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Assessment of the Current State of In Situ Conservation and Use of Sweet Potato (*Ipomoea batatas* L.) in Colombia

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Abstract

Sweet potato is a valuable staple crop that guarantees food security to a large segment of the world population. The wide phenotypic and genetic variability of this species is an indication of its high adaptation capacity to diverse environmental conditions. In Colombia, it is a neglected and underutilized crop, mainly managed by traditional knowledge. The aim of this study was to recognize the contribution of in situ conservation and to characterize the habitats and the traditional uses to shed light on the design of their management and conservation strategies. Germplasm and data collection were conducted in the Caribbean and Andean regions of the country. This collection resulted in 750 accessions from 131 municipalities, belonging to 19 departments of the two regions. In these regions, sweet potato has been conserved in situ in a wide spatial and altitudinal distribution. The major collection sources were wild and cultivated habitats, which highlight the invaluable contribution of farmers and communities in the preservation of this species and its associated knowledge. In situ *conservation seemed to be an efficient strategy for conserving and using plant genetic resources; therefore, it should be considered by conservation efforts.* [germplasm collection, habitats, *in situ* conservation, *Ipomoea batatas*]

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Introduction

Sweet potato (*Ipomoea batatas* (L.) Lam) is an herbaceous species from Convolvulaceae family. More than half of its species are concentrated in America, where they have been grown as crops, medicinal plants, and weeds (Austin and Huáman 1996). *I. batatas* is the only species with economic importance as crop (Woolfe 1992). Sweet potato is a native crop of America, but its center of primary origin and diversity are located between Central America and northern South America (De la Puente 1989; Fuentes and Chujoy 2009; Huáman and Zhang 1997; Muñoz-Rodriguez et al. 2018; Mwanga et al. 2017; Zhang et al. 1997). Other secondary centers of diversity are found in Asia and Oceania (Lebot 2009; Prain and Campilan 1999; Roullier et al. 2013a).

Sweet potato is a versatile and important crop for food security (Motsa et al. 2015), since its storage roots have a high content of dietary fiber, minerals, vitamins, and antioxidant compounds (including phenolic acids, anthocyanins, tocopherols, and beta carotenes). These nutrients are especially accumulated in varieties with orange and purple flesh (Agili et al. 2012; Grace et al. 2014; Teow et al. 2009). Worldwide, sweet potato is one of the main crops used as a source of energy, with 66.03% of production concentrated in Asia, 28.28% in Africa, and 4.57% in America. China is the greatest sweet potato producer, followed by Uganda

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and Nigeria (Arguedas-Gamboa et al. 2015; FAOSTAT 2018).

In Colombia, the sweet potato crop is associated with ancestral and local cultures. There is evidence of its cultivation before colonization by indigenous people of the Malibúes along the Magdalena River in the Caribbean region (Gutiérrez Usillos, 2002). During the Spanish conquest, the economy of the Muisca culture in the Andean region was based on the exploitation of agricultural products including sweet potato (García 2012; Rodríguez-Cuenca 1999). Nowadays, the cultivation of sweet potato occurs mainly in small areas as a traditional crop, especially in the Caribbean region (FAO 2015), and its production is mainly used for family consumption and rarely for sale in local markets (Flórez et al. 2016; Garrido-Rubiano et al. 2017). Its management is based on empirical knowledge and depends on the availability of traditional or local varieties, which are cultivated in association with other crops such as cassava, yams, tobacco, corn, and others.

Genetic resources are important for agriculture and food security in the world (Granados-Sanchez et al. 2009). Therefore, integration of management and conservation strategies with farmers and plant breeders is key to promote the rescue, value recognition, and use of this crop (Macías-Figueroa et al. 2011; Prain and Campilan 1999). *In situ* conservation (on-farm) has been recognized as a strategy to ensure greater accessibility to genetic diversity of traditional crop varieties, lower their conservation costs, reduce vulnerability to their losses, and allow their sustainable management. Traditional agriculture management and its association with wild, weed and horticultural species, ensures production, and selection that simultaneously undergo adaptive evolution in specific eco-geographic regions (Bioversity International 2012; Dhillon et al. 2004; Prain and Campilan 1999). Farmers value genetic diversity following a common pattern, depending on the number of local varieties and new cultivars used, and the areas occupied: cultivars for food security and marketing use large areas and are grown by many families, while local varieties are established in small areas and are grown by very few families (Sthapit et al. 2006). Furthermore, local in situ conservation and seed supply systems evolve to adapt to farmers' needs and environmental changes, favoring cultural and territorial ties (García-López et al. 2019). However, on-farm conservation should be complemented with actions supported by the official seed supply system to provide assurance and conservation of useful genetic resources, to increase available diversity, as well as to promote the dynamic management of the agricultural system and genetic diversification (Bioversity International 2012; Wood and Lenne, 1997). This is in line with the Convention on Biological Diversity (CBD) that ratifies conservation at all levels (ecosystems, species, and genetic resources) is a common interest to all humanity and its measures must provide for complementary *ex situ* and *in situ* conservation actions (CBD 2010; Maxted et al. 2002).

One of the world's largest cultivated sweet potato genebanks is currently maintained by the International Potato Center (CIP), with over 5,500 accessions maintained *in vitro*. Currently, Colombia is represented by 169 available accessions from initially 309 collected accessions, including 113 accessions belonging to the *Ipomoea batatas* species, and 47 of crop wild relatives, from *I. amnicola*, *I. hederifolia*, *I. leuchantha*, *I. purpurea*, *I. trifida,* and *I. triloba* (GRIN-Global 2021). In addition, there is a record of 124 accessions maintained by the Colombian national germplasm bank system (Valencia et al. 2010). However, there is not a study addressing the status of *in situ* strategies for sweet potato conservation. Therefore, the objective of this study is to recognize the contribution of *in situ* conservation of sweet potato through germplasm collection in different geographical regions of Colombia. In doing so, the study aims to answer two research questions: (1) What are the conditions of the habitats that have allowed the conservation of sweet potato? (2) What type of traditional knowledge and uses contribute to the conservation of this species?

Materials and Methods

Study Area

The study was conducted in the Caribbean and Andean natural regions of Colombia (IGAC 2016). These regions were selected considering the passport data from previous collections since the 1980s (Muñoz-Rodríguez et al. 2018), which also were identified as a high-priority areas for collecting *Ipomoea* species (Khoury et al. 2015). Germplasm and data were collected during expeditions conducted between 2013 and 2016 in 131 municipalities from 8 departments of the Caribbean region (Cesar, Antioquia, Córdoba, Bolivar, Atlántico, La Guajira, Sucre, and Magdalena) and 12 departments of the Andean region (Caldas, Santander, Tolima, Boyacá, Valle del Cauca, Quindío, Risaralda, Antioquia, Norte de Santander, Cauca, Huila, and

Nariño). The north part of the department of Antioquia belongs to the Caribbean region and its south part to the Andean region.

Collection of Plant Material and Survey

The collection followed the methodology suggested by CIP (1991). As there were no data on the individual farmers that were visited in the previous collection missions, information was gathered in every municipality or community, with the assumption that this snowball technique would deliver some information about the current holders or areas were sweet potato would be growing. Before starting both material and data collection, farmers were informed about the purpose of the study, and they agreed to provide the material and data to the collectors. The interviews were conducted through a questionnaire with 32 questions, which was designed following the CIP (1991) guidelines. The questionnaire included questions about taxonomy (genus, species), collection sites (country, department, municipality, village, farm, owner, geographic coordinates, and altitude), germplasm, habitats, and agroecosystems characterization. Most of this information was filled in by collectors (agronomists or phytotechnicians), which were previously trained. All farmers who provided germplasm were asked about the use and management of sweet potato crops. The interviews were conducted with either men or women depending on the availability. Landraces were only collected when the morphological appearance was slightly different from the synonym landrace. When the sweet potato was found in a ruderal environment, only the information about germplasm and habitats was collected.

Plant Material Preservation

Propagation material from each accession was collected, either stem sections (20 cm approx.) or storage roots or both. All sweet potato samples were collected according to the permission obtained by Agrosavia from the national environmental licensing authority of Colombia for the collection of specimens for non-commercial scientific research. Sample identification was carried out by I. Pastrana and A. Rosero (Agrosavia). Several morphological polymorphisms were visually detected among the collected samples. Each specimen was registered using information about collection date (month and year), collection site (three initials of the department where the specimen was found), and a consecutive number assigned in order of collection. Subsequently, the collected specimens were adapted under 35% shade and established in nurseries at Cereté (8°51′2.158″N, 75°49′10.809″W) and Agustín Codazzí (10°0′3.615″N, 73° 14′54.49″W), where they are currently being kept.

In Situ Germplasm Characterization

Germplasm was characterized *in situ* based on the collection source (farmland, institute, wild habitat (defined as an environment that has not been intervened by cropping activities), backyard, village market, other-ruderal environment), the status of sample (landrace/native cultivar, weedy, breeder's line, ornamental, wild), the population density (high, intermediate, low), and the use (vegetable, food, spice, oil, medicinal, wood, fruit, other).

Characterization of Agroecosystems and Habitats of Sweet Potato Conservation

Habitats of collection sites were described with the following parameters: terrain topography, highest level landform, gradient shape, vegetation in the surroundings, soil drainage, soil erosion, soil color, soil organic matter content, soil textural type, light exposure, and associated and main crops. Considering the environmental conditions of the collection sites, accessions were categorized based on their location within the two natural regions, Caribbean and Andean.

Data Analysis

The data collected were analyzed based on the categories established for each variable. Global analysis was done to obtain information as a representative result for Colombia as a country. Further, data from each region were used to characterize the germplasm and habitats found in specific Andean and Caribbean regions. Frequency and relative frequency distributions were used for the geographical and altitudinal characterization, five ranges were defined for altitudinal distribution (0–500, 501–1,000, 1,001–1,500, 1,501–2,000, and from 2,001–2,555 masl). To determine a potential association between the variables and the natural regions, Chi-square tests were performed. For multidimensional description of the agroecosystems, a multiple correspondence multivariate analysis was performed for the characteristics whose relationship was explained by the X1 and X2 dimensions, with a percentage of the accumulated variance >35%. All analyses were performed in R free software version 4.0.3 using the MASS, ggplot2, and ggpubr libraries (Venables and Ripley 2002; Wickham 2016).

Results and Discussion

Geographical and Altitudinal Distribution of the Sweet Potato in Colombia

Systematic exploration and collection in areas of great genetic diversity in Colombia resulted in seven hundred and fifty (750) collected accessions, including 25 wild relative species belonging to the Convolvulacea family. Most accessions were collected in the departments of Antioquia, Boyacá, Caldas, Cesar, Santander, and Tolima. The remaining 271 accessions (36.13%) were collected in several departments with <50 accessions. (Table 1, Figure 1A). This collection significantly overpassed the number of accessions collected in Colombia and conserved in the current CIP genebank, which initially reported 310 accessions belonging to *Ipomoea batatas* (219 accessions) and 16 related species (91 accessions). However, 48% of accessions are not available, which reduce the collection from Colombia to a total of 113 accessions belonging to *Ipomoea batatas* and 47 accessions from seven related species (GRIN-Global 2021). The high density of accessions found in this study, especially in Caribbean and Andean regions, confirmed previous reports about distribution and richness of sweet potato and their wild relatives in these areas (De la Puente 1988; Khoury et al. 2015; Roullier et al. 2013b). Although the area covered for this exhaustive inventory was based in areas with high potential of sweet potato distribution in Colombia (Khoury et al. 2015; Muñoz-Rodríguez et al. 2018), other regions such as the Orinoquia, Pacific, Insular, and Amazon could be explored to recognize the status in those regions. Previous reports indicate that six new species belonging to the genus *Ipomoea* were collected in the Amazon rainforest. The low number of species, as well as their uncommonness, show that the environmental conditions in this region cause a differential diversity (Wood and Scotland 2017).

Moreover, most of the genotypes initially collected by CIP came mainly from the Andean region and less from the Caribbean region. Specifically, they were found in Nariño (67 accessions), Córdoba (30), Huila (27), Cesar (26), Quindío (22), Cundinamarca (20), and Valle del Cauca (20). But the departments of Antioquia, Atlántico, Bolivar, Boyacá, Caldas, Cauca, La Guajira, Magdalena, Norte de Santander, Risaralda, Santander, Sucre, and Tolima only had between 1 and 28 accessions (GRIN-Global 2021). Thus, the collection in this study allowed to increase the number of accessions from the Caribbean region, which is an area with high diversity potential (Flórez-Martínez et al. 2016).

Sweet potatoes were collected in a wide altitudinal distribution from sea level to altitudes of 2,555 masl. These results are consistent with previous reports, which showed that species of the genus *Ipomoea* are adapted to altitudes between 0 and 3,200 masl (Carranza 2007). However, the species showed a bimodal

Table 1.
Distribution of Sweet Potato (*Ipomoea batatas*) Accessions Collected in 19 Departments of Colombia

Department	No. accessions	Percentage
Caribbean region		
Cesar	92	12.27
Antioquia	62	8.26
Córdoba	45	6.00
Bolívar	37	4.93
Atlántico	24	3.20
Guajira	19	2.53
Sucre	7	0.93
Magdalena	4	0.53
Sub-total	290	38.7
Andean region		
Caldas	124	16.53
Santander	82	10.93
Tolima	55	7.33
Boyacá	51	6.80
Valle del Cauca	47	6.27
Quindío	41	5.47
Risaralda	33	4.40
Antioquia	13	1.73
Norte de Santander	11	1.47
Cauca	1	0.13
Huila	1	0.13
Nariño	1	0.13
Sub-total	460	61.3
Total	750	100%

distribution in relation to altitudinal gradient, to say the greatest amount of accessions (287 and 189) were collected at the altitudinal ranges of 0–500 and 1,501–2,000 masl, respectively (Figure 1B). Similar results were reported by Alcántar-Mejía et al. (2012), who studied the altitudinal distribution of the genus *Ipomoea* in the state of Michoacán, Mexico, where they managed to collect accessions from sea level to 3,000 masl but found the greatest amount of materials in the 0–299 and 1,800–2,099 masl ranges.

Sweet potato is a complex species due to the great genetic and morphological variation (Carranza 2007; Jackson et al. 2020; Wadl et al. 2018). It exhibits a wide natural distribution and adaptation to different environmental conditions. The geographical distribution of sweet potato germplasm is very important for its

Figure 1.
Total collection sites of sweet potato accessions in Colombia. (A) Geographical distribution of sweet potato accessions collected in Colombia. Black points represent collection sites of *Ipomoea batatas* L., and blue diamonds represent wild species of *Ipomoea* genus. Several colors identified the five natural regions in continental Colombia and collection points are distributed in Caribbean and Andean regions. (B) Frequency distribution of collected accessions by altitudinal range of total collection sites. The bars show the total number of collected accessions according to defined altitudinal ranges of total collection sites in Colombia. [Color figure can be viewed at wileyonlinelibrary.com]

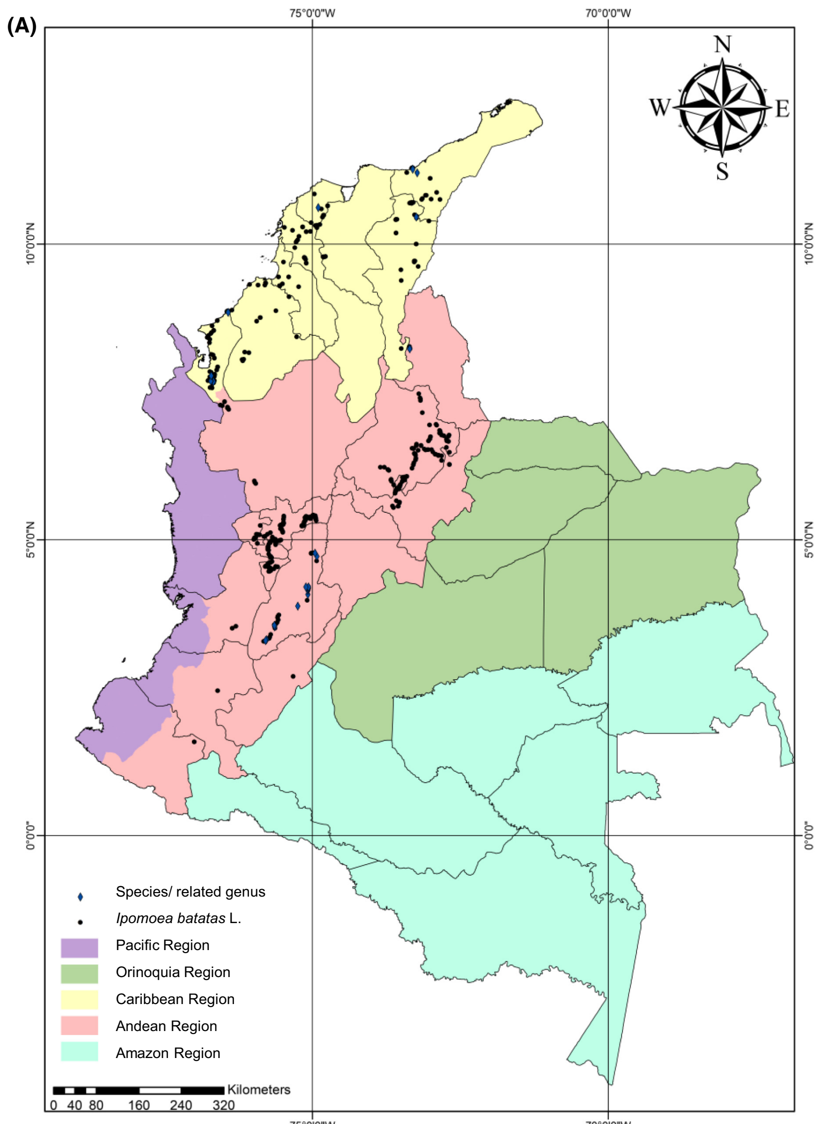
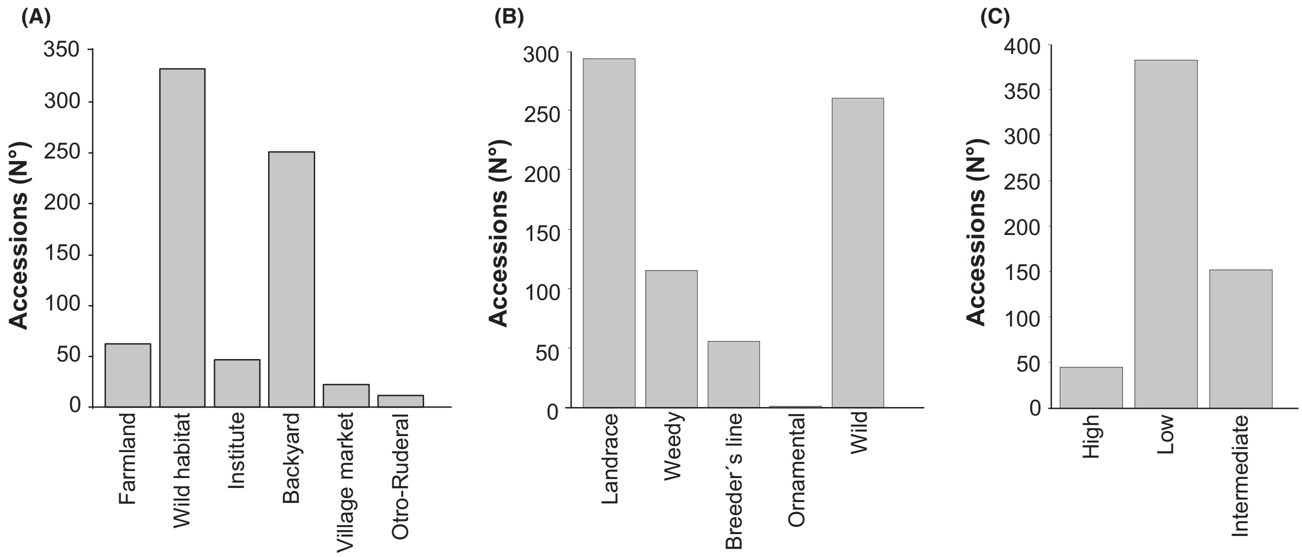


Figure 2.

General description of total collected germplasm in Colombia. (A) Frequency of total collected accessions according to collection source. (B) Frequency of total collected accessions according to status of sample. (C) Frequency of total collected accessions according to population density. The bars show the number of total collected accessions according to defined parameter in each variable.



utilization, since farmers have used local cultivars for a long time, which are well adapted to different soil and climatic conditions. High number of accessions from Caldas, Santander, Tolima, and Quindío were collected in wild habitats, meanwhile, the accessions from Cesar, Córdoba, Antioquia, and Bolivar proceeded mostly from cultivated areas (Table 1). These results are consistent with Flórez-Martínez et al. (2016), who indicated that the departments of the Caribbean region, especially Cesar and Córdoba, are the main producers and consumers of sweet potato in Colombia. However, farmers in this region depend on traditional or local materials for planting sweet potato, which limits its production to family consumption only and rarely to sale in local markets.

In Situ Germplasm Characterization

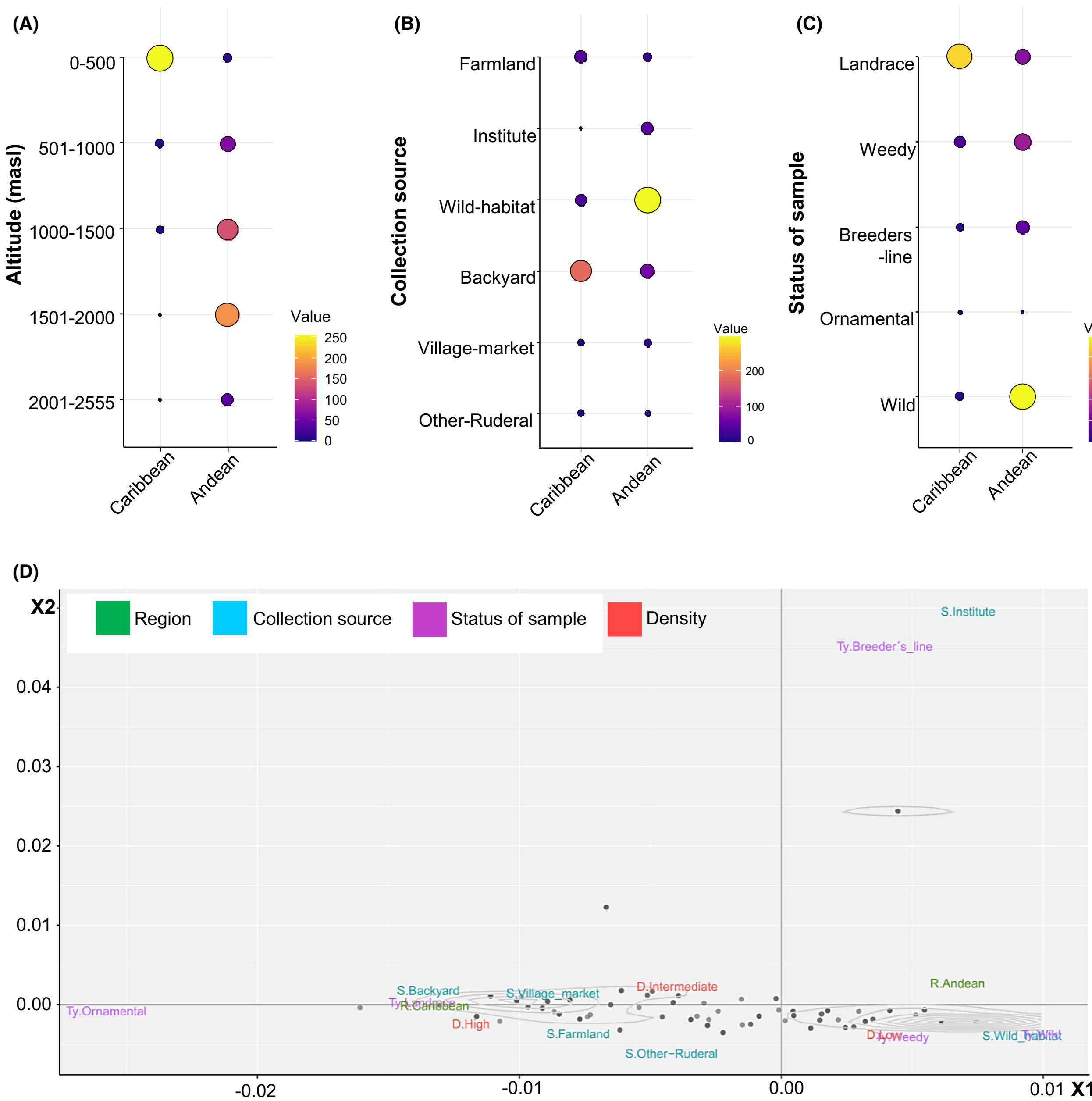
The collected accessions were characterized with respect to collection source, status of sample, and population density. Sweet potato was found in six different collection sources, with a high number of accessions found in wild habitats and orchards (Figure 2A). However, some genotypes were also found as main crops and even in local markets. A small number was found in ruderal environments, especially at the edge of roads or near canals. Forty-six accessions were breeder lines received from Clayuca Corporation, from CIP's germplasm bank, and were catalogued as "institutional." Since a high percentage of accessions were collected from wild habitats, this study confirmed the high adaptability and competitive capacity of this species to survive in environments without human intervention. The high rusticity of *I. batatas* under explored environments could confirm the archeological, linguistic, and historical evidence about its tropical origin in Central America, Colombia, Ecuador, and Peru. (Fuentes and Chujoy 2009; Muñoz-Rodríguez et al. 2018).

Regarding the status of sample, most of the genotypes were recognized as landraces, followed by those growing in wild habitats, and by those considered as weeds amidst other crops (Figure 2B). Forty-six accessions were breeder lines transferred by Clayuca Corporation, and finally a genotype that was being used as an ornamental. Moreover, most accessions had a low population density and were not a main crop (Figure 2C).

Colombia is part of the center of origin and diversity of sweet potato (De la Puente 1989; Fuentes and Chujoy 2009; Huáman and Zhang 1997; Mwanga et al. 2017). Consistently, the results of this study

Figure 3.

Characterization of Caribbean and Andean regions of Colombia in terms of habitat and germplasm description. (A) Distribution of collected accessions in two regions according to altitudinal ranges of collection sites (habits). (B) Distribution of collected accessions in two regions according to collection source. (C) Distribution of collected accessions in two regions according to status of sample. The bars show the number of collected accessions in two regions according to defined parameter in each variable. (D) Relationship of collection source, status of sample, and population density in two natural regions. Each point in the biplot is representing the collected accessions. Letters accompanying the specific category indicate the corresponding variable, S: collection source, Ty: status of sample (germplasm type), D: density, R: region. [Color figure can be viewed at wileyonlinelibrary.com]



demonstrated that sweet potato in Colombia is still conserved according to its native origin, since most of the accessions were found in wild habitats with low densities, and some of them were even considered as weeds. In this sense, this native species has developed high resilience mechanisms that have allowed its

Table 2.
Contributions of Dimensions Used in Correspondence Analysis of Germplasm and/or Habitat Description in Two Explored Regions

Dimensions	Eigenvalue	Percentage of variance	Cumulative percentage of variance
Collection source, status of sample and population density			
X1	0.66	20.61	20.61
X2	0.56	17.25	37.86

Table 3.
Relationship Between Habitats and Germplasm Description, and Natural Regions

Germplasm/habitat description	Gl	Value	Probability
Altitudinal range	4	573.44	<0.0001
Collection source	5	292.96	<0.0001
Status of sample	4	322.44	<0.0001
Population density	2	33.46	<0.0001
Use	11	397.42	<0.0001
Terrain topography	6	309.1	<0.0001
highest level landform	7	385.19	<0.0001
Gradient shape	5	284.54	<0.0001
Soil Drainage	3	37.94	<0.0001
Soil erosion	3	105.16	<0.0001
Soil color	10	45.01	<0.0001
Soil organic matter	5	36.22	<0.0001
Soil textural type	10	77.71	<0.0001
Vegetation in the surroundings	10	169.04	<0.0001
Light exposition	3	20.21	<0.0002

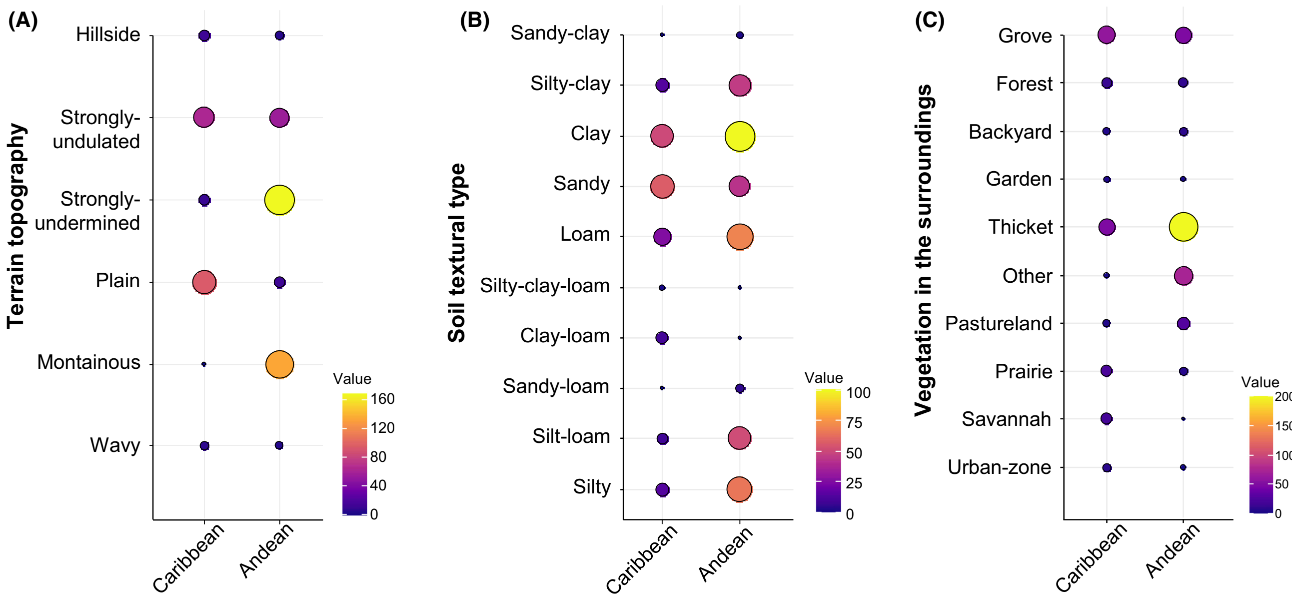
survival, multiplication, and conservation. In addition, the results of this study showed that farmers as well as local and indigenous communities play an important role in conservation of landraces in their orchards or fields. This valuable strategy of *in situ* conservation has guaranteed the conservation not only of cultivars, but also of neglected and underutilized species and crop wild relatives. Consistently, the results showed that *in situ* conservation represents a selection environment with high complexity, where the natural selection is integrated with the conscious selection made by farmers; thus avoiding genetic erosion and ensuring an essential source for the development of new cultivars (Bellon et al. 2017; Maxted et al. 2002). The role of farmers in unregulated *in situ* conservation had previously been recognized and valued in sweet potato cultivation in Asia (Prain and Campilan 1999), as well as in other crops such as cassava in Thailand (Fu et al. 2014), Colombia (Pérez et al., 2019), and Brazil (Carrasco et al. 2016), potato in Peru (de Haan et al. 2010, 2013), and Ecuador (Monteros-Altamirano 2018), among others. In all these cases, the genetic richness found in farmers' fields is highlighted, and the on-farm *in situ* conservation strategy is considered a determining factor in the conservation of several local varieties that are not necessarily being conserved in gene banks. The accessions collected in Colombia showed preliminarily the richness and diversity of sweet potato genepool in these two natural regions. However, some of the accessions were found in wild habitats or even were considered as weed. These findings demonstrate the potential to improve this crop based on its current genetic diversity, which is currently neglected and underutilized in Colombia and could be in danger of continued erosion. They also ratify the importance of further exploration, collection, and conservation of germplasm for medium and long-term use. The conservation of these genetic resources must recognize that farmers are active users of sweet potato diversity and have made selection based on their cultural and culinary background and current preferences.

Characterization of Sweet Potato Conservation Habitats and Agroecosystems

The accessions collected in different areas of Colombia were classified according to the environmental conditions of the two regions: 38% of the accessions proceeded from the Caribbean region (290 accessions) and 61% from the Andean region (460 accessions) (Table 1). The largest number of accessions collected in the Caribbean region come from altitudes below 1,500 masl, especially between 0 and 500 masl. While most of the accessions in the Andean region were concentrated at altitudes above 500 masl, and even reaching 2,555 masl (Figure 3A). In relation to the collection source, Caribbean accessions were

Figure 4.

Characterization of habitats found in Caribbean and Andean regions according to agro-ecosystemic parameters. (A) Distribution by terrain topography. (B) Distribution by soil textural type. (C) Distribution by surrounding vegetation. The bars show the number of collected accessions in two regions according to defined parameter in each variable. [Color figure can be viewed at wileyonlinelibrary.com]



landraces mostly found in orchards and fields, while Andean accessions were mainly classified as wild and were found in wild habitats and orchards (Figure 3B,C). The multiple correspondence analysis showed that accessions considered as landraces were preferentially grown in agricultural fields and horticultural gardens (orchards) with intermediate and high population densities and were sold in local markets (Figure 3D, Table 2). In contrast, the accessions classified as wild or weedy were generally found in wild habitats, especially in the Andean region, and were found in low population densities. The breeder lines were directly linked to the institutional source. The Chi-square test showed significant differences between the explored regions in terms of all evaluated characteristics (Table 3). The genotypes were mostly found in low density both in the Caribbean and Andean regions. Consistently, sweet potato showed a wide adaptation to several environmental conditions since the collected ecotypes showed a clear differentiation from the environment where they were growing. This is in line with the study of Glato et al. (2017), who stated that sweet potato diversity in phenotypic and genotypic traits is related to climatic variables.

Regarding the description of conservation habitats, the topography of the Caribbean terrains where sweet potato was collected were flat and heavily undulated, in contrast, the Andean terrains were heavily undermined and mountainous (Figure 4A, Table 4). Moreover, the edaphic conditions of collection sites showed that Caribbean soils had good drainage, high erosion, low to intermediate levels of organic matter content, and were predominantly sandy and clayey (Figure 4B). The Andean soils exhibited moderate to good drainage, intermediate to low erosion, intermediate to high levels of organic matter content, and were mainly clay, loam, and silty. In the Caribbean region, sweet potatoes were growing among thickets, trees, and savannah vegetation, while in the Andean region, they were growing among thickets (Figure 4C). The different environmental conditions, where sweet potato was growing in these two regions, could suggest a potential wide diversity of this species, since potential functional adaptation to diverse environments was reported for several crops and their relatives. The genetic composition of plant species varies across geographic range and is associated with adaptation to different ecological conditions (Castañeda-Álvarez et al. 2016; Eckert et al. 2008; Glato et al. 2017).

Table 4.
Modal Description of Germplasm and Habitats of Collected Accessions in Two Explored Regions

Germplasm/ Hábitat description	Caribbean region	Andean region
Collection source	Backyard	Wild habitat
Germplasm type	Landrace/native cultivar	Wild, weedy
Population density	Low	Low
Terrain topography	Plain, strongly wavy	Strongly undermined, mountainous
Highest level landform	Plain, valley, hill	Mountain, cuenca
Gradient shape	Plain	Irregular
Vegetation in the surroundings	Grove, thicket	Thicket, other
Soil Drainage	Well drained	Moderately drained, well drained
Soil erosion	Low, intermediate	Intermediate, low
Soil color	Brown, yellowish brown	Yellowish brown, brown, gray
Soil organic matter	Intermediate, low	Intermediate, high
Soil textural type	Sandy, clay	Clay, loam, silt
Light exposition	Sunny, shading	Sunny, shading

Table 5.
Description of Sweet Potato Use and Crop Management Reported in Collections Sites From Two Explored Regions

Use and crop management	Caribbean region	Andean region
Use	Weedy (8.2%), food (83.9%), food/weedy (1.07%), ornamental (0.35%), none (6.0%), other (0.35%)	Weedy (13.7%), food (11.0%), food/forage (0.89%), food/medicinal (1.5%), forage (2.2%), none (68.9%), other (1.8%)
Parts used	Leaves and tuberous roots	Tuberous roots
Crop	management (from 105 collection sites)	Associated with other crops (10.7%), traditional management (13.3%), irrigation/weed and pest control (56.0%), none (20.0%)
Associated with other crops (33.3%), traditional	management (18.2%), irrigation/weed and pest control (15.2%), none (33.3%)	
Associated crops (from 160 collection sites)	Sugarcane (*Saccharum officinarum* L.), plantains (*Musa* spp.), citrus fruits (*Citrus* ssp.), cacao (*Theobroma cacao* L.), timber trees, pigeonpea (*Cajanus cajan* L.), guava (*Psidium guajava* L), vegetable	Coffea (*Coffea arabica* L.), vegetable crops, cassava (*Manihot esculenta* Crantz), Sugarcane (*Saccharum officinarum* L.), plantains (*Musa* spp.), coconut (*Cocos nucifera* L.), maize (*Zea mays* L.), beans

Uses and Traditions Related to Sweet Potato Conservation

In the Caribbean region, the main use of sweet potatoes was as a food source (Table 5), while in the Andean region no specific uses were reported and it is generally considered as a weed. Specifically, both tuberous roots and leaves of sweet potatoes were used by farmers in the Caribbean region, while the tuberous root were only used by a low percentage of farmers in the Andean region. As expected, high percentage of collection sites in Caribbean region reported crop management practices related to irrigation and weed or pest controls. Meanwhile, this crop did not receive any

Table 5. (*Continued*)

Use and crop management	Caribbean region	Andean region
	crops, soursop (*Annona muricata* L.), castor bean (*Ricinus communis* L.), mango tree (*Mangifera indica* L.), maize (*Zea mays* L.), papaya (*Carica papaya* L.), cassava (*Manihot esculenta* Crantz), ornamental plants, taro (*Colocasia esculenta* Schott), achiote (*Bixa orellana* L.), sesame (*Sesamum indicum* L.), calabash tree (*Crescentia cujete* L.), coconut (*Cocos nucifera* L.)	(*Phaseolus* ssp.), citrus fruits (*Citrus* ssp.), timber trees, castor bean (*Ricinus communis* L.), leucaena (*Leucaena leucocephala* Lam.),
Major crops	Cassava and plantain	Coffea and vegetables

crop management in the Andean region. The sweet potato accessions were found next to sugar cane, plantains, citrus fruits, timber trees, vegetables, castor beans, maize, and coconut in the two regions. In the Caribbean region, sweet potatoes were mainly found in association with cassava and plantain crops, and to a lesser extent with cocoa, pigeon pea, guava, mango, papaya, and other crops. In the Andean region, sweet potatoes were grown mainly in association with coffee and vegetable crops, and to a lesser extent with beans, plantains, and leucaena crops, among others (Table 4). These results show that the direct uses of sweet potatoes in local diets have been maintained in the Caribbean but have been lost in the Andes over time. There is evidence that Muisca indigenous people in the Andes roasted, baked, or used sweet potatoes in soups. After the arrival of the Spanish in Colombia, they began to be prepared in the Andes as a dessert (Patiño 1990). However, the study showed that sweet potatoes in the Andean regions are commonly considered as weed.

Results also showed that there is a diverse culture in relation to sweet potato in Colombia. In the Caribbean, the conservation of this genetic resource is mainly in charge of farmers and communities. Even though sweet potato crop in Colombia is neglected and underutilized, the cultural background behind this species has guaranteed its conservation *in situ*. Consistently, local indigenous communities, mainly from the Caribbean region, such as the Arhuacos, Kankuamos, Wiwas, and Koguis, have grown sweet potato not only as source of food, but also for therapeutic, medicinal, ceremonial, handicraft, and ornamental products (FAO 2015). In the area explored in the Andean region and in some parts of the Caribbean region, the capacity of adaptation and rusticity of sweet potato (possibly due to its native origin) (De la Puente 1989; Fuentes and Chujoy 2009; Huáman and Zhang 1997; Mwanga et al. 2017) has guaranteed its survival, multiplication, and conservation, in spite of not being recognized as a crop in these regions. The diversity of sweet potato accessions maintained by farmers in these regions also demonstrated the dynamic events and evolutionary processes of some species, which are not faced by the diversity conserved in the gene banks (Bellon et al. (2017). In fact, this diversity can finally be promoted through the exchange of materials that allow diversification in the use and cultural preference of different cultivars (Prain and Campilan 1999). This preliminary exploration demonstrated the great reservoir of sweet potato germplasm conserved *in situ*, for a crop that is currently neglected and underutilized in Colombia and is in high risk of genetic erosion. Several efforts should be included to guarantee the conservation and use of this genetic richness, including its promotion as an alternative crop in Colombia. As it is also stated by Bellon et al. (2017), on-farm conservation has shown to be an efficient strategy for conserving and using rare or new genetic resources of value to the future of agriculture; therefore, it has to be considered within national conservation efforts.

Conclusions

This study showed the current condition of the diversity of sweet potato conserved *in situ* in Colombia, due to its condition of native species and its possible primary center of diversity. It appeared in a wide spatial and altitudinal distribution in two explored natural regions, and in varied topographic and edaphic conditions. It also was found in wild or cultivated habitats, as wild-type germplasm or landraces. It was associated with conventional crops in each region and was mostly recognized as food or weed.

The results of this study recognize the invaluable contribution of farmers and communities in the *in situ* preservation of germplasm and its associated knowledge. The two explored regions show a wide presence of sweet potato accessions, demonstrating the reservoir of this crop gene pool and the need to protect it in national conservation efforts. New zones should be explored in order to safeguard the diversity of sweet potato in Colombia.

In addition, the high diversity of this species is also a source of adapted genetic resources to improve the sustainability of current agricultural systems and ensure food security of vulnerable communities under climate change scenarios.

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Conflict of Interest

The authors declare that they have no conflict of interest.

Author Contributions

AR, IP, RM, LE, EG, and LG visited and collected planting material and information of accessions. LG, JP, RM, and LE processed the planting material and organized the database. AR, MR, LG, ER, IP, GA, TR, and SS analyzed the data, wrote the initial manuscript, and corrected version. All authors have read and approved the manuscript for publication.

Consent for Publication

All authors have read and approved the manuscript for publication.

Data Availability Statement

The data sets supporting the conclusions of this article are included in this article.

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