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Chapter 1

Wild plant genetic resources in North America: an overview

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Abstract North America, including Canada, Mexico and the United States, is rich in plant species used by humans in both ancient and modern times. A select number of these have become globally important domesticated crops, including maize, beans, cotton, and sunflower. Many other native and also naturalized species have potential for use, either directly or as genetic resources for breeding agricultural crops. However, despite increasing recognition of their potential value, deficiencies in information, conservation, and access to the diversity in these plants hinder their further use. This chapter provides an overview of the agriculturally relevant wild plant resources of North America, with focus on wild relatives of globally important major crops, as well as the wild cousins of regionally and locally important domesticates. The chapter concludes by providing an overview of strategies for conserving wild plant genetic resources, including the international regulatory frameworks affecting policies to various degrees in Canada, Mexico and the United States.

Keywords: Germplasm, genetic resources, wild species, conservation, North America, crop resources

1.1 Introduction

Increasingly variable weather, shifting disease and pest pressures, soil degradation, loss of arable lands and water scarcity are not only on the horizon; they are already our reality. Canada and the United States are experiencing higher temperatures and more severe weather events, storms, and wildfires (Field et al. 2007). Mexico is undergoing an even greater range of climatic changes, including increased temperatures, especially in the north; decreased rainfall in the central regions; and more storms and prolonged drought during the dry season (National Intelligence Council 2009). Farmers in North America face a turbulent ride as they navigate the Anthropocene to continue to produce a considerable portion of the food, fiber and other plant-based resources utilized around the world.

An important strategy for preparing for these challenges is breeding plants that can handle the emerging abiotic and biotic challenges. Wild plant species that are closely related to crops are increasingly recognized as some of the most promising genetic resources that plant breeders can turn to in their efforts to develop cultivars adapted to more extreme conditions (Dempewolf and Guarino 2015; Dempewolf et al. 2017; Castañeda-Álvarez et al. 2016, Zhang et al. 2017). They have already proven their worth in breeding (Hajjar and Hodgkin 2007; Maxted et al. 2012). Ironically, however, the very wild species being promoted as essential tools in resolving agricultural problems are themselves vulnerable to the accelerating environmental changes (Jarvis et al. 2008; Lira et al. 2009; Thomas et al 2016), as well as to the persistent threats presented by habitat modification, pollution, invasive species, and other anthropogenic impacts (Brummitt et al. 2015).

Confounding progress on conservation of these important species is the fact that agriculturally relevant wild plants occupy a niche that is generally neglected by agricultural researchers, who tend to focus their attention on a handful of crops. At the same time, agriculturally relevant wild species are often also overlooked by habitat and endangered species conservation practitioners, who focus on securing rare and threatened taxa and their ecosystems, rather than on safeguarding the intraspecific variation in frequently common, and often weedy, crop wild relatives.

The information in this introductory chapter sets the stage for the rest of the book. We begin by defining essential terms and concepts. We then discuss the process of domestication, focusing on the crops domesticated in North America. We briefly discuss the importance of wild utilized species, then focus on an overview of the occurrence and conservation status of North American crop wild relatives of important crops. We conclude by discussing in broad strokes the general strategies for conserving wild plant genetic resources, including the international regulatory frameworks affecting policies to various degrees in the region.

1.2 An agricultural perspective on North America's wild flora

The number of native vascular plant species in the three countries increases from north to south. Canada has almost 5,860 (Brouillet et al. 2010) and the United States has nearly 16,200 native plant species (Stein 2002). With 23,314 species (Villaseñor 2016), Mexico is a megadiverse country and fourth in the world for number of native vascular plants. Given such broad diversity

in species, it is perhaps surprising that modern day humans use a relatively small number. The United Nations Food and Agriculture Organization (FAO) global aggregate statistics tell us that just 18 or so plants contribute to 90% of the world's calories, and that of these, only two, maize and sunflower, are indigenous to North America (Khoury et al. 2014). However, calories are not the only important component of diet. Plant species also provide protein, fat, starch, fiber, vitamins, minerals, phytonutrients, and flavor. For example, chili peppers, the main cultivated species of which originated in North America, are the world's most important spice by essentially all measures. Moreover, many plant species are used for purposes other than food. Examples of important North American species valued for non-food uses include cotton (as a textile), echinacea and American ginseng (as medicines), guayule and jojoba (for industrial uses), hops and vanilla (as flavorings), and rudbeckia and phlox (as ornamentals).

Useful plants fall along a continuum that can be categorized according to the extent that humans have influenced their form. At one end of the continuum are domesticated species, that we call "crops". Crops display a very considerable suite of changes driven by selection pressures placed upon them by humans, typically including the loss of natural dispersal mechanisms, larger sizes of seeds, fruits, or other plant parts, and the loss of dormancy. At the other end, are wild species that show no morphological evidence of human use. Both crops and wild species can be managed by humans (e.g. wild fruit trees managed *in situ* by burning or annual crops cultivated *ex situ* by planting and harvesting in fields), and management of wild species can lead to domestication (i.e. Casas et al. 2007). The focus of this book is on wild plant species with relevance for agriculture and other human uses, which we term "wild plant genetic resources". These species include the wild plant populations from which domesticated varieties evolved (crop progenitors), wild species that can be used to improve contemporary crops (crop wild relatives), wild species that have a record of use by people (wild utilized species), and any other wild species with potential for future crop development (new crops).

1.2.1 Wild Utilized Species

Historically, wild plant species have underpinned the diets of gatherer-hunter and forager cultures and continue today to contribute significantly to diets, particularly in rural regions of the developing world (Bharucha and Pretty 2010). In Mexico, it is estimated that 5,000-7,000 wild plant species were used for food and other purposes (Casas et al. 1994; Caballero et al. 1998). North of Mexico, approximately 1,800 species have been documented as having been used by the indigenous peoples of North America (Moerman 2003), and Uprety et al. (2012) reported that 546 medicinal plants were used by indigenous peoples in the boreal forests of Canada. Many of these wild food and medicinal species were adopted by early colonists in North America (Turner and von Aderkas 2012), and foraging for wild plant species to use as food or medicine continues to be important in North America. In recent decades, there has been growing interest in using wild plants, especially native species, to revegetate or restore wild lands. For example, in the United States, an alliance of federal and private partners has developed the National Seed Strategy for Rehabilitation and Restoration, driven by Federal mandates to use native plant materials (Plant Conservation Alliance 2015).

1.2.2 Domestication in North America

For a select group of plant species, human use has led to domestication. Larson et al. (2014) provides a general definition of domestication as "a selection process for adaptation to human

agro-ecological niches and at some point in the process, human preference.” Archaeological remains provide ample evidence for the domestication of North American wild progenitors of crop plants, beginning 12,000-8,200 BP in Mesoamerica and 8,200-4,200 BP in temperate regions (Larson et al. 2014). A number of these domesticates have over time become globally important (Table 1.1) (Khoury et al. 2016). A few, such as marsh-elder (*Iva annua* L.), little barley (*Hordeum pusillum* Nutt.) and devil’s claw (*Proboscidea parviflora* [Wool.] Wool and Standi), have largely been abandoned (Smith 2006; Bretting 1986).

The process of domestication is driven by the interaction of environmental factors, biology and human needs, which results in crops that range from plants that differ only slightly from their wild ancestors to species that cannot persist without human interaction (Larson et al. 2014; Meyer et al. 2012). Mesoamerica provides a fine example of this (Lira 2009). Over 20 plant species have been domesticated and have reached globally important food crop status, including maize (*Zea mays* L.), beans (*Phaseolus* L. spp.), chili pepper (*Capsicum annuum* L.), pumpkins and squashes (*Cucurbita pepo* L.), cotton (*Gossypium hirsutum* L.), avocado (*Persea americana* Mill), cacao (*Theobroma cacao* L.), and vanilla (*Vanilla planifolia* Jacks). Within this same region, a study limited to the Tehuacán-Cuicatlán Valley, Mexico, found that there were over 200 species currently in incipient stages of domestication, the result of management in traditional agricultural systems (Casas et al. 2007; Avendaño et al. 2009; Blancas et al. 2010). Table 1.1 provides a select list of native North American domesticated species, including the approximate time of start of domestication, the degree to which the crop has changed from its wild counterpart. The list demonstrates that a wide range of crops have been domesticated in North America, that crops have been domesticated from the pre-Columbian era to the present era, and that the domestication level of the majority of these plants tends to be medium to low.

Domestication causes a number of phenotypic changes, frequently referred to as the domestication syndrome. Pickergill (2007) discussed morphological changes in New World domesticates, which generally included loss of dispersal mechanisms, increases in size and morphological variation, changes in plant habit, loss of seed dormancy and loss of chemical and mechanical protection. Changes to developmental and morphological domestication traits tend to occur through selection on transcriptional regulators while selection on structural genes and regulatory genes influence domestication traits that involve specific metabolic pathways (Doebley et al. 2006; Olsen and Wendel 2013).

1 Table 1.2 Selected native North America domesticates

Taxon	Common Name	Location	Date ^a	Domestication level ^b	Comments/ Key references
<i>Agave tequilana</i> Weber and other Agave species	Agave	Yucatan, Mexico	9000	Low	Meyer et al. (2012); Colunga-Garcia Marin and Zizumbo-Villarreal (2007)
<i>Amaranthus caudatus</i> L., <i>A. cruentus</i> L., and <i>A. hypochondriacus</i> L.	Amaranth	Mexico	6000	Low	Pickersgill (2007); Janick (2013)
<i>Andropogon gerardii</i> Vitman	Big bluestem	United States	50	Low	Price et al (2012)
<i>Annona cherimola</i> Mill.	Cherimoya	Southern Mexico	4000	Low	Casas et al (2007)
<i>Apios Americana</i> Medik.	Indian bean	Midwestern to Northeastern United States	500	Low	Reynolds et al. (1990)
<i>Asimina triloba</i> (L.) Dunal	Pawpaw	Southeastern, United States	100	Low	Meyer et al. (2012)
<i>Bouteloua dactyloides</i> (Nutt.) Columbus	Buffalograss	United States	50	Low	Riordan and Browning (2003)
<i>Canavalia ensiformis</i> (L.) DC.	Horse bean, jack bean	Mexico	1050	Low	Sauer and Kaplan (1969)
<i>Capsicum annuum</i> L. var. <i>annuum</i>	Chili pepper	Highlands of Mexico	6000	High	Meyer et al. (2012)
<i>Carica papaya</i> L.	Papaya	Southern Mexico	2000	Medium	Meyer et al. (2012)
<i>Carya illinoensis</i> (Wangenh.) K. Koch	Pecan	Southeastern United States	400	Medium	Grauke (2016)
<i>Casimiroa edulis</i> Llave & Lex.	White sapote	Central Mexico	5000	Medium	Meyer et al. (2012)

<i>Chenopodium berlandieri</i> subsp. <i>jonesianum</i>	Chenopod	Eastern United States	3700	Low	No longer cultivated/ Smith (2006)
<i>Chenopodium berlandieri</i> subsp. <i>nuttalliae</i>	Huauzontle	Southern Mexico	700	Low	Smith (2006)
<i>Chenopodium ambrosioides</i> L.	Epazote	Mexico	100	Low	Blanckaert et al. (2012)
<i>Cucurbita argyrosperma</i> Huber subsp. <i>argyrosperma</i>	Silver-seed gourd, green-stripe cushaw	Southwest Mexico	<7000	Medium	Sanjur et al (2002); Hernandez Bermejo and Leon (1994)
<i>Cucurbita pepo</i> L. subsp. <i>ovifera</i>	Squash	Eastern United States	8000	High	Meyer et al. (2012)
<i>Cucurbita pepo</i> L. subsp. <i>pepo</i>	Pumpkin	South-Central Mexico	10,000	High	Meyer et al. (2012)
<i>Diospyros nigra</i> (J.F. Gmel.) Perrier	Black Sapote	Mexico	5400	Medium	Meyer et al. (2012)
<i>Fragaria x ananassa</i> Duchesne ex Rozier	Modern cultivated strawberry	Eastern United States	1740	High	<i>F. virginiana</i> parent came from eastern North America, however hybrid was developed in France/ Meyer et al (2012)
<i>Echinacea purpurea</i> (L.) Moench	Purple coneflower	Eastern United States	50	Low	Ault (2003)
<i>Gossypium hirsutum</i> L.	Cotton	Eastern central Mexico	5500	High	Meyer et al. (2012)
<i>Helianthus annuus</i> L.	Sunflower	Eastern United States	4300	High	Meyer et al. (2012)
<i>Helianthus tuberosus</i> L.	Jerusalem artichoke	Eastern United States	1000	Medium	Used by indigenous peoples but major steps in domestication probably by Europeans/ Pickersgill (2007)

<i>Iva annua</i> L. var. <i>macrocarpa</i>	Sumpweed, marshelder	Eastern United States	4000	Low	No longer cultivated/ Meyer et al. (2012)
<i>Leucaena</i> spp.	Leucaena, guaje	Mexico	3000	Low	Zarate (1999)
<i>Opuntia ficus-indica</i> (L.) Mill.	Prickly pear	Central Mexico	9000	Low-Medium	Griffith (2004)
<i>Pachyrhizus erosus</i> L. (L.) Urb	Jicama, yam bean	Mexico	4400	Medium	Pickersgill (2007)
<i>Panicum hirticaule</i> J. Presl var. <i>hirticaule</i>	Mexican panic grass	Mexico	4000	Low	Nabhan and de Wet (1984)
<i>Panicum virgatum</i> L.	Switchgrass	United States	100	Low	Casler (2012)
<i>Parthenium argentatum</i> Gray	Guayule	United States	50	Low	Ray et al. (2005)
<i>Persea americana</i> Mill.	Avocado	Southern Mexico	7000	Medium - High	Meyer et al. (2012)
<i>Phaseolus acutifolius</i> Gray	Tepary Bean	Central or Northern Mexico, Southwestern United States	5000	High	Blair et al. (2012)
<i>Phaseolus coccineus</i> L.	Runner bean	Mexico	900	High	Guerra-García et al. (2017)
<i>Phaseolus lunatus</i> L.	Sieva bean	Central Western Mexico	1800	High	Chacón-Sánchez and Martínez-Castillo (2017)
<i>Phaseolus vulgaris</i> L.	Common bean	Central Mexico	7000	High	Bitocchi et al. (2017)
<i>Phlox paniculata</i> L.	Phlox	United States	50	Low	Zale and Jourdan (2015)
<i>Physalis philadelphica</i> Lam.	Tomatillo, husk tomato	Western Mexico	2750	High	Zamora-Tavares et al. (2014)

<i>Podophyllum peltatum</i> L.	Mayapple	United States	50	Low	Lata et al. (2009)
<i>Pouteria sapota</i> (Jacq.) H. E. Moore & Stearn	Mamey sapote	Southeast Mexico	>450	Medium	Arias et al. (2015)
<i>Proboscidea parviflora</i> (Wooton) Wooton & Standl. subsp. <i>parviflora</i>	Devil's claw	Southern Arizona, United States and Northern Sonora, Mexico	1700	Low	Rarely cultivated/ Bretting and Nahban (1986)
<i>Psidium guajava</i> L.	Guava, guayaba	Southern Mexico	5000	Medium	Ladizinsky (1998); Meyers et al (2012)
<i>Rubus plicatus</i> Weihe & Ness and hybrids	blackberry	North American, North of Mexico	150	Medium	Janick (2013)
<i>Rubus occidentalis</i> L.	Black raspberry	North America, North of Mexico	120	Medium	Sauer (1993)
<i>Salvia hispanica</i> L.	Chia	Mexico	450	Medium	Cahill (2005)
<i>Sassafras albidum</i> (Nutt.) Nees	Sassafras	Eastern United States	500	Low	Meyer et al. (2012)
<i>Sechium edule</i> (Jacq.) Sw.	Chayote	Mexico	>450	Medium	Lira Saade (1994)
<i>Setaria parviflora</i> (Poir.) Kerguelen	Knot-root fox tail, bitter grass	Mexico, United States	6000	Low	No longer cultivated/Austin (2006)
<i>Spondias purpurea</i> L.	Jocote, Purple Mombin, Hog Plum	Southern Mexico	>450	Low	No archeological evidence; plants widely grown when Europeans arrived/ Piperno and Smith (2012)
<i>Spondias mombin</i> L.	Ciruela, hog plum	Southern Mexico	7000	Low	Piperno and Smith (2012)

<i>Theobroma cacao</i> L.	Cacao	Southern Mexico	1500	Medium	Meyer et al. (2012)
<i>Vaccinium corymbosum</i> L.	Blueberry (highbush)	Eastern United States	100	Medium	Meyer et al. (2012)
<i>Vaccinium macrocarpon</i> Ait.	Cranberry	Eastern United States	100	Medium	Meyer et al. (2012)
<i>Vanilla planifolia</i> Jacks	Mexican vanilla	Southeastern Mexico	1800	Low	Lubinsky et al. (2008)
<i>Zea mays</i> L. subsp. <i>mays</i>	Corn, maize	Mexico	6250	High	Meyer et al. (2012)
<i>Zizania palustris</i> L.	Wildrice (American)	Northcentral United States	25	Low	Meyer et al. (2012)

2 ^a First evidence of domestication. Approximate date based on “years ago” (YA) standardized at 1950 as present.

3 ^b Level of domestication: high- cannot survive in the wild; medium- some domestication traits present; low- few domestication traits
4 present

5
6
7
8

1.2.3 Improving crops using wild genetic resources

A frequent and unintended consequence of domestication is a reduction in genetic diversity, the consequence of genetic drift due to limited sampling of only a small subset of individuals from wild populations via the selection of domestication traits (Olsen and Wendel 2013). This process is frequently termed the “domestication bottleneck” (Olsen and Gross 2008). Domestication bottlenecks have been reported in many North American domesticates, such as maize (Wright et al. 2005), common bean (Rendón-Anaya et al. 2017), sunflower (Tang and Knapp 2003), and squash and pumpkin (Kates et al. 2017). Miller and Gross (2011) reviewed the literature for 22 annual and perennial taxa and compared neutral genetic diversity between wild species and their domesticated counterparts. Across the following North American domesticates, the average proportion of total diversity retained in domesticates was 75%: common bean, lima bean, scarlet runner bean, chile pepper, maize, sunflower, pecan, red guaje, columnar cactus, and jocote. Annual domesticates retained an average of 70% of diversity, compared to perennial crops, which had little change (Miller and Gross 2011). Maintenance of variation in perennial crops was attributed to the fact that compared to annual crops, perennials have undergone fewer sexual cycles since domestication as a result of their long juvenile phase, clonal propagation, and a broad range of mating systems.

The diversity studies reviewed by Miller and Gross (2011) highlight that for many crops, potentially useful traits have not only been left behind in their wild counterparts, due to sampling bias, but have also been lost during the selection process because they were not useful traits for de novo domestication (Fig 1.1). However, with our current efforts to improve crops that are more resilient to climate change, traits left behind in the wild or lost during selection, have the potential to provide valuable adaptations to abiotic and biotic stresses, enhance nutritional quality and improve a host of other attributes (Dempewolf et al. 2017; Zhang et al. 2016).

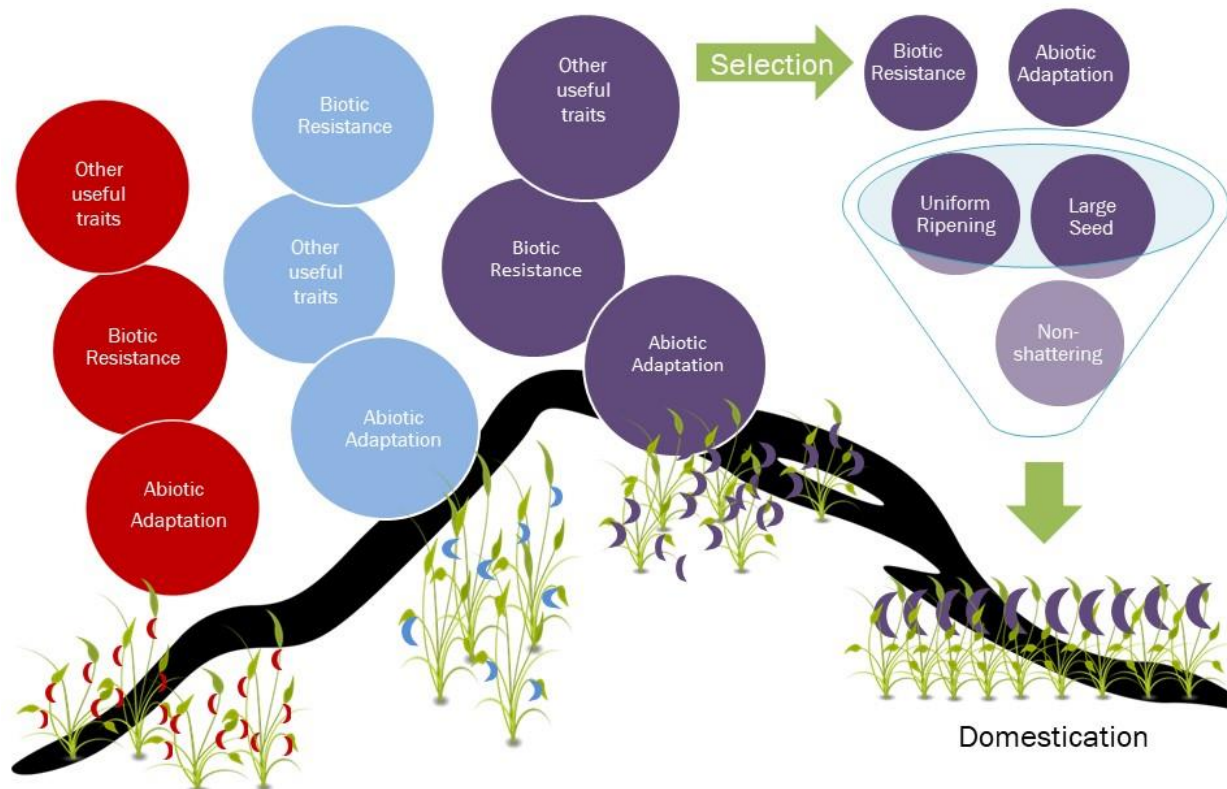


Fig 1.1 Although the domestication process results in crops more suitable for human use, a general trade-off is the reduction in genetic diversity (relative neutral allelic diversity is represented by the size of bubble). Adaptive traits, the results of natural selection in diverse environments (colors represent ecotypes) may be left behind in wild progenitors due to sampling bias or be lost during selection for domestication traits

1.3 Categorizing Wild Genetic Resources by their Potential for Use in Crop Improvement

We define crop wild relatives (CWR) as “wild plants that can be used to improve crops because they are close enough genetically for successful gene transfer”. Harlan and de Wet (1971) developed the “gene pool” concept, based on the relative success of interspecific hybridization, to classify the usefulness of wild taxa for crop improvement. However, these types of studies have not been conducted for all crops, and crossing success may not be indicative of CWR usefulness in crop improvement (Wiersema and León 2016). To counter this, Maxted (2006) proposed the “taxon group” concept, based on infrageneric taxonomic classifications with wild taxa in closer sections or other groupings within the crop genus being considered more closely related to the crop and thus having higher potential value. However, there are limitations to this approach since some genera lack such classification, and classifications based on morphology may overlook issues such as ploidy differences that influence crossability. More recently,

Wiersema and León (2016) have attempted to integrate the gene pool concept with an enhanced taxon group concept (i.e. phylogenetic and ploidy data are incorporated) to develop genetic relative classes that are descriptive of CWR with crossability data, and predictive of CWR having unknown crossability with the crop. Primary genetic relatives cross readily with the crop or can be predicted to cross readily based on taxonomic relationships, and produce (or can be expected to produce) fertile hybrids with good chromosome pairing. Secondary genetic relatives cross readily or can be predicted to cross readily based on taxonomic relationships, but produce (or can be expected to produce) partially or mostly sterile hybrids and have poor chromosome pairing; therefore some effort is needed to overcome barriers to the production of viable offspring. Tertiary genetic relatives can be crossed or can be predicted to cross based on taxonomic relationships, but produce (or can be expected to produce) lethal or sterile hybrids, necessitating special techniques (some not yet developed) for successful gene transfer. Wiersema and León (2016) also include a fourth class, “graft stock” that includes CWR useful as rootstocks, or as genetic resources for breeding root-stocks.

Genomic data are rapidly expanding our understanding of the phylogenetic relationships between crops and closely related species and promise to further refine attempts to classify CWR based on their usefulness to improve crops. Miller and Khoury discuss this potential further in Chapter 6 (this volume). CWR lists are available from GRIN Global (<https://npgsweb.ars-grin.gov/gringlobal/taxon/taxonomysearchcwr.aspx>) (Wiersema et al. 2012) and from the ‘Harlan and de Wet Crop Wild Relative Inventory’ (<https://www.cwrdiversity.org/checklist/>) (Vincent et al. 2013).

1.4 Overview of crop wild relatives in North America

An important first step in conservation planning is the creation of a species inventory (Maxted et al. 2012). National inventories of CWR have been published for a growing list of countries, including the United States (Khoury et al. 2013). Mexico is close to publishing an inventory, and Canada has identified this as a priority. At the global level, the Crop Trust (formally known as the Global Crop Diversity Trust, www.croptrust.org) and the Royal Botanic Garden, Kew, with funding from the Norwegian Government, have supported the development of the “Harlan and de Wet Crop Wild Relative Inventory” (Vincent et al. 2013), and a global “gap analysis” of crop wild relatives (Castañeda-Álvarez et al. 2016). The goal has been to develop a global inventory of CWR of major food crops, and to gain a better understanding of the representation of these CWR in the world’s major public genebanks. The inventory (<https://www.cwrdiversity.org/checklist/>) contains information on 1,667 CWR taxa related to 173 globally important crops (see Vincent et al. [2013] for their definition of globally important crops). These data were used to obtain an overview of CWR found in Canada, Mexico and the United States. Tables 1.3, 1.4 and 1.5 summarize the number of CWR taxa by genus, taken from the inventory for each country. Canada, with the smallest number of globally important CWR taxa (84), still possesses a large number of taxa closely related to sunflower, currants, gooseberries, and strawberry. Mexico with 240 CWR taxa in the inventory, is not surprisingly, rich in CWR taxa related to maize and several beans, crops that were domesticated in that region. The United States has 351 CWR taxa (351) listed in this inventory. The large number may be reflective of efforts in the United States to better document native CWR resources. The United

States is rich in CWR taxa for sunflower, grape, stone fruits, and small fruits (blackberries, blueberry, cranberry, currants, gooseberries, raspberries and strawberry).

There are many more CWR found in North America than those listed in the Harlan and de Wet Crop Wild Relative Inventory. Although these plants are not genetic resources for globally important food crops, they are important to support the breeding of minor and specialty crops, non-food crops, and for new crop development. Fig. 1.2 illustrates where 618 CWR taxa, including the full set of wild species mapped for the chapters of this book, are concentrated across North America. Regions with a large number of taxa include central and southwestern Mexico, the north and central parts of the eastern United States, the major mountain ranges in Mexico and the United States, and coastal areas. Figures 1.3, 1.4 and 1.5, and 1.6 show the richness of CWR species based on the standard categories of economic plants used in Wiersema and León (2013). Cereals and legumes are concentrated in the central and southern region of western Mexico (Fig. 1.3). Wild genetic resources of vegetables are concentrated in central and southern Mexico, and also in the northern and southeastern United States, as well as the Midwestern region of the United States (Fig. 1.4). Wild relatives of fruit crops are concentrated in the northeastern United States and southeastern Canada, as well as in the northwestern United States and southwestern Canada (Fig. 1.5). Wild resources of medicinal, ornamental, industrial and social use crops are concentrated in the central and eastern United States (Fig. 1.6)

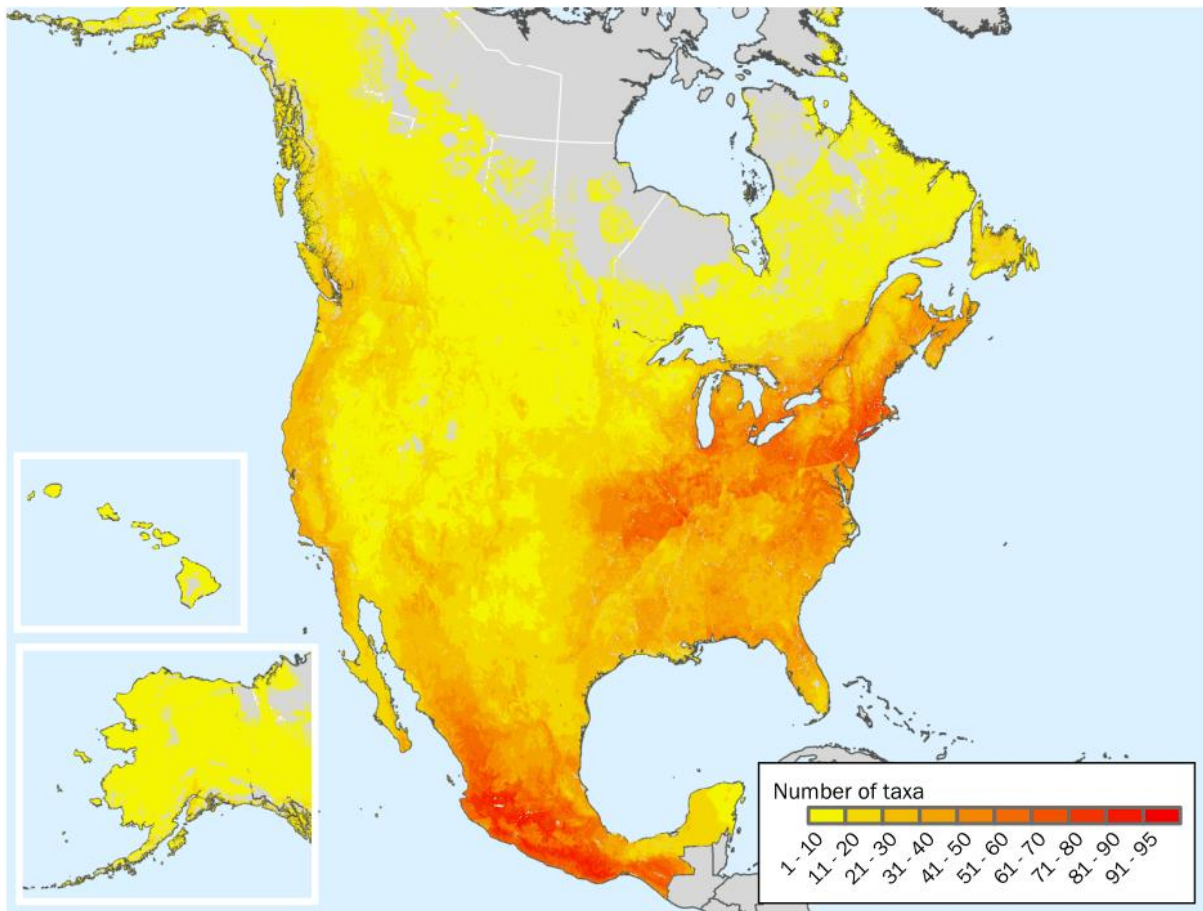


Fig 1.2 Species richness map illustrating the concentration of crop wild relatives across Canada, Mexico and the United States. The map displays overlapping potential distribution models for

618 assessed taxa, amounting to all species mapped in this book. Warmer colors indicate areas where greater numbers of taxa potentially occur in the same geographic localities. Full methods for generation of maps and occurrence data providers are listed in Appendix 1

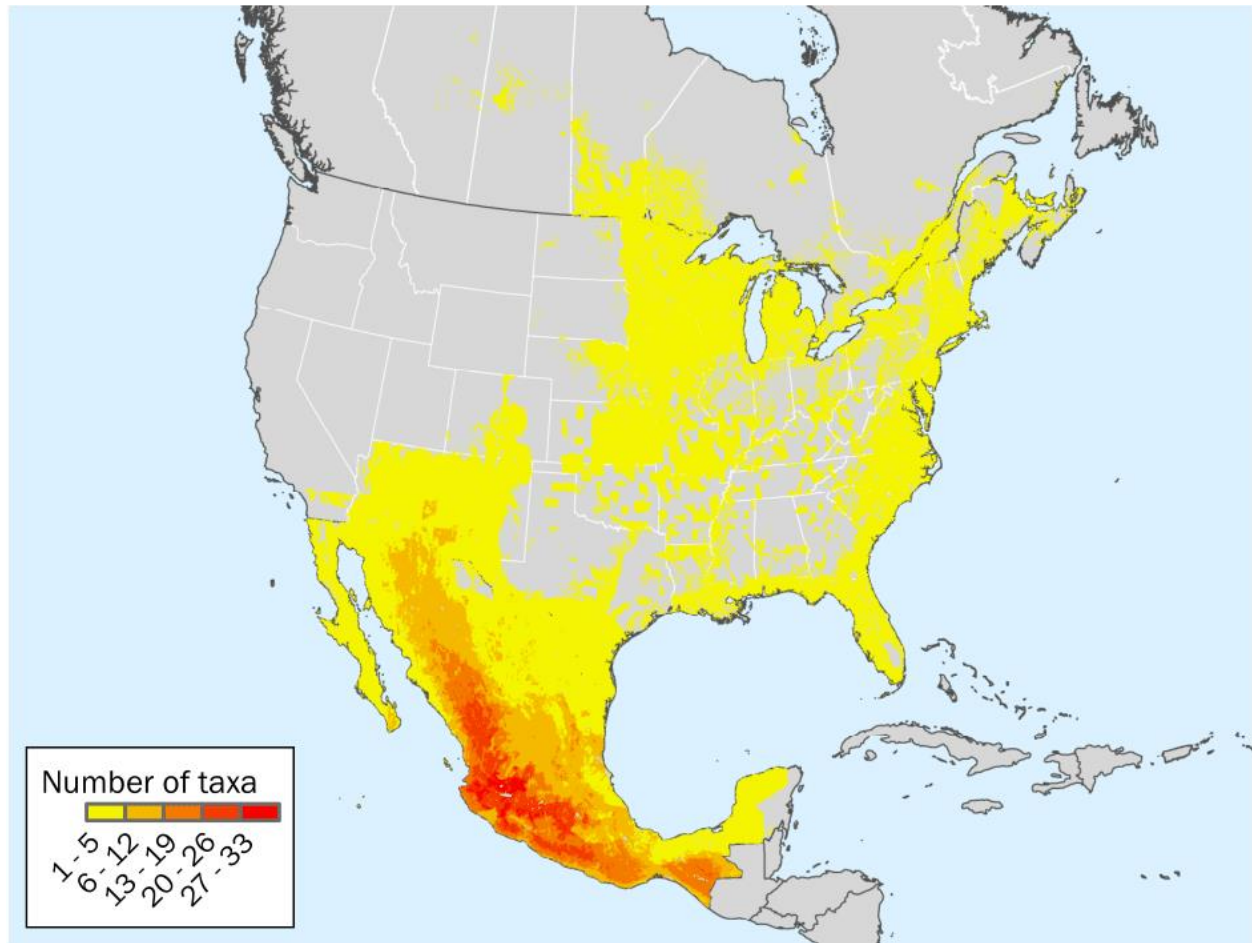


Fig 1.3 Species richness map illustrating the concentration of 81 crop wild relatives of cereals and legumes mapped in the chapters of this book. Warmer colors indicate areas where greater numbers of taxa potentially occur in the same geographic localities. Full methods for generation of maps and occurrence data providers are listed in Appendix 1

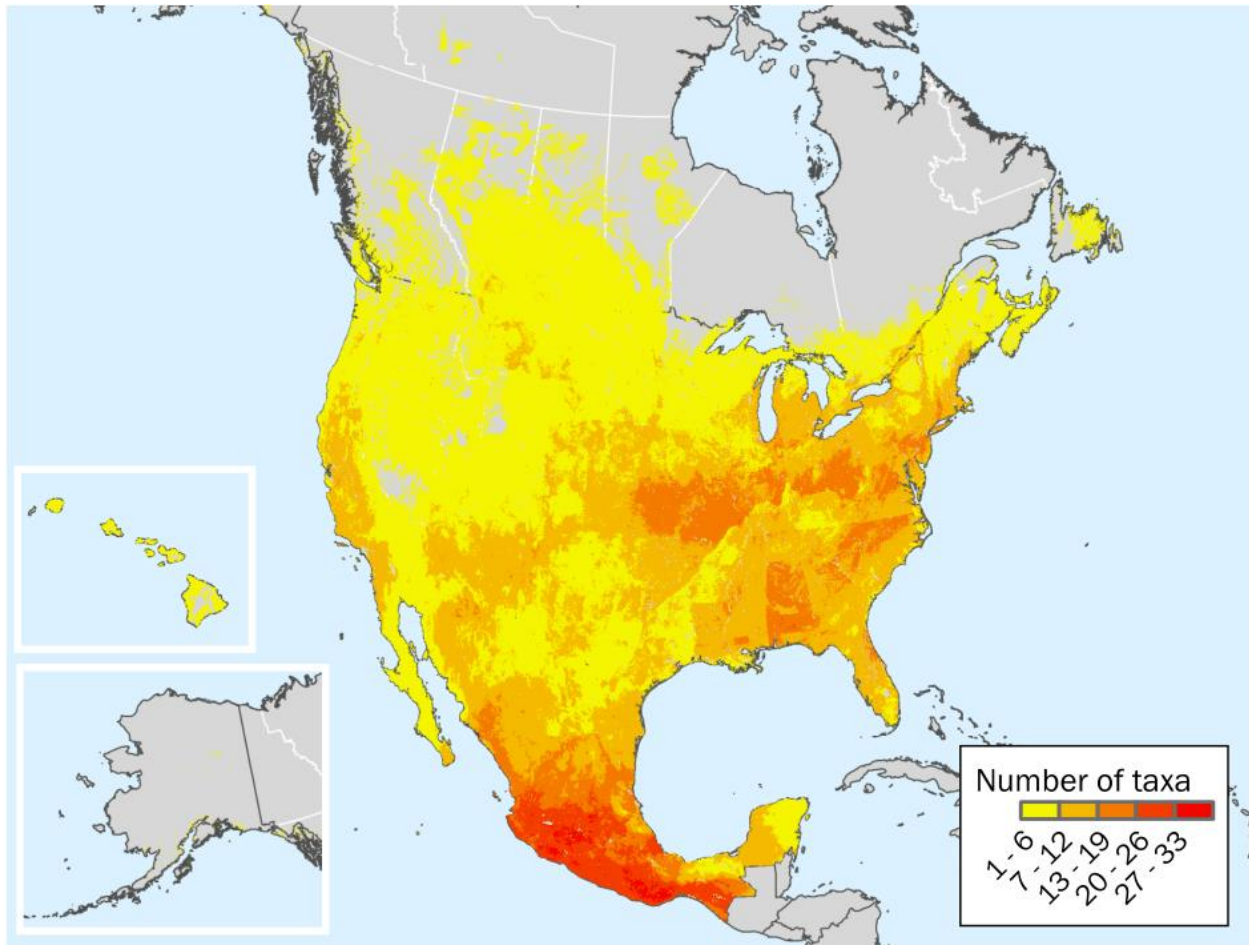


Fig 1.4 Species richness map illustrating the concentration of 158 crop wild relative species related to, or used as, vegetables, mapped in the chapters of this book. Warmer colors indicate areas where greater numbers of taxa potentially occur in the same geographic localities. Full methods for generation of maps and occurrence data providers are listed in Appendix 1

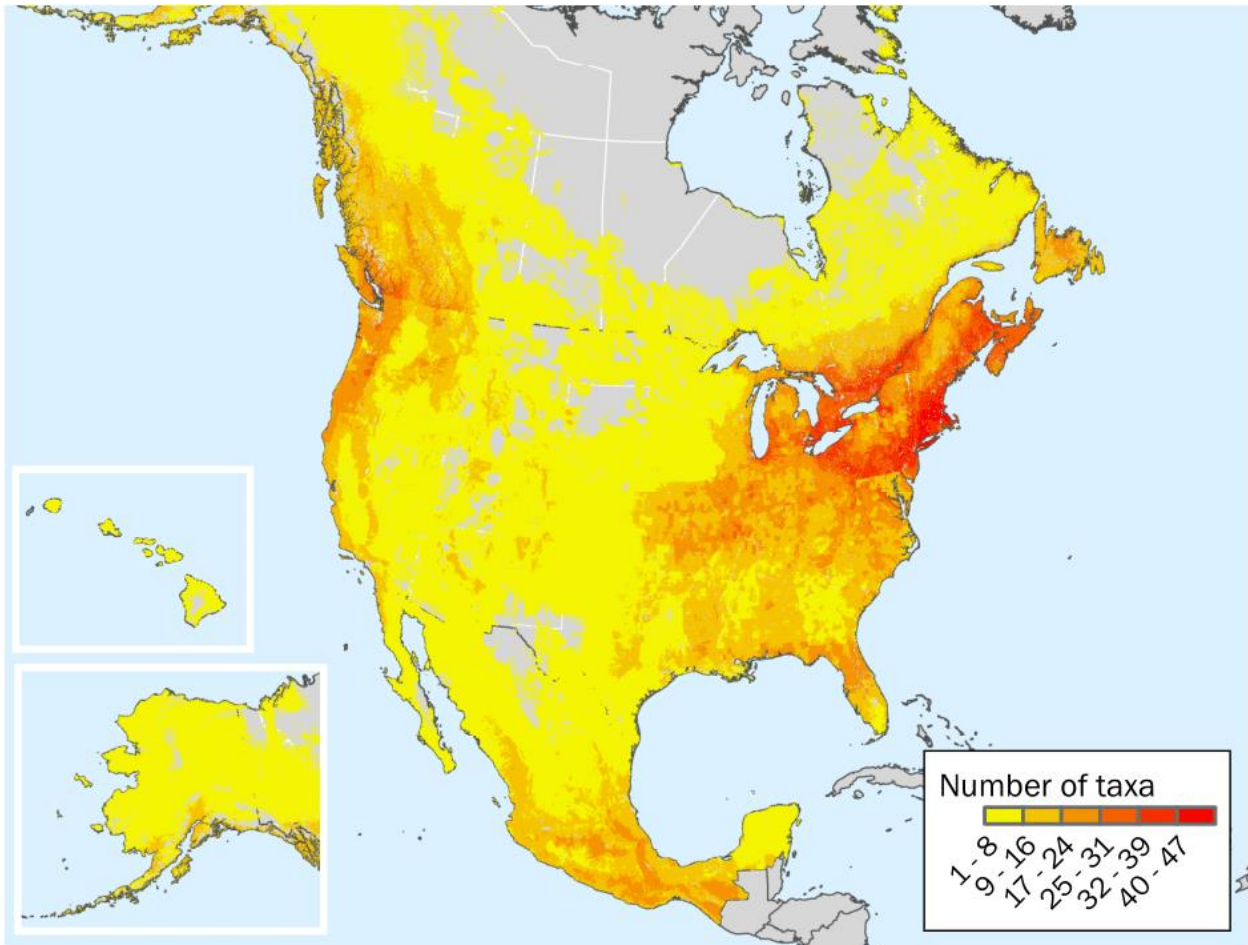


Fig 1.5 Species richness map illustrating the concentration of 190 crop wild relative species related to, or used as, fruits, mapped in the chapters of this book. Warmer colors indicate areas where greater numbers of taxa potentially occur in the same geographic localities. Full methods for generation of maps and occurrence data providers are listed in Appendix 1.

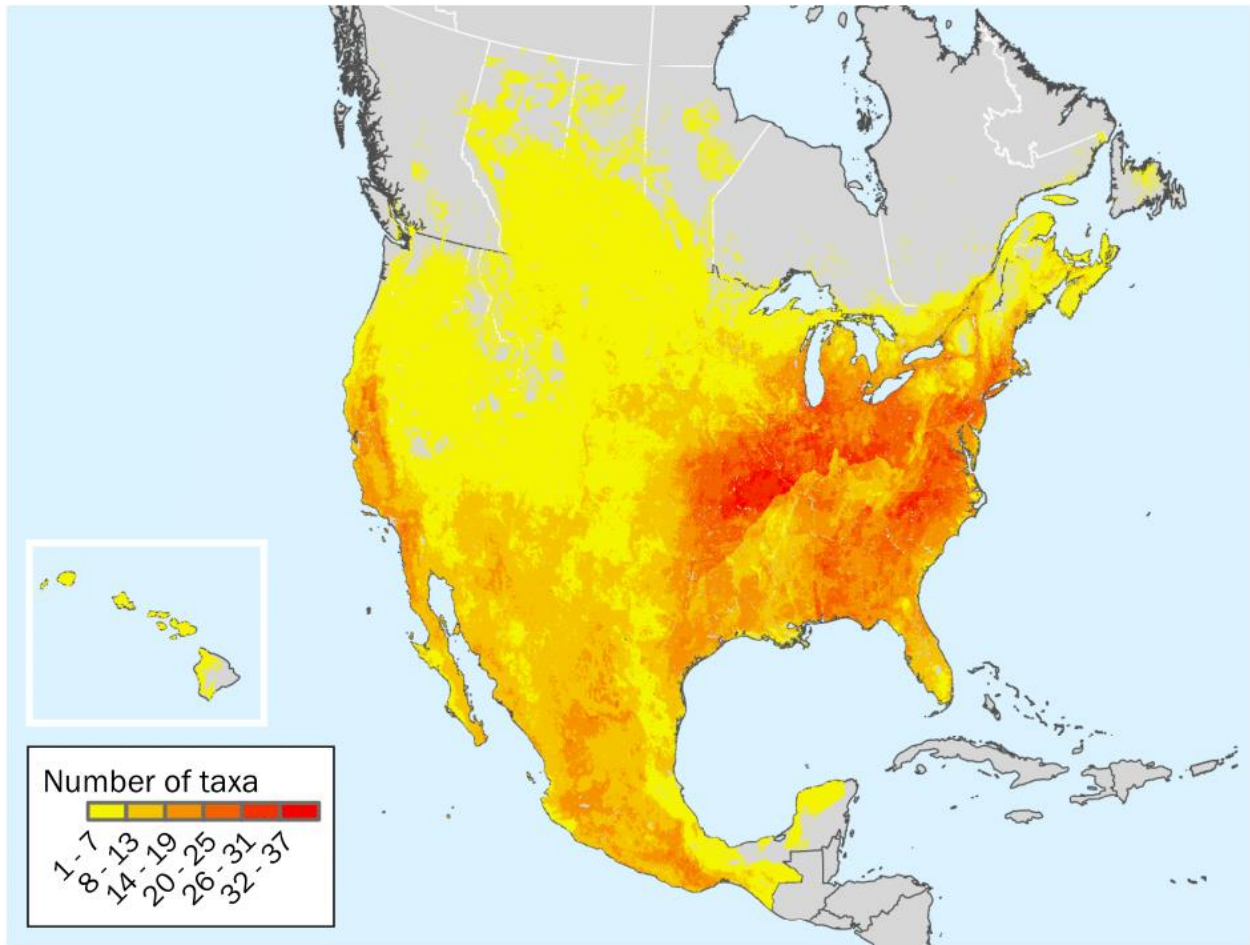


Fig 1.6 Species richness map illustrating the concentration of 256 crop wild relative species and wild utilized species related to, or used as, medicinal, ornamental, industrial and social use crops/plants, mapped in the chapters of this book. Warmer colors indicate areas where greater numbers of taxa potentially occur in the same geographic localities. Full methods for generation of maps and occurrence data providers are listed in Appendix 1

Table 1.3 Number of wild taxa by genus of CWR of internationally important crops, native or naturalized in Canada (taken from The Harlan and de Wet Crop Wild Relative Inventory [2017])

Genus	Taxa	Genus	Taxa	Genus	Taxa
<i>Allium</i> L.	2	<i>Diploaxis</i> DC.	2	<i>Lactuca</i> L.	4
<i>Armoracia</i> G.Gaertn. B. Mey. &Scherb.	1	<i>Echinochloa</i> P. Beauv.	2	<i>Malus</i> Mill	2
<i>Barbarea</i> W.T. Aiton	1	<i>Eruca</i> Mill.	1	<i>Prunus</i> L.	6
<i>Chenopodium</i> L.	3	<i>Fragaria</i> L.	11	<i>Ribes</i> L.	14
<i>Comarum</i> L.	1	<i>Helianthus</i> L.	13	<i>Rorippa</i> Scop.	8
<i>Corylus</i> L.	3	<i>Hordeum</i> L.	4	<i>Setaria</i> P.Beauv.	1
<i>Digitaria</i> Haller	1	<i>Juglans</i> L.	1	<i>Vitis</i> L.	3

Table 1.4 Number of wild taxa by genus of CWR of internationally important crops, native or naturalized in Mexico (taken from The Harlan and de Wet Crop Wild Relative Inventory [2017])

Genus	Taxa	Genus	Taxa	Genus	Taxa
<i>Capsicum</i> L.	1	<i>Ipomoea</i> L.	8	<i>Rorippa</i> Scop.	5
<i>Chenopodium</i> L.	2	<i>Juglans</i> L.	11	<i>Saccharum</i> L.	2
<i>Cucumis</i> L.	2	<i>Lactuca</i> L.	2	<i>Setaria</i> P.Beauv.	1
<i>Cucurbita</i> L.	6	<i>Lupinus</i> L.	1	<i>Solanum</i> L.	24
<i>Digitaria</i> Haller	23	<i>Manihot</i> Mill.	6	<i>Theobroma</i> L.	1
<i>Echinochloa</i> P. Beauv.	6	<i>Oryza</i> L.	2	<i>Thespesia</i> Sol. ex Correa	1
<i>Eruca</i> Mill.	1	<i>Panicum</i> L.	1	<i>Tripsacum</i> L.	17
<i>Fragaria</i> L.	4	<i>Persea</i> Mill.	1	<i>Vasconcellea</i> A. St.-Hil.	1
<i>Gossypium</i> L.	11	<i>Phaseolus</i> L.	50	<i>Vitis</i> L.	10
<i>Helianthus</i> L.	9	<i>Pistacia</i> L.	2	<i>Xanthosoma</i> Schott	6
<i>Hordeum</i> L.	4	<i>Prunus</i> L.	4	<i>Zea</i> L.	5
<i>Ilex</i> L.	8	<i>Ribes</i> L.	2		

Table 1.5 Number of wild taxa by genus of CWR of internationally important crops, native or naturalized in the United States (taken from The Harlan and de Wet Crop Wild Relative Inventory [2017]).

Genus	Taxa	Genus	Taxa	Genus	Taxa
<i>Allium</i> L.	7	<i>Digitaria</i> Haller	27	<i>Panicum</i> L.	3
<i>Armoracia</i> G.Gaertn. B. Mey. &Scherb	1	<i>Diploaxis</i> DC.	3	<i>Phaseolus</i> L.	8
<i>Artocarpus</i> J.R. Forst. & G. Forst.	1	<i>Echinochloa</i> P. Beauv.	7	<i>Pistacia</i> L.	1
<i>Asparagus</i> L.	4	<i>Eruca</i> Mill.	1	<i>Prunus</i> L.	23
<i>Avena</i> L.	5	<i>Fragaria</i> L.	19	<i>Pyrus</i> L.	1
<i>Barbarea</i> W.T. Aiton	3	<i>Gossypium</i> L.	2	<i>Raphanus</i> L.	3
<i>Beta</i> L.	1	<i>Helianthus</i> L.	67	<i>Ribes</i> L.	22
<i>Brassica</i> L.	4	<i>Hordeum</i> L.	8	<i>Rorippa</i> Scop.	23
<i>Capsicum</i> L.	1	<i>Ilex</i> L.	7	<i>Saccharum</i> L.	7
<i>Carthamus</i> L.	1	<i>Imperata</i> Cirillo	1	<i>Setaria</i> P. Beauv.	2
<i>Chenopodium</i> L.	5	<i>Ipomoea</i> L.	5	<i>Sinapis</i> L.	1
<i>Coincya</i> Rouy	1	<i>Juglans</i> L.	7	<i>Solanum</i> L.	2
<i>Colocasia</i> Schott	1	<i>Lactuca</i> L.	6	<i>Sorghum</i> Moench	1
<i>Comarum</i> L.	1	<i>Lathyrus</i> L.	1	<i>Thespesia</i> Sol. ex Correa	1
<i>Corylus</i> L.	4	<i>Lupinus</i> L.	1	<i>Tripsacum</i> L.	4

<i>Cucumis</i> L.	3	<i>Malus</i> Mill.	6	<i>Vicia</i> L.	4
<i>Cucurbita</i> L.	2	<i>Manihot</i> Mill.	3	<i>Vitis</i> L.	25
<i>Daucus</i> L.	2	<i>Medicago</i> L.	2		

Table 1.6. Native CWR of internationally important crops, that occur in Canada, Mexico and the United States, and which were given a high priority for further collecting based on their limited representation in major *ex situ* collections, as identified by the Global CWR Gap Analysis project (Castañeda-Álvarez et al. 2016).

Canada		
<i>Chenopodium berlandieri</i> Moq	<i>Helianthus giganteus</i> L.	<i>Prunus americana</i> Marshall
<i>Comarum palustre</i> L.	<i>Helianthus hirsutus</i> Raf.	<i>Prunus emarginata</i> (Douglas ex Hook.) D. Dietr.
<i>Diplotaxis muralis</i> (L.) DC	<i>Helianthus maximiliani</i> Schrad.	<i>Prunus maritima</i> Marshall
<i>Diplotaxis tenuifolia</i> (L.) DC	<i>Helianthus pauciflorus</i> Nutt.	<i>Prunus pumila</i> L.
<i>Fragaria chiloensis</i> (L.) Mill	<i>Helianthus tuberosus</i> L.	<i>Setaria faberi</i> Herrm.
<i>Fragaria virginiana</i> Duchesne	<i>Lactuca saligna</i> L.	<i>Vitis aestivalis</i> Michx.
<i>Helianthus divaricatus</i> L.	<i>Malus fusca</i> (Raf.) C.K. Schneid.	
Mexico		
<i>Capsicum annuum</i> L.	<i>Ipomoea ramosissima</i> (Poiret) Choisy	<i>Phaseolus longiplacentifer</i> Freytag
<i>Chenopodium berlandieri</i> Moq.	<i>Ipomoea tiliacea</i> (Willdenow) Choisy in D.C.	<i>Prunus emarginata</i> (Douglas) Eaton
<i>Cucurbita lundelliana</i> L.H.Bailey	<i>Lactuca saligna</i> L.	<i>Prunus minutiflora</i> Engelm. ex A. Gray
<i>Cucurbita okechobeensis</i> (Small) L.H.Bailey	<i>Manihot aesculifolia</i> Pohl	<i>Setaria faberi</i> R. A. W. Herrm.
<i>Cucurbita pepo</i> L.	<i>Manihot angustiloba</i> (Torr.) Mill.Arg.	<i>Solanum clarum</i> Correll
<i>Gossypium harknessii</i> Brandegee	<i>Manihot chlorosticta</i> Standl. & Goldman	<i>Solanum hintonii</i> Correll
<i>Gossypium turneri</i> Fryxell	<i>Manihot davisiae</i> Croizat	<i>Solanum hjertingii</i> Hawkes
<i>Helianthus hirsutus</i> Raf.	<i>Manihot rubricaulis</i> I.M.Johnst.	<i>Solanum hougasii</i> Correll
<i>Helianthus niveus</i> (Benth.) Brandegee	<i>Manihot walkerae</i> Croizat	<i>Theobroma cacao</i> L.
<i>Ipomoea batatas</i> (L.) Lam.	<i>Oryza alta</i> Swallen	<i>Vasconcellea cauliflora</i>
<i>Ipomoea cordatotriloba</i> Dennstedt	<i>Oryza latifolia</i> Desv.	<i>Tripsacum dactyloides</i> (L.) L.

<i>Ipomoea leucantha</i> Jacquin	<i>Panicum stramineum</i> Hitchc. & Chase	<i>Zea diploperennis</i> H. H. Iltis et al.
<i>Ipomoea littoralis</i> Blume	<i>Phaseolus albescens</i> McVaugh ex Ramirez-Delgadillo & A. Delgado	<i>Zea luxurians</i> (Durieu & Asch.) R. M. Bird

United States

<i>Allium ampeloprasum</i> L.	<i>Helianthus debilis</i> Nutt. <i>vestitus</i>	<i>Panicum nephelophilum</i> Gaudich.
<i>Artocarpus</i> <i>mariannensis</i> Tr	<i>Helianthus deserticola</i> Heiser	<i>Panicum stramineum</i> Hitchc. & Chase
<i>Asparagus horridus</i> L.	<i>Helianthus divaricatus</i> L.	<i>Prunus americana</i> Marshall
<i>Asparagus officinalis</i> L.	<i>Helianthus giganteus</i> L.	<i>Prunus cerasifera</i> Ehrh.
<i>Avena hybrida</i> Peterm.	<i>Helianthus maximiliani</i> Schrad.	<i>Prunus emarginata</i> (Douglas) Eaton
<i>Avena trichophylla</i> K. Koch	<i>Helianthus niveus</i> (Benth.) Brandege	<i>Prunus maritima</i> Marshall
<i>Capsicum annuum</i> L. <i>glabriusculum</i>	<i>Helianthus niveus</i> (Benth.) <i>Brandege canescens</i>	<i>Prunus minutiflora</i> Engelm. ex A. Gray
<i>Carthamus leucocaulos</i> Sm.	<i>Helianthus pauciflorus</i> Nutt. <i>pauciflorus</i>	<i>Prunus pumila</i> L.
<i>Chenopodium</i> <i>berlandieri</i> Moq.	<i>Helianthus tuberosus</i> L.	<i>Prunus pumila</i> L. <i>besseyi</i>
<i>Comarum palustre</i> L.	<i>Ipomoea cordatotriloba</i> Dennstedt	<i>Prunus rivularis</i> Scheele
<i>Cucurbita okeechobeensis</i> (Small) L.H. Bailey subsp. <i>okeechobeensis</i>	<i>Ipomoea leucantha</i> Jacquin	<i>Pyrus cordata</i> Desv.
<i>Daucus carota</i> L.	<i>Ipomoea littoralis</i> Blume	<i>Tripsacum dactyloides</i> (L.) L.
<i>Daucus carota</i> L. subsp. <i>gummifer</i> (Syme) Hook. f.	<i>Ipomoea tenuissima</i> Choisy	<i>Tripsacum dactyloides</i> (L.) L. var. <i>dactyloides</i>
<i>Fragaria chiloensis</i> (L.) Mill.	<i>Lactuca saligna</i> L.	<i>Vitis aestivalis</i> Michx. <i>aestivalis</i>
<i>Fragaria chiloensis</i> (L.) Mill. subsp. <i>lucida</i> (E. Vilm. ex Gay) Staudt	<i>Malus fusca</i> (Raf.) C.K. Schneid.	<i>Vitis californica</i> Benth.
<i>Fragaria chiloensis</i> (L.) Mill. subsp. <i>pacifica</i> Staudt	<i>Manihot angustiloba</i> (Torr.) Mill. Arg.	<i>Vitis cinerea</i> (Engelm.) Engelm. ex Millardet <i>cinerea</i>
<i>Fragaria virginiana</i> Mill. subsp. <i>glauca</i> (S. Watson) Staudt	<i>Manihot davisiae</i> Croizat	<i>Vitis cinerea</i> (Engelm.) Engelm. ex Millardet <i>helleri</i>

Fragaria virginiana Mill.
subsp. *platypetala* (Rydb.)
Staudt

Fragaria virginiana
Mill. subsp. *virginiana*

Helianthus debilis Nutt.
cucumerifolius (Torr. &
A. Gray) Heiser

Manihot walkerae Croizat

Medicago sativa L. *falcata*

Panicum fauriei Hitchc.

Vitis labrusca L.

Vitis monticola Buckley

Vitis mustangensis Buckley

1.5 The value of North American crop wild relatives

Utilization of CWR in plant breeding has steadily increased over the past decades, providing improved pest and disease resistance, tolerance to abiotic stresses, increased yield, novel cytoplasm, and quality traits (Hajjar and Hodgkin, 2007; Maxted et al. 2012; Dempewolf et al. 2017). Advances in breeding, particularly through modern molecular approaches, promise to further facilitate the use of wild germplasm (Zhang et al. 2015; Brozynska et al 2016; Dempewolf et al. 2017; Prohens et al 2017).

Well-documented examples exist for the use of North American native CWR. For example, native germplasm was instrumental in developing modern varieties of plum, blueberry and pecan in the United States (Greene 2012). Perhaps the most important North American CWR utilized since modern breeding began have been the sunflower wild relatives. Dempewolf et al. (2017) identified sunflower as having the most “CWR breeding use” citations among major crops in a recent literature review. The annual economic contribution of sunflower CWR has been estimated between \$267 to \$384 million USD (Seiler et al. 2017). Most of the value comes from the use of the PET1 cytoplasm from *Helianthus petiolaris* (which facilitates the generation of hybrid sunflower varieties), as well as disease resistance genes, abiotic salt tolerance, and resistance to herbicides (Dempewolf et al. 2017).

1.6 Conservation of North American wild plant genetic resources

An estimated one out of every five plant species worldwide is threatened by habitat loss or modification, agricultural modernization, pollution, over-exploitation, invasive species, and/or climate change (Brummitt et al. 2015). In the United States, 32% of the native flora has been identified as threatened by NatureServe (Havens et al. 2014). Khoury et al. (2013) compiled the conservation status of 3,512 taxa in the United States inventory of CWR based on NatureServe rankings. Five taxa were known or presumed extinct in the wild; 4% were ranked as “globally critically imperiled” or “imperiled” and almost 6% were “vulnerable” (See <http://explorer.natureserve.org/ranking.htm> for definition of rankings). Sixty-two taxa were also listed as endangered under the Endangered Species Act (7 U.S.C. § 136, 16 U.S.C. § 1531 et seq.). The CWR identified as high priority to collect in the list compiled by Castañeda-Álvarez et al. (2016) included the following North American threatened taxa (based on NatureServe ranking): *Cucurbita okechobeensis* subsp. *martinezii* (L. H. Bailey) T. C. Andres & Nabhan ex T. W. Walters & D. S. Decker, *Cucurbita okechobeensis* (Small) L. H. Bailey subsp. *okechobeensis*, *Fragaria chiloensis* subsp. *sandwicensis* (Decne.) Staudt, *Helianthus niveus* subsp. *tephrodes* (A. Gray) Heiser, and *Manihot walkerae* Croizat.

Threat assessments have also been performed by the International Union for Conservation of Nature (IUCN). From the IUCN Red List for Canada, Mexico and the United States (IUCN 2017), the following taxa listed in Castañeda-Álvarez et al. (2016) were assigned:

- Near Threatened: *Helianthus exilis* A. Gray.
- Vulnerable: *Helianthus anomalus* S. F. Blake
- Data Deficient (i.e. insufficient data to make an assessment): *Carica papaya* L., *Cucurbita okechobeensis* (Small) L. H. Bailey, *Helianthus arizonensis* R.C. Jacks., *H.*

deserticola Heiser, *H. niveus* (Benth.) Brandegee, *Prunus harvardii* (W. Wight) S. C. Mason, *P. maritima* Marshall, *P. rivularis* Scheele

The large discrepancy between number of threatened species in the United States identified by NatureServe (5935 species) and the IUCN Red List (273 species), pointed out by Havens et al. (2014), underscores the need for more information on species distributions and rarity, especially for wild plant genetic resources and reflects results based on different methodologies (See Frances et al., [2018], Chapter 7 for description of threat assessment methods).

1.6.1 Strategies for conserving wild plant genetic resources

The ideal management of wild plant genetic resources (i.e., crop progenitors, crop wild relatives, wild utilized species, and wild species with potential new use) involves a complementary approach incorporating both *in situ* (conserved “in the wild”) and *ex situ* (conserved outside of the wild in seed or field banks) conservation.

The community of researchers and practitioners conserving and managing biodiversity under *in situ* conditions has historically viewed *ex situ* conservation as supplementary (Havens et al. 2014). The common philosophy embraced by this community is reflected by Ralston (2004), who wrote: “a plant is what it is where it is, *in situ*. In the wild, both the individual plants and the species...are embedded in ecosystems.” In contrast, the community that focuses on conserving wild genetic resources for use in crop breeding has prioritized *ex situ* conservation because access and availability are important considerations. However, there is general and increasing agreement on both sides that the most effective conservation strategies incorporate the strengths of both aspects.

In situ conservation allows the natural trajectory of evolution to occur; plant species continue to co-evolve with pests and pathogens and adapt to changing climates. Furthermore, it is sometimes easier to recollect from an *in situ* population than produce additional wild seed under *ex situ* conditions (a process called regeneration). It can also be cost effective to conserve wild genetic resources *in situ*, especially if many different taxa already occur in a protected area.

On the other hand, *ex situ* conservation allows rapid access to germplasm needed by the research community. An inevitable limitation of the *ex situ* strategy for genetic diversity conservation is that it captures a single genetic snapshot, reflecting a wild population’s adaptation to the biotic and abiotic conditions when and where it was collected. The degree to which the sample reflects the genetic structure of the original population depends on the adequacy of the sampling. In addition, the assumption that subsequent *ex situ* seed increases represent the original sample is dependent on minimizing genetic change (through genetic drift or selection) during the regeneration process. The genetic resources community is acutely aware of the challenges of *ex situ* conservation and attempts to follow protocols outlined in a body of literature guided by the mantra “sample population diversity and maintain genetic integrity” (i.e., Hoban and Schlarbaum 2014; Dulloo et al. 2008; FAO 2014). Although the static nature of *ex situ* conservation has drawbacks, there is no question that easily accessible *ex situ* samples provide the means to discover and use valuable diversity and provide backup to *in situ* populations that may be vulnerable to a myriad of threats. *Ex situ* accessions have been shown to preserve alleles that were subsequently lost in *in situ* populations from which they were collected

(Greene et al. 2014).

Conservation of wild plant genetic resources requires the cooperation of many players: different federal, state and tribal agencies, non-governmental organizations including botanical gardens and academic institutes, and, increasingly, citizen scientists and other local groups (Havens et al. 2014). Sometimes the emphasis on making wild genetic resources available for use can conflict with resource management directives aimed at controlling over-harvesting or maintaining the genetic integrity of source populations. For example, the United States National Plant Germplasm System has been incorporating germplasm from the Bureau of Land Management-led Seeds of Success (SOS) program, which has been collecting wild species in the United States to support restoration activities. Information on SOS accessions is entered in the GRIN-Global database (<https://www.ars-grin.gov/npgs>), and seed is available to researchers. However, the location where samples were originally collected is not readily available in GRIN-Global due to land managers' concerns that map coordinates will lead to overharvesting of wild populations by unscrupulous collectors. This lack of information has been a stumbling block for companies seeking germplasm adapted to specific areas for the breeding of native species used in restoration. A solution being explored is making accessions searchable by seed transfer zone, which is obtained using the original locations' map coordinates that are themselves not shared. This example illustrates the importance of recognizing that although the *modus operandi* of various partners may not match, open discussion can lead to innovative solutions that meet different organizational missions while moving native plant conservation objectives forward.

1.6.2 International regulatory frameworks for conserving plant genetic resources

The acquisition, distribution and use of plant genetic resources are regulated at various levels in Canada, Mexico, and the United States. Each country has its own national and state/provincial regulatory frameworks, as do certain indigenous groups within these countries. The specific regulations in all three countries are also influenced by international agreements, particularly the three described in the following sections.

1.6.2.1 The Convention on Biological Diversity (CBD)

The CBD is an international treaty with the three main goals: conservation of biodiversity, sustainable use of its components, and fair and equitable sharing of the benefits arising from the utilization of genetic resources. It is the foundation for the current international framework on access and benefit sharing of all biodiversity, including plant genetic resources. The Convention was opened for signature at the United Nations Conference on Environment and Development (the "Earth Summit") in Rio de Janeiro in 1992 and entered into force in December 1993. As of 2017, the CBD has 196 parties, including Canada and Mexico. While the United States signed the Convention in 1993, as of late 2017 it has not ratified the agreement.

1.6.2.2 The Nagoya Protocol

The Nagoya Protocol on Access to Genetic Resources and the Fair and Equitable Sharing of Benefits Arising from their Utilization elaborates on the provisions of the CBD on access to genetic resources and benefit sharing (Moore and Williams 2011). It was adopted by the Conference of the Parties to the CBD in 2010 in Nagoya, Japan and entered into force on 12

October 2014. The Protocol aims to establish clear requirements and procedures for accessing genetic resources and establishing mutually agreed terms in each Contracting Party. It obligates Contracting Parties to provide for the issuance of a permit or its equivalent when access is granted as evidence of the granting of prior informed consent, if required, and the establishment of mutually agreed terms. The benefits to be shared may be monetary, such as royalties, or non-monetary, such as sharing of research results. The Protocol has provisions concerning the traditional knowledge associated with genetic resources held by indigenous and local communities, as well as the rights of these communities to grant access to certain genetic resources.

The Access and Benefit-sharing Clearing-House (<https://absch.cbd.int/>) set up by the Protocol shares relevant information, such as on domestic regulatory access and benefit sharing requirements and on national focal points and national authorities. Parties are to establish checkpoints in their country to collect or receive information regarding whether genetic resources being utilized have been acquired in compliance with relevant laws on access and benefit sharing. The Protocol recognizes that other international instruments addressing access and benefit sharing, such as the International Treaty on Plant Genetic Resources for Food and Agriculture (Plant Treaty) may apply to specific genetic resources and determine the terms in certain cases. Of the three countries covered in this book, only Mexico has ratified the Protocol.

1.6.2.3 International Treaty on Plant Genetic Resources for Food and Agriculture (Plant Treaty)

The Plant Treaty is a legally binding international agreement adopted by the Conference of the Food and Agriculture Organization of the UN in 2001 and entered into force in 2004. Its objectives are the conservation and sustainable use of plant genetic resources for food and agriculture, and the fair and equitable sharing of the benefits arising from their use, for sustainable agriculture and food security. Recognizing that many countries need more straightforward access to agricultural genetic resources occurring outside their borders than is provided by the CBD, the Plant Treaty established a multilateral system (MLS) for access and benefit sharing to facilitate exchange of genetic resources of 64 internationally important crops and forages and (most of) their wild relatives for the purpose of conservation, research, breeding, and training for food and agriculture.

Material in the MLS is transferred on terms specified in a standard material transfer agreement (SMTA) that was adopted by the Governing Body of the Treaty in 2006. The terms prohibit recipients from claiming intellectual property rights on “genetic parts and components, in the form received” that limit access to these resources. The Treaty states that benefits arising from use of the materials in the MLS should be shared through both non-monetary and monetary mechanisms. Non-monetary mechanisms include the exchange of information, capacity building, and transfer of technology. It also establishes a mechanism for monetary benefit-sharing in the form of a benefit-sharing fund. A recipient of germplasm who commercializes a product that incorporates materials from the MLS and is not available for further research and breeding is required to make mandatory payments to the benefit-sharing fund. If the product is available for research and breeding, the payment is voluntary. These funds are to be used to support projects that promote conservation of plant genetic resources, particularly by farmers in developing countries. Canada and the United States are Parties to the Plant Treaty.

Table 1.7 The status of participation of Canada, Mexico and the United States in international agreements on access and benefit sharing of plant genetic resources

Country	Party to CBD	Party to Nagoya Protocol	Party to Plant Treaty
Canada	yes	no	yes
Mexico	yes	yes	no
United States	no	no	yes

The three countries thus differ in their participation in the international agreements that most affect access and benefit sharing for plant genetic resources (Table 1.7). The national genebanks in Canada and the United States have placed their public collections into the MLS established by the Plant Treaty and germplasm is distributed internationally under the terms of the SMTA. A legal framework for international distribution of germplasm from the national collections in Mexico has not yet been established (see Chapter 3).

Access to *in situ* genetic resources in the three countries depends on the existence of national legislation. The United States is not a Party to the CBD and does not require national level collection permits: access requirements are determined by individual landowners or managers, including federal, state, county and tribal entities. Both Mexico and Canada are parties to the CBD, and thus permission for access is obtained from the designated national authorities to the CBD. Mexico provides national level collecting permits, which are obtained from the Ministry of the Environment and Natural Resources (SEMARNAT). The National Focal Point for the CBD and Nagoya Protocol in Canada is in the National Wildlife Section of the Canadian Wildlife Service, Department of Environment and Climate Change Canada. There is currently no specific legislation in place in Canada to govern access to genetic resources, although working groups at the federal, provincial, and territorial levels are considering this issue.

1.6.3 Global and Regional Targets and Networks to Conserve Wild Plant Genetic Resources

Growing awareness of the value of crop wild relatives to food security and recognition of the increasing threats to these genetic resources has led to the explicit targeting of the comprehensive conservation of wild relatives by 2020 within the highest-level global agreements on agriculture, development, and conservation, including the United Nations Sustainable Development Goals (SDG). Target 2.5 of the SDGs states “by 2020 maintain genetic diversity of seeds, cultivated plants, farmed and domesticated animals and their related wild species, including through soundly managed and diversified seed and plant banks at national, regional and international levels, and ensure access to and fair and equitable sharing of benefits arising from the utilization of genetic resources and associated traditional knowledge as internationally agreed”. Similarly, the CBD’s Aichi Biodiversity Target 13 states that “By 2020, the loss of genetic diversity of cultivated plants and farmed and domesticated animals and of wild relatives, including other socio-economically as well as culturally valuable species is maintained and strategies have been developed and implemented for minimizing genetic erosion and safeguarding their genetic diversity”.

The public genetic resources conservation systems in all three North American countries are working on strengthening an already long history of collaboration. Under the umbrella of the Inter-American Institute for Cooperation on Agriculture (IICA; <http://www.iica.int/en>)'s North American regional network for agricultural research (PROCINORTE; www.procinorte.net), the NORGEN task force brings together representatives from Canada, Mexico and the United States to coordinate cooperation and exchange of technical and scientific knowledge in the area of managing and preserving genetic resources. Representatives of the member countries of NORGEN meet yearly and cooperate in activities and knowledge sharing throughout the year. Activities have included participation in development of the 2006 Americas Hemispheric Conservation Strategy for Plant Genetic Resources for Food and Agriculture in the Americas (https://www.croptrust.org/wp-content/uploads/2014/12/AMS_Hemispheric_FINAL_210208.pdf), several workshops on GRIN-Global attended by Mexican and Canadian curators and facilitated by ARS experts, promotion of strategies for *in situ* conservation by farmers in Mexico, an *in vitro* and cryopreservation workshop to increase capacity at the Mexico national genebank, and collection and evaluation of germplasm (IICA 2015). A workshop on conservation of ancestral genetic resources was held in Quebec, Canada in 2016.

1.7 Conclusion

While many of the targets set forth in the international agreements on sustainable development and biodiversity conservation allow for a decade or more to finish the job, conservation of genetic resources is much more urgently prioritized. This is due to the fact that extinction is a permanent and irreversible loss. It may also be because these targets are entirely technically feasible in that given adequate resources, the scientific ability to complete the task already exists. There is no technical reason why North American wild plant genetic resources should be inaccessible to plant breeders and scientists, much less become extinct.

Linkages between the agricultural research and natural resources conservation communities are also growing stronger, giving some hope that these connections will enable the communities to overcome the traditional economic, mandate, and legislative divides between them. The national laws protecting wild species, although currently deficient in their coverage of all vulnerable North American crop wild relatives, do provide a legislative framework for enhancing their conservation. Thus, although we have a long way to go, the essential institutional, policy, and scientific foundations not only exist in North America, but also are being actively improved. There is reason to believe that the continent can be successful in its ambitious efforts to comprehensively conserve and make available its wild plant genetic resources. We hope that this book contributes to the foundational knowledge needed to advance this worthy agenda.

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