	740	INIA SURDIGEB Peru
<i>Chenopodium quinoa</i>	1,936	INIA SURDIGEB Peru
<i>Lupinus mutabilis</i>	2,103	INIA SURDIGEB Peru
<i>Oxalis tuberosa</i>	2,217	INIA SURDIGEB Peru

* = including ssp. andigena, native potatoes.

Table A3. Number of accessions of selected underutilized species, conserved in Brazilian genebanks. Source: country report to FAO and WIEWS.

Crop	No. Accessions	Holding Institutions
<i>Colocasia</i>	3	various
<i>Eugenia stipitata</i>	6	various
<i>Pachyrrhizus</i> sp.	8	various
<i>Dioscorea</i> spp.	10	various
<i>Spondias purpurea</i>	11	various
<i>Spondias</i> spp.	21	various
<i>Arracacia xanthorrhiza</i>	22	various
<i>Anacardium occidentale</i>	35	various
<i>Spondias</i> spp.	42	various
<i>Rubus</i> spp.	60	various

Table A3. Cont.

Crop	No. Accessions	Holding Institutions
<i>Myrciaria dubia</i>	70	various
<i>Acca sellowiana</i>	76	various
<i>Annona muricata</i>	105	various
<i>Spondias tuberosa</i>	123	various
<i>Eugenia uniflora</i>	132	various
<i>Spondias mombin</i>	136	various
<i>Acca sellowiana</i>	165	various
<i>Acca sellowiana</i>	193	various
<i>Carica papaya</i>	210	various
<i>Psidium guayaba</i>	323	various
<i>Theobroma grandiflora</i>	529	various
<i>Anacardium occidentale</i>	643	various
<i>Passiflora</i> spp.	1,292	various
<i>Vigna unguiculata</i>	1,787	various
<i>Phaseolus lunatus</i>	2,673	various
<i>Capsicum</i> spp.	3,137	various
<i>Cucurbita</i> spp.	5,675	various

Table A4. Number of accessions of selected underutilized species, conserved in genebanks of Mexico. Source: WIEWS.

Crop (genus)	No. Accessions	Holding Institutions
<i>Amaranthus</i> spp.	700	University of Chapingo
<i>Anacardium occidentale</i>	14	University of Chapingo
<i>Annona cherimola</i>	2	INIFAP
<i>Annona chirimola</i>	12	University of Chapingo
<i>Annona muricata</i>	8	University of Chapingo
<i>Annona squamosa</i>	1	INIFAP
<i>Bactris gasipaes</i>	8	INIFAP
<i>Bactris</i> spp.	1	University of Chapingo
<i>Capsicum annuum</i>	248	University of Chapingo
<i>Capsicum annuum</i>	1,211	INIFAP
<i>Capsicum chinense</i>	25	University of Chapingo
<i>Capsicum chinense</i>	100	INIFAP
<i>Capsicum</i> spp.	3,350	INIFAP
<i>Carica papaya</i>	1	INIFAP
<i>Carica</i> spp.	60	INIFAP
<i>Chrysobalanus icaco</i>	1	University of Chapingo
<i>Cnidoscolus chayamansa</i>	23	University of Chapingo
<i>Colocasia esculenta</i>	8	University of Chapingo
<i>Cucurbita</i> spp.	1,580	INIFAP
<i>Dioscorea alata</i>	6	University of Chapingo
<i>Dioscorea bulbifera</i>	8	University of Chapingo
<i>Eugenia</i> spp.	5	University of Chapingo
<i>Feijoa sellowiana</i>	2	INIFAP

Table A4. Cont.

Crop (genus)	No. Accessions	Holding Institutions
<i>Hylocereus undatus</i>	9	University of Chapingo
<i>Ipomea batatas</i>	15	University of Chapingo
<i>Ipomoea batatas</i>	178	INIFAP
<i>Lagenaria siceraria</i>	6	INIFAP
<i>Luffa cylindrica</i>	2	INIFAP
<i>Mammea americana</i>	3	University of Chapingo
<i>Manihot esculenta</i>	30	University of Chapingo
<i>Manihot</i> spp.	200	INIFAP
<i>Manilkara zapota</i>	9	University of Chapingo
<i>Maranta arundinacea</i>	2	University of Chapingo
<i>Opuntia</i> spp.	133	INIFAP
<i>Pachyrhizus erosus</i>	49	INIFAP
<i>Passiflora edulis</i>	4	University of Chapingo
<i>Passiflora edulis</i>	2	INIFAP
<i>Persea americana</i>	14	University of Chapingo
<i>Persea americana</i>	58	INIFAP
<i>Phaseolus acutifolius</i>	88	University of Chapingo
<i>Phaseolus acutifolius</i>	40	INIFAP
<i>Phaseolus coccineus</i>	209	University of Chapingo
<i>Phaseolus dumosus</i>	104	University of Chapingo
<i>Phaseolus lunatus</i>	93	University of Chapingo
<i>Pouteria sapota</i>	5	University of Chapingo
<i>Psidium guajaba</i>	8	University of Chapingo
<i>Psidium guajava</i>	4	INIFAP
<i>Psidium</i> spp.	4	University of Chapingo
<i>Rubus occidentalis</i>	6	INIFAP
<i>Sechium edule</i>	93	University of Chapingo
<i>Spondias mombim</i>	3	University of Chapingo
<i>Spondias purpurea</i>	17	University of Chapingo

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