NATIONAL SEED STRATEGY

for Rehabilitation and Restoration

PROGRESS REPORT 2015-2020

The Plant Conservation Alliance (PCA) is a collaboration of public and private partners who share the same goal: to protect native plants by ensuring that native plant communities and their habitat are maintained, enhanced, and restored. The PCA Federal Committee, now chaired by the U.S. Fish & Wildlife Service, developed the "National Seed Strategy for Rehabilitation and Restoration" in cooperation with federal and non-federal partners.

This publication is dedicated to all the hardworking botanists who are on the frontline of protecting, conserving, and restoring native plant communities throughout the United States.

For more information on the Plant Conservation Alliance and its members and activities, please visit www.blm.gov/pca.

Copies of this publication may be obtained online at www.blm.gov/seedstrategy.

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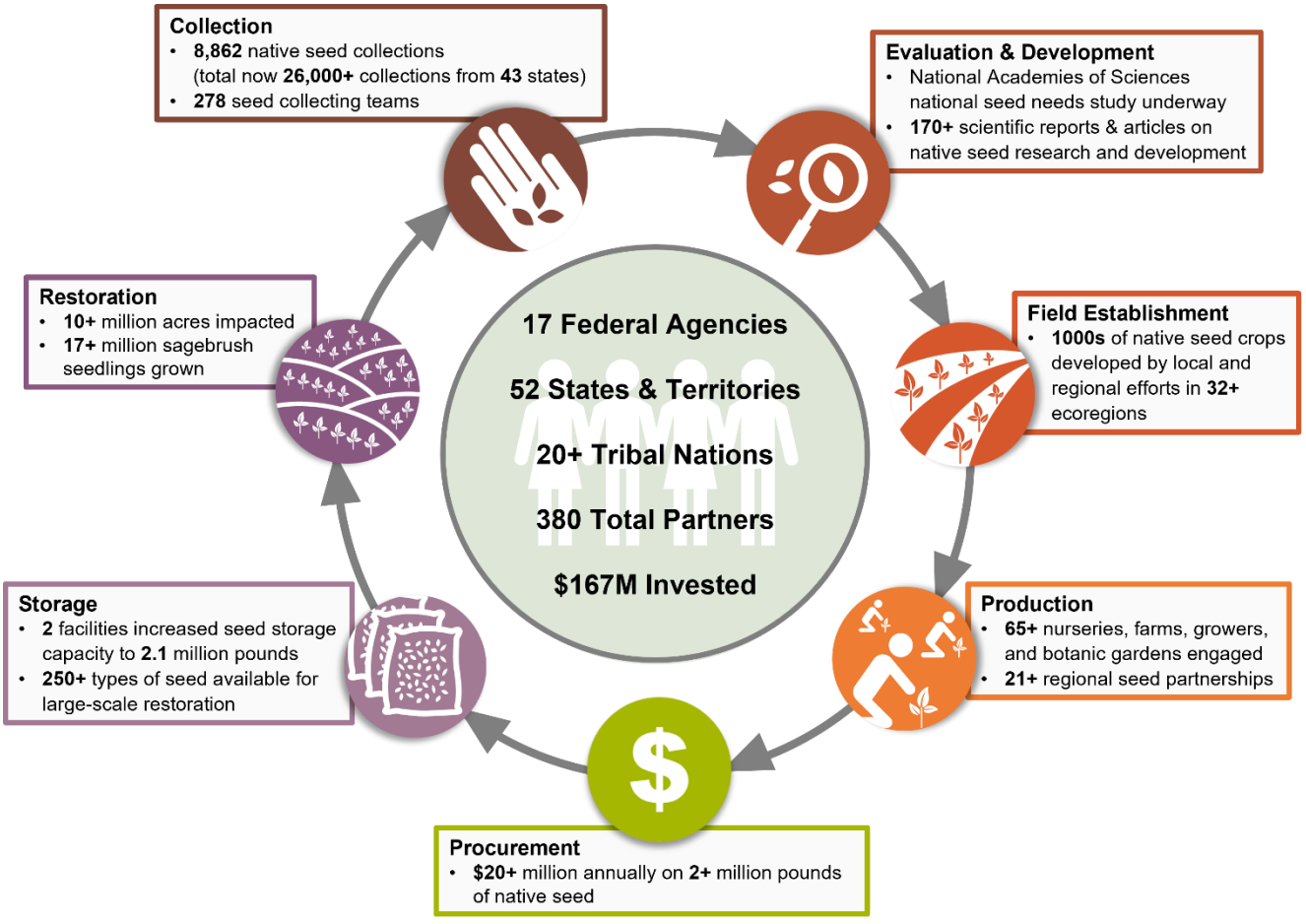
Executive Summary

Native plants are the true green infrastructure we rely on for healthy, resilient, and biodiverse ecosystems. They protect us against climate change and natural disasters; create habitat for wildlife, rare species, and pollinators; and are vital for carbon sequestration. Without native plants, especially their seeds, we do not have the ability to restore functional ecosystems after natural disasters and mitigate the effects of climate change. Investing *now* in coordinated, research-driven native seed production is an efficient and cost-effective nature-based solution for improving ecosystem resilience in the face of the climate and extinction crisis.

Federal government agencies (see list on page 10) and their partners are collaborating to increase the supply of native seeds for restoration through the National Seed Strategy for Rehabilitation and Restoration (National Seed Strategy) to get the right seed in the right place at the right time.

2015-2020 ACCOMPLISHMENTS

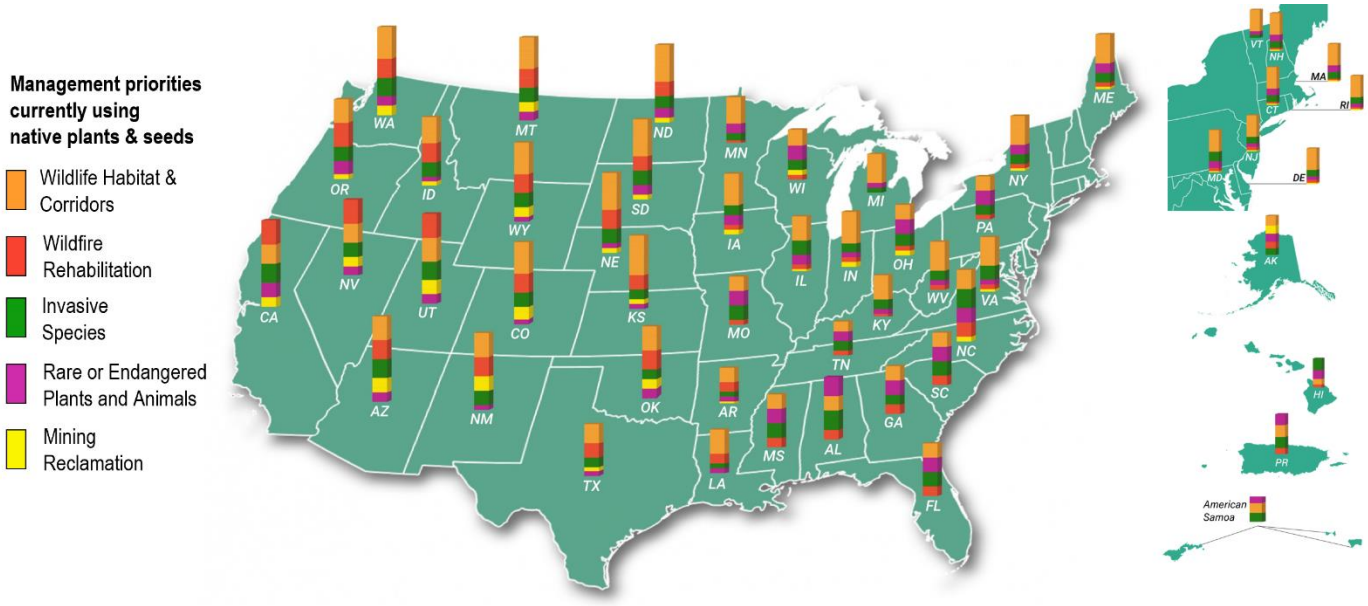


The National Seed Strategy is a public-private collaboration to increase the supply of native seeds for restoration projects to ensure ecosystem resilience and the health and prosperity of future generations.

Developed by the Plant Conservation Alliance (PCA) in 2015, the National Seed Strategy harnesses cross-sector botanical expertise; supports rural, agricultural, minority, and tribal livelihoods; and provides training opportunities to the next generation of natural resource professionals to maintain and preserve our iconic habitats. This science-driven national effort is integral to the Nation's conservation priorities, including the commitment to conserve 30% of America's lands and waters by 2030 as outlined in Executive Order 14008, *Tackling the Climate Crisis at Home and Abroad* (2021). Moreover, the National Seed Strategy is recognized in the objectives of the 2021 U.S. Department of the Interior (DOI) Invasive Species Strategic Plan (2021) and DOI Climate Action Plan (2021, *in progress*) and addresses national priorities such as climate change, wildland fire, and tribal engagement.

The National Seed Strategy charts a course for federal, tribal, state, local and private partners to increase private and public sector coordination on native seed development, thereby accelerating the pace and scale of restoration. Success is being achieved through the establishment of nationwide networks of seed collectors, researchers to develop seed, farmers to grow native seed, nurseries and seed storage facilities to supply adequate quantities of appropriate seed, and restoration ecologists who know how to put the right seed in the right place at the right time.

THE NATIONAL SEED STRATEGY IN YOUR BACKYARD



INVESTING IN THE FUTURE

OUR WORK HAS JUST BEGUN! The accomplishments highlighted here demonstrate how groups of individuals are creatively leveraging funds and other resources to accomplish goals in the National Seed Strategy. The National Seed Strategy Business Plan (Olwell & Bosak 2015) estimated it would take about $72 million a year to implement the National Seed Strategy. Currently, there are not enough resources for ensuring the availability of biodiverse, genetically appropriate native plants for every ecoregion at the scale of disturbances and needs.

NEXT STEPS

- Expand economic opportunities for farmers to grow locally adapted native seed.
- Actively engage with Native American tribes and Alaska Native villages to honor their Indigenous knowledges and ensure culturally important plants are conserved.
- Increase botanical expertise in federal agencies to inform all restoration, rehabilitation, and reclamation projects.
- Develop regional "Seed Networks" with partners who develop, store, and deliver locally adapted native seeds.
- Support evidence-based decision making through research, monitoring, and consistent scientist-practitioner engagement.
- Increase public education and awareness on the importance of locally adapted native seed in ecological restoration.

Ensuring the availability of locally adapted seed that America urgently needs is an important, achievable commitment to the health and prosperity of future generations.

NATIONAL SEED STRATEGY

FOR REHABILITATION AND RESTORATION

Success looks like…

Nationwide networks of people working together:

- **Botanists to collect native seed,**
- **Researchers to identify and develop the appropriate native seed,**
- **Farmers to grow native seed,**
- **Nurseries & seed storage facilities to supply native seed, and**
- **Restoration ecologists who know how to "put the right seed in the right place at the right time."**

Image credit: Chicago Botanic Garden (with permission)

Introduction

Climate change is increasing the frequency and severity of tropical storms, hurricanes, droughts, wildfires, tornadoes, and floods across the United States. Nearly every county in the Nation is affected by these extreme weather events (Figure 1). The Inter-Governmental Panel on Climate Change (IPCC) recognizes that urgent measures are needed to stop and reverse the overexploitation of natural resources that exacerbate the impact of catastrophic disturbances and biodiversity loss (IPCC 2019). "From forests and farmlands to freshwater, oceans and coasts, the vitality and diversity of Earth's ecosystems are the basis of human prosperity and well-being" (United Nations 2020).

Our native plants provide the true green infrastructure needed to restore altered habitats, decrease vulnerability to natural disasters, and reduce risk and recovery costs.

One of our most powerful assets to protect and strengthen healthy and resilient habitat is found right in nature. Our native plant communities are nature-based solutions that serve as natural buffers that control erosion, act as wind breaks, and filter and keep water clean. As the natural buffers in our ecosystems are degraded, they become more vulnerable to extreme weather and climate events and less resilient to disturbance. Using native plants to restore functional habitats is not only a disaster-risk management tool, but it can also provide socioeconomic security, sequester carbon, safeguard drinking water, enhance food security, and contribute to human health (International Union for Conservation of Nature 2020). To harness these nature-based solutions for ecosystem restoration and ecological resilience, we must have native seeds available when we need them.

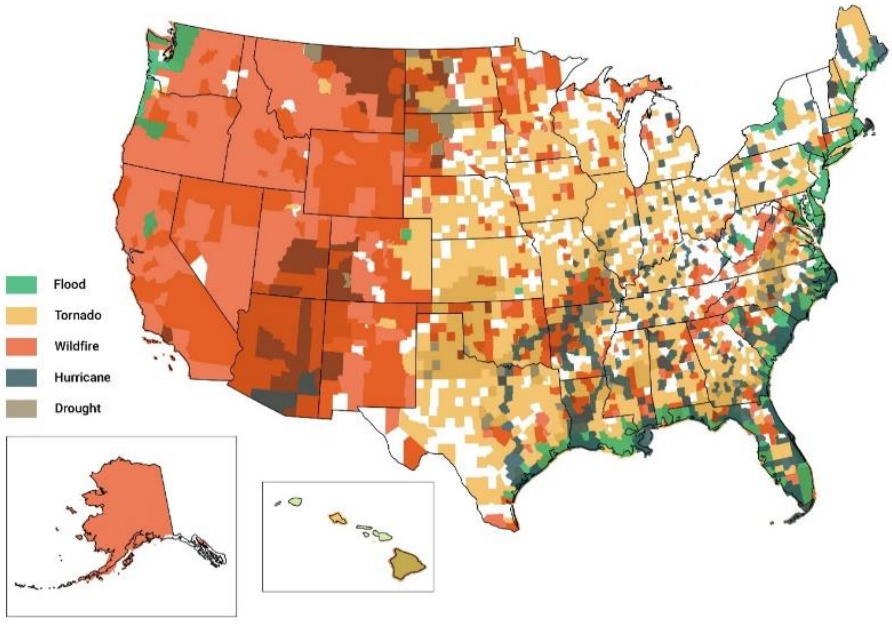


Figure 1. EXTREME WEATHER EVENTS ARE IMPACTING EVERYONE. This map shows the type of extreme weather and climate events categorized as a "natural disaster" in the period 2015-2020. Natural disasters impact every state in the Nation, with most states enduring multiple types of natural disasters. As the U.S. experiences more frequent and larger extreme events, the Federal government must develop and use anticipatory strategies such as the National Seed Strategy to build resilience in natural ecosystems and other infrastructure to help speed the recovery process and mitigate damages. Map data: National Climate Data Center (2019), National Drought Mitigation Center (2019), and National Interagency Fire Center (2019), United States Geological Survey (2019)

Does the U.S. have the right native seed and other plant materials[1] needed for disaster mitigation and other ecological restoration projects on public and private lands? In short, no. To successfully restore highly functioning ecosystems, we must consider the type of seed used in restoration projects. Seeds are adapted to their local environment, which means that seed source and genetic diversity affect restoration outcomes and ecosystem function (Baughman et al. 2019; Whitham et al. 2006) (Figure 2). It has been estimated that 74% of native plant species needed for restoration in the U.S. are unavailable commercially (White et al. 2018). Within the commercial native seed industry, even fewer locally adapted plant species[2] are available for restoration. This is particularly true for those plant species that are difficult to farm, like certain wetland plants or biocrusts (Kettenring & Tarsa 2020; Doherty et al. 2015). When large, unexpected disturbances impact public lands, federal land management agencies often need a bigger selection of locally adapted native plants than is available (Oldfield & Olwell 2015). Lack of species and genetic diversity of commercially available seed sources increases the risk that, in the short-term, ecosystems become less resilient to the effects of climate change, and, in the long-term, ecosystems do not recover at all (Nef et al. 2021).

Figure 2. WHY USE LOCALLY ADAPTED, GENETICALLY APPROPRIATE NATIVE SEED? Scientific research has shown that native plants adapt to local environmental conditions that increase their chance of surviving and reproducing. For example, experimental comparisons of locally sourced plants vs. non-locally sourced plants of the same native species in the Great Basin of Nevada, Utah, Oregon, and Wyoming, showed locally sourced plants survived best in 67% of comparisons, and produced more plants in 90% of comparisons (Baughman et al. 2019). This shows how locally sourced plants generally perform better than native plants sourced from a different (non-local) environment and can be more locally adapted to the restoration site.

Native plants and plant ecology should be at the forefront of restoration and land management if we are to successfully restore resilient ecosystems. Having genetically appropriate seed can mean the difference between a successful restoration project and a failing one. When restorations fail, we risk increased erosion and flooding; increased damage by non-native invasive species; reduced biodiversity and productivity of working lands; and depleted plant and animal habitats. Additionally, we risk economic losses, including jobs and livelihoods, and increased cost of repeated plantings.

[1] The term "plant materials" encompasses seed as well as other plant materials, including seedlings and container stock (Plant Conservation Alliance [PCA] 2015).

[2] The term "locally adapted plants" is defined as plants from an area geographically near a planting site that are environmentally adapted and likely to establish and persist (PCA 2015).

Seeds are a critical natural resource that need to be recognized, valued, protected, and managed. As such, our nation's seed resources need the same kind of forward-thinking management that we demand for other natural resources such as timber. Given their importance as the foundation of resilient ecosystems, genetically appropriate native seed need to be developed and available *before* the natural disasters occur and not as an afterthought of disaster recovery. Ensuring the availability of genetically appropriate native seed takes forethought, planning, and time. We have the expertise and the plan, and we are taking action!

The National Seed Strategy is needed now more than ever.

What is the National Seed Strategy for Rehabilitation and Restoration?

The National Seed Strategy (Plant Conservation Alliance 2015) fosters a science-informed, collaborative approach to improving the use and availability of native plants needed for restoration. Developed by conservation and restoration experts of the Plant Conservation Alliance (PCA)[3] in 2015, it charts a course for federal, tribal, state, local, and private partners to increase coordination on native seed development, thereby accelerating the pace and scale of restoration. The National Seed Strategy Business Plan (Olwell & Bosak 2015) outlines the costs to achieve the Strategy's four goals (Figures 3 and 4). Success is achieved through the establishment of nationwide networks of botanists to collect seed, researchers to identify and develop appropriate native seed, farmers to grow native seed, nurseries and seed storage facilities to supply adequate quantities of appropriate seed, and restoration ecologists who know how to put the right seed in the right place at the right time.

Figure 3. THE NATIONAL SEED STRATEGY HAS FOUR MAJOR GOALS. These goals support the Strategy's mission to ensure the availability of genetically appropriate seed to restore viable and productive plant communities and sustainable ecosystems.

[3] The PCA was formed in 1994 and consists of both federal members and non-federal cooperators. For more information, see the PCA Federal Committee webpage: www.blm.gov/pca; and the PCA Non-Federal Cooperators Committee webpage: www.plantconservationalliance.org.

NATIONAL SEED STRATEGY BUSINESS PLAN	FIVE-YEAR COST ESTIMATE
Goal 1: Native Seed Needs & Availability	26,370,000
Goal 2: Research - Genetics to Restoration Outcomes	39,442,000
Goal 3: Tools, Training & Planning Resources for Land Managers	5,241,000
Goal 4: Communications & Outreach	585,000
TOTAL FIVE-YEAR ESTIMATE	358,190,000
TOTAL ANNUAL ESTIMATE	71,638,000

Figure 4. WHAT DOES IT COST TO ACHIEVE THE GOALS? The National Seed Strategy Business Plan (Olwell & Bosak 2015) outlines the costs to achieve the four goals of the National Seed Strategy. From 2015-2020, only $20 million was designated through the Bureau of Land Management to implement the National Seed Strategy. Additional funds were leveraged via various federal and non-federal program funding and grants (Figure 8). The 2015 Business Plan still serves as a useful cost estimate for continued implementation of the National Seed Strategy.

What Are Genetically Appropriate Native Plants and Why Do They Matter?

Native plants are the building blocks of ecosystems – they are integral components of our iconic American landscapes, supporting the unique assemblages of species found across our great country. Native plants are adapted to the local precipitation, temperature, and soil conditions where they naturally occur. Because these conditions may vary across the range of a plant species, different populations of the same species often adapt to different environmental conditions. These adaptations can be expressed in the genetics of plants and inherited across generations. Genetically appropriate plants are thus uniquely suited to growing in the environment where they originate and may be maladapted or unable to thrive under different environmental conditions. The concept that locally adapted, genetically appropriate plants generally outperform non-local plants should thus inform restoration efforts. For example, a culturally significant and important pollinator plant known as yellow bee plant (*Cleome lutea*), from Vernal, Utah, will not likely be a good choice for a restoration project on the Navajo Nation, where the climate is more prone to drought (Massatti 2020). Local adaptation in woody and herbaceous plant populations is well documented in research across the world and from a variety of ecosystems. It is critical that restoration practitioners and land managers consider seed source when creating seed mixes for restoration, with the aim of selecting seed from populations that are more local and/or come from similar environmental conditions to the restoration site. Given the strong relationship between species diversity and ecosystem function, carefully selecting seed sources for plant species will likely lead to more effective restoration and improved habitat for wildlife (McKay et al. 2005; Baughman et al. 2019).

Lack of genetic diversity in seeds makes restored populations of plants vulnerable when in a location that is susceptible to disturbance or adverse climatic events. When we use agriculture to produce seed for restoration, genetic diversity can be reduced throughout the seed production cycle. Seed collections

need to follow protocols, including making collections from multiple individuals over the course of seed production in a given season and from populations in less-than-ideal growing conditions or during less-than-ideal years (like during drought) (Bureau of Land Management [BLM] 2018; McCormick et al. 2021). During field establishment, processes that select for certain traits or ease of production should be avoided. During production, farmers should work to maintain diversity by keeping the number of generations of a species in a single field to a minimum. These practices raise the price of genetically diverse seed compared to other types of native seed on the market. However, the ecological value of increased genetic diversity has been shown to offset the differences in production costs (Leger & Baughman 2015).

As a Nation, we lack basic information on the biology of many of our native plant species, such as seed germination requirements and pollination ecology, and how and where to grow them. This type of information has been developed for native plants that we value as commodities and products, such as timber and forage species. During the 1960s and 1970s, the U.S. Forest Service (USFS) developed seed transfer zones for timber species to inform where they can be successfully grown and sourced for restoration (USFS 1973). This is similar to the USDA Plant Hardiness Zones for horticultural plants and crops, which are based on temperature gradations for use by gardeners and growers (Agricultural Research Service [ARS] 2012). While empirical seed zones based on genetics and common garden studies are being created for a broader range of non-timber native species (e.g., Massatti 2020; Pike et al. 2020; Shryock et al. 2021), provisional climate-based seed zones currently help guide the development and use of diverse seeds for restoration (Figure 5) (Bower et al. 2014).

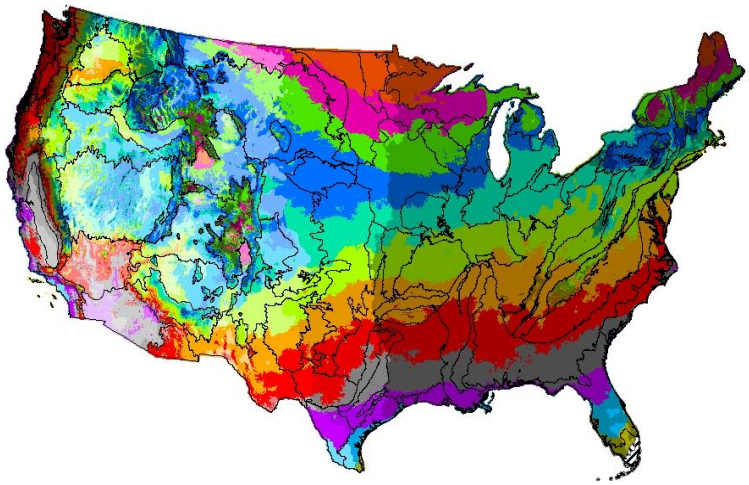


Figure 5. PROVISIONAL SEED TRANSFER ZONE MAP FOR THE CONTINENTAL UNITED STATES. A seed zone is a mapped area with fixed boundaries in which plants can be transferred with minimal risk of maladaptation. Each color represents a region based on climate similarity where plants can be sourced and used. The black lines are level III ecoregions within which seed zones can be further delineated (Omernik 1987). This means that an aster growing in Michigan will likely not be a good seed source location for a prairie restoration project in Minnesota.
Map source: Bower et al. 2014

How Progress Is Being Made

In 2020, the federal agencies of the Plant Conservation Alliance coordinated a federal data call to inform this Progress Report. A total of 460 projects were submitted by federal agencies and represent a sample of the work being done across the U.S. and its territories by organizations and individuals at the national, state, and local levels. Many of the projects addressed more than one goal, which underscores the multi-faceted approach to restoration that is being implemented through the National Seed Strategy (Figure 6). **This work demonstrates effective interagency collaboration and achievements; highlights joint problem-solving for natural resource challenges; and showcases effective land management**

tools to sustain native ecosystems, assist in endangered species recovery, improve wildlife habitat, promote recovery from natural hazards and other disturbances, and sustain multiple types of land use. While there is much to be done to meet our national restoration needs, below we highlight case studies that represent positive progress.

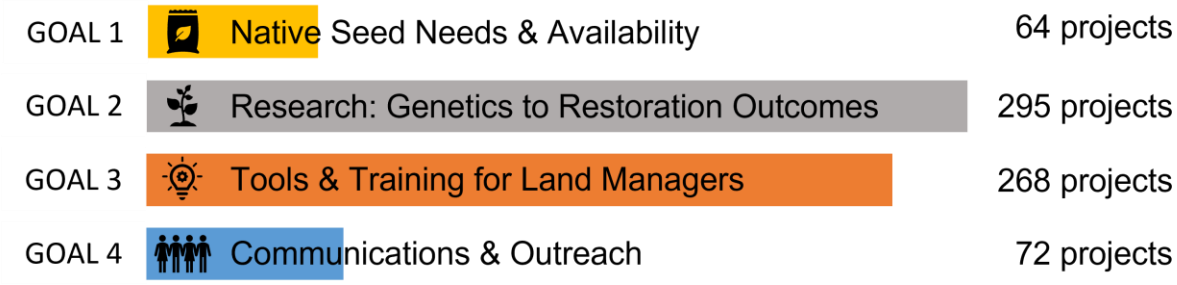


Figure 6. WHERE ARE WE MAKING PROGRESS? The 460 projects submitted as part of the 2020 National Seed Strategy Progress Report demonstrate that all four goals are being addressed. The largest number of projects were reported under Goals 2 and 3, indicative of the amount of research and effort necessary to take seed from wildland collection to commercial production and into restoration. Many projects met more than 1 goal, which is why the number of projects in this figure adds up to more than 460.

Unprecedented Collaboration

Starting in 2015, the National Seed Strategy initiated an effort to address widespread shortages of native seed. Since that time, the number of partners increased, including new collaborators from the native plant industry, seed cooperatives, landscape architects, and watershed managers. Working across jurisdictional boundaries, organizations and individuals at the national, tribal, state, and local levels are contributing to common goals, pooling resources, sharing information, and achieving results for advancing the National Seed Strategy. Thirty-two percent of projects reported involved more than one federal agency and 69% of projects involved at least one non-federal partner (Table 1). These projects ranged from large geographic areas spanning jurisdictional boundaries to smaller-scale, local area efforts (Figure 7).

Federal agencies that were identified as partners in the reported projects included:

Environmental Protection Agency (EPA); National Aeronautics and Space Administration (NASA); Smithsonian Institution (SI); U.S. Botanic Garden (USBG); **Department of Defense (DoD):** U.S. Army; U.S. Army Corp of Engineers (USACE); **Department of Interior (DOI):** Bureau of Indian Affairs (BIA), Bureau of Land Management (BLM), National Park Service (NPS), U.S. Geological Survey (USGS), U.S. Fish and Wildlife Service (USFWS); **U.S. Department of Agriculture (USDA):** Agricultural Resource Service (ARS), Farm Service Agency (FSA), Natural Resource Conservation Service (NRCS), National Institute of Food and Agriculture (NIFA), and U.S. Forest Service (USFS).

Table 1. FEDERAL COLLABORATION. Each agency has its own mission and niche within the National Seed Strategy while also contributing overall to the four goals of the National Seed Strategy. This chart shows inter-agency partnership reported from the 460 projects submitted to the progress report data call. If a project reported meeting an objective, we listed the partner agencies on this table. This is not a complete list of all the work being done by various agencies, but it shows how federal government agencies are working together to increase the supply of native seed for restoration. A list of acronyms is found in Appendix 3.

FEDERAL AGENCIES WORKING TOGETHER													
GOAL ONE			GOAL TWO				GOAL THREE				GOAL FOUR		
Obj 1.1	Obj 1.2	Obj 1.3	Obj 2.1	Obj 2.2	Obj 2.3	Obj 2.4	Obj 3.1	Obj 3.2	Obj 3.3	Obj 3.4	Obj 4.1	Obj 4.2	Obj 4.3
ARS	ARS	ARS	ARS	ARS	ARS	ARS	ARS	ARS	ARS	ARS	ARS	ARS	ARS
BIA	BIA	BIA	BIA	BIA	BIA	BIA	BIA	BIA	BIA	BIA	BIA	BIA	BIA
BLM	BLM	BLM	BLM	BLM	BLM	BLM	BLM	BLM	BLM	BLM	BLM	BLM	BLM
			DOD		DOD		DOD	DOD	DOD	DOD		DOD	DOD
	EPA				EPA								
					FSA	FSA	FSA		FSA				
NASA			NASA			NASA				NASA		NASA	NASA
		NIFA		NIFA	NIFA	NIFA	NIFA		NIFA	NIFA	NIFA	NIFA	NIFA
NPS	NPS	NPS	NPS	NPS	NPS	NPS	NPS	NPS	NPS	NPS	NPS	NPS	NPS
NRCS	NRCS	NRCS	NRCS	NRCS	NRCS	NRCS	NRCS	NRCS	NRCS	NRCS	NRCS	NRCS	NRCS
SI		SI		SI	SI	SI	SI				SI	SI	SI
			US Army		US Army		US Army	US Army	US Army			US Army	US Army
				USACE	USACE	USACE	USACE		USACE	USACE			
USBG	USBG	USBG		USBG	USBG				USBG		USBG	USBG	USBG
USFS	USFS	USFS	USFS	USFS	USFS	USFS	USFS	USFS	USFS	USFS	USFS	USFS	USFS
USFWS	USFWS	USFWS	USFWS	USFWS	USFWS	USFWS	USFWS	USFWS	USFWS	USFWS	USFWS	USFWS	USFWS
USGS	USGS	USGS	USGS	USGS	USGS	USGS	USGS	USGS	USGS	USGS	USGS	USGS	USGS

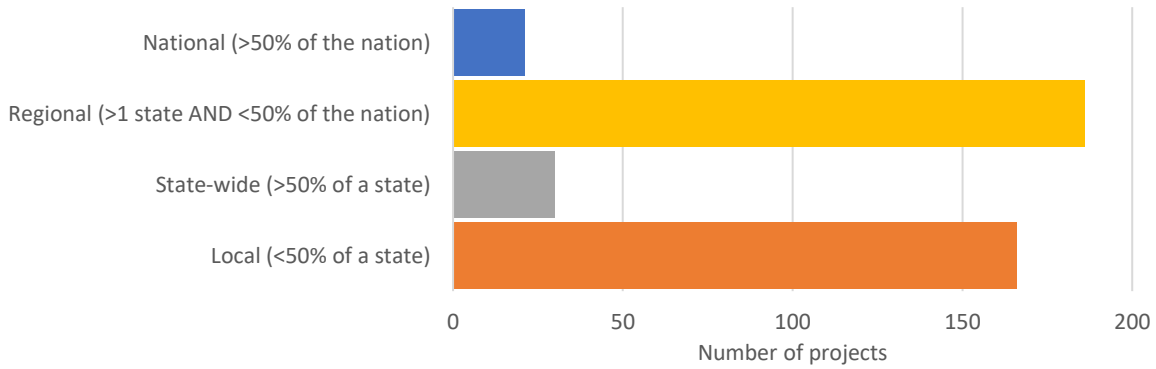


Figure 7. WORKING ACROSS JURISDICTIONS. To meet the goals of the National Seed Strategy, efforts take place at various scales. This includes small projects in a National Park or in a BLM field office to efforts that cross jurisdictional boundaries and span entire ecoregions and multiple states. This chart demonstrates the size of seed needs and the scale at which we need to work to accomplish the goals of the National Seed Strategy.

The data also show that most of the projects were federally funded, demonstrating that programmatic dollars are playing a significant role in implementing the National Seed Strategy (Figure 8). As this was a federal data call, it was anticipated that the projects would be federally funded, but it is notable that the federal dollars were leveraging multiple sources of funding, and that funding for new projects came primarily from pre-existing lines of funding.

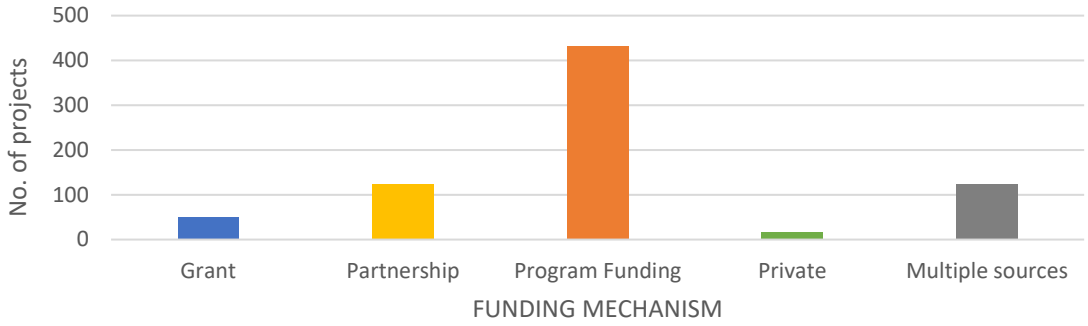


Figure 8. HOW ARE PROJECTS FUNDED? In the 2020 National Seed Strategy Progress Report data call, 300 of 460 projects reported costs totaling $167 million. These efforts are funded in a variety of ways. Most projects are funded by existing federal agency programmatic funding, or base funding federal programs receive to accomplish their mission. New money for projects comes from a variety of other sources. Grant funding is typically received via a competitive process from an external or internal funding source. Partnership funding is money contributed from various project partners. Private funding is money coming from a non-federal source that is not from a grant. Multiple sources is funding that was acquired through more than one of the listed mechanisms. A list of Funding Contributors is available in Appendix 2.

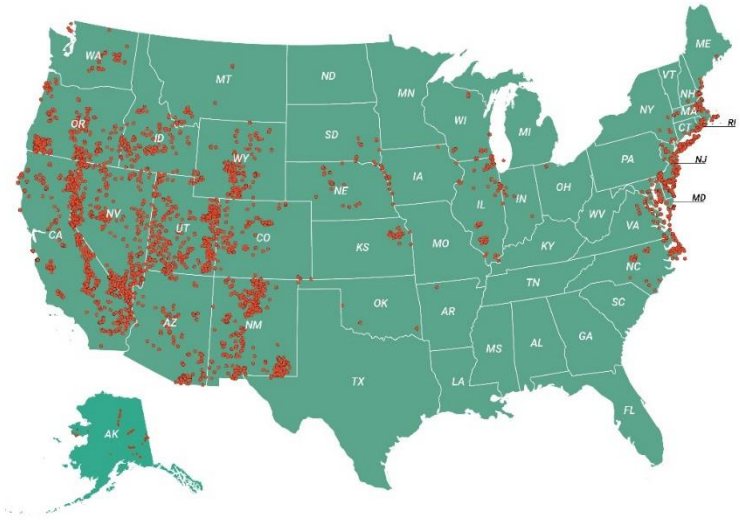
WORKING TOGETHER. Snapshots of people working to increase the supply of genetically appropriate seed and restore public lands. Left: Native seed agricultural increase field in Arizona funded by the USFS. Middle: A tribal youth crew member collects grass seed. Right: Volunteers help install riparian tree seedlings in Nevada. Image credit (left to right): Melanie Gisler/Institute for Applied Ecology (used with permission), Ben Goodman/USFS, Chris Otahal/BLM

Case Studies

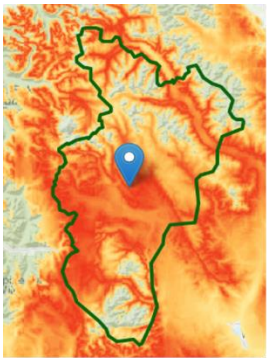
The case studies in this section demonstrate how actions under the National Seed Strategy facilitate the development of native seed and other plant materials for ecological restoration, as exemplified by the native seed development process (Figure 9) (McCormick et al. 2021). These case studies are organized by the steps in this process with a focus on the diverse types of collaborative efforts and ecosystem restoration that produce and use genetically appropriate native seed.

Figure 9. THE NATIVE SEED DEVELOPMENT PROCESS. This iterative, non-linear, and adaptable process includes collecting wildland native seed, developing production protocols during field establishment, producing seed as an agronomic crop, developing stable procurement procedures, testing seed for quality and placing in short and long-term storage, installing these genetically appropriate seeds in a restoration context, and conducting research that supports the entire cycle (McCormick et al. 2021).

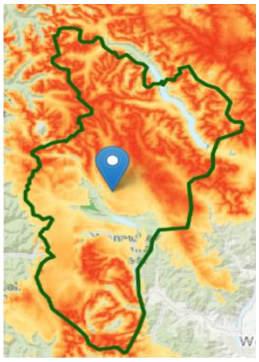
CASE STUDY #1: COLLECTION – SEEDS OF SUCCESS. Producing the right seed is a long process that takes dedication and collaboration. The process starts with collection of wild seed from the right place. Seeds of Success (SOS) is a national native seed collection project led by BLM in partnership with the USFS Bend Seed Extractory, ARS, USFWS, and many non-federal partners. As the first step of the native seed development process, SOS's mission is to collect wildland native seed for research, development, germplasm conservation, and ecosystem restoration. All SOS collections are tested for quality, including purity, germination, and weed content. The map shows the 8,430 SOS seed collections from 2,293 unique taxa made between 2015-2020. Since the project's inception in 2001, SOS teams have made over 26,000 collections from 5,800 taxa. Map credit: Seeds of Success



CASE STUDY #2: COLLECTION – IT TAKES A VILLAGE. The Medford BLM field office developed a native seed program through staff willing to pitch in when needed and leadership having the foresight to advocate for the importance of genetically appropriate native seed (left photo). These efforts led to the use of 100% genetically appropriate native seed for projects and fire recovery for Medford BLM, and restoration projects with diverse plant communities capable of supporting wildlife, resisting invasive plants, and protecting water resources. The results are demonstrated by this successfully restored meadow along Trail Creek in Oregon (right photo). Similarly, in the Rogue River Basin of Oregon, the Rogue Native Plant Partnership (RNPP) is working to meet the seed needs of the region. Currently there are 32 signatories on the RNPP Memorandum of Understanding with representation from BLM, USFWS, USFS along with a host of tribal, state, and private partner organizations. To date, the seed inventory generated through RNPP includes 112 species and over 200 collections. Image credit: Cristina Beslin/BLM (left) and Sasha Joachims/BLM (right)



(A) Seed Deployment Area
Current Climate
(red area 1100-1500 m)



(B) Seed Deployment Area
Mid-Century Climate
(red area > 1800 m)

CASE STUDY #3: EVALUATION & DEVELOPMENT – SCIENCE TAKES THE LEAD. Scientific research forms the foundation of every step of the native seed development process and Goals 2 and 3 of the National Seed Strategy. How do we know which plant species or population of that species is best suited for current and future habitats? How do we ensure that seed growing practices retain the genetic diversity important for survival? How can we improve restoration outcomes so that seeds grow, reproduce, and thrive at restoration sites? The answer is with long-term research programs and adaptive management dedicated to building our knowledge in best practices for developing and using genetically appropriate seed. Many federal agencies, universities, and private research institutions have research programs that contribute to research needs of the National Seed Strategy (see Appendix 1 for a list of scientific publications). The photo at left shows USGS biologists installing a fence around a common garden experiment. Common garden experiments are used to characterize the degree of local adaptation and define empirical seed transfer zones. The maps at left shows projections from the USFS Seedlot Selection Tool (SST, https//seedlotselectiontool.org/sst) that illustrate the climate match of a seed source (blue pin) to potential planting sites within a seed zone (green boundary) under (A) current and (B) projected climate conditions. The SST and the Climate Smart Restoration Tool (CRST, climaterestorationtool.org/csrt/) help land managers determine which seed sources will be best adapted to a given planting site under current and future climate scenarios. This is invaluable for planning seed collections and coordinating with other national forests, agencies, or landowners for seed needs for the near future and beyond. Image credit: Ella Samuel/BLM; Map credit: Vicky Erickson/USFS

CASE STUDY #4: EVALUATION & DEVELOPMENT – NATIONAL ACADEMIES OF SCIENCES' SEED NEEDS ASSESSMENT. The following is used with permission from the National Academies of Sciences, Medicine, and Engineering (NASEM) webpage for their ongoing study, *An Assessment of Native Seed Needs and Capacities* (https://www.nas.edu/seedneeds). In 2019, an *ad hoc* study committee appointed by NASEM began assessing federal, state, tribal and private sector needs and capacity for supplying native plant seeds for ecological restoration and other purposes (Goal 1 of the National Seed Strategy). The two-phase assessment will focus on the western continental United States and incorporate information from assessments of other U.S. regions, as available, towards the goal of a nationwide perspective. During phase one, completed in October 2020, the committee conducted fact-finding, developed a framework to gather information for the assessment, and prepared an interim

report describing the framework and implementation strategy (NASEM 2020). In the second phase, the committee will oversee the data and information-gathering process, analyze the information obtained, and prepare a final report summarizing the committee's findings and conclusions. The final report also will provide recommendations for improving the reliability, predictability, and performance of the native seed supply.

The assessment will include information on:

- how native seed is being used by public (federal, state, municipal, tribal) and private (land trusts, companies, nongovernmental) organizations in ecological restoration and other activities;
- the frequency and scale of the demand and the characteristics of the seeds pursued by users, as well as the scale of applications for which they are sought;
- how users find seeds that are appropriate for their intended purpose, and how users communicate their needs for seeds to potential suppliers;
- how suppliers make known their capacity to potential users;
- the different kinds of entities and roles that compose the seed supply chain (from professionals and organizations involved in the identification of site-specific needs, to the collection, propagation, cleaning, storage, and supply of seed) and their respective capacities;
- the relationship of seed availability to other agricultural, land management, or conservation activities, generally;
- procurement processes for native seed and the cost, availability of funds, infrastructure, market, and other factors that influence decision-making on the part of users and suppliers of native seed;
- opportunities to increase the size and capacity of the native seed supply chain (and number of suppliers); and
- other relevant issues identified by native seed users and suppliers and other stakeholders.

CASE STUDY #5: EVALUATION & DEVELOPMENT – INTEGRATING SCIENCE, AGRICULTURE & RESTORATION. The Institute for Applied Ecology held two interdisciplinary National Native Seed Conferences since the unveiling of the National Seed Strategy in 2015. With national and international participation from researchers, industry, growers, land managers, and restoration specialists, these Conferences provided the unique opportunity to share information about the latest research on seed collection, field establishment, production, and use of native plants in restoration. The 2015 Conference (held in Santa Fe, New Mexico, with sponsorship from BLM and USFWS) included a panel discussion on the yet-to-be-released National Seed Strategy and key concepts of the Strategy were highlighted. In 2017, the Conference was held in Washington, D.C., with sponsorship from several USDA and DOI agencies. It was organized entirely around the goals and objectives of the National Seed Strategy to highlight progress being made on implementing the Strategy, to discuss areas where more work is needed, and to identify partnerships and funding. Attendees took part in cross-disciplinary, short-term, project-oriented Task Forces designed to each accomplish a specific National Seed Strategy related task (see table below). By diversifying input and mobilizing action across a variety of small groups, the task forces maximized impact and generated broader participation in and knowledge of the Strategy.

	Goal description	Task Force
Goal 1	Native seed needs & availability	Before the Storm – The Need for Seed
		Identifying Existing Federal Seed and Restoration Policies and Guidance
		USDA Programs and Native Plants
Goal 2	Research	Soil Activities under the National Seed Strategy
		Seeing is Believing: Demonstration Sites for Native Plants
		Selecting the Right Seed for the Right Place Right Now
Goal 3	Tools, training, & planning	Tools for Seed Collectors
		Training Tools on the Use of Native Seed
Goal 4	Communications & outreach	Communicating the National Seed Strategy
		Non-Federal Native Plant Advocacy
		Native Plants Support Native Wildlife
		Public/Private Partnerships

CASE STUDY #6: EVALUATION & DEVELOPMENT – PROMOTING FOOD SECURITY. We rely on wild plant species that are close cousins to agricultural crops for many reasons, including improving crop yields, increasing drought tolerance, and enhancing disease and insect resistance. These native plant cousins of agricultural crops, like the common sunflower (*Helianthus annuus*) pictured at right, are called crop wild relatives. In the U.S., research and collection of crop wild relatives has only recently begun. It is important to increase our understanding of their utility and importance, and increase their conservation, collection, and banking. In a study that examined crop wild relatives in the U.S., authors from ARS examined 600 native plant taxa prioritized as crop wild relatives, and found that nearly half are either extinct, imperiled, or vulnerable (Khoury et al. 2020). The National Seed Strategy lays out a plan that not only restores ecosystems, but also conserves important genetic resources for agriculture. From 2001-2017, around 30% of species collected by the Seeds of Success project had multiple uses beyond ecosystem restoration, including food, livestock forage, horticulture, materials, and medicine (Greene et al. 2019). The National Seed Strategy and the Seeds of Success project help in the effort to conserve wild crop relatives and the Nation's food security through collecting and banking seeds of native plants. Image credit: BLM WY080/Seeds of Success

CASE STUDY #7: FIELD ESTABLISHMENT – DEVELOPING GROWING PROTOCOLS. Growing native seed in an agricultural setting presents a number of unique challenges. The Oregon State University's Malheur Experiment Station, in cooperation with the USFS Rocky Mountain Research Station, is developing methods for producing native forbs and grasses. From 2015-2019, this work has included developing irrigation protocols that favor natives instead of agricultural weeds, seeding systems (manipulating seasonality and depth), and other seed increase protocols. This work contributes to restoring native diversity in the Great Basin. The photo shows an irrigation research field of nine-leaf desert parsley (*Lomatium triternatum*) at Malheur Experiment Station. Image credit: BLM

CASE STUDY #8: FIELD ESTABLISHMENT – LEARNING TO GROW WILD SEED. Farming native plants from wildland-collected seed is challenging. It can take many years to produce a commercial crop. Wild-harvested seeds of genetically appropriate plants do not necessarily germinate, grow, and reproduce all at the same time for an easy harvest. Farmers must be willing to experiment, change harvesting practices to capture multiple harvest windows, obtain or modify equipment for harvesting and seed cleaning, and settle for small yields, especially during the first few years of working with a new species. Some of these challenges are demonstrated in the photos below of two-year-old milkweed fields growing at the NRCS Lockeford Plant Materials Center in Lockeford, CA. Narrowleaf milkweed (*Asclepias fascicularis*) (left) is easier to grow than woollypod milkweed (*Asclepias eriocarpa*) (middle) or showy milkweed (*Asclepias speciosa*) (right). NRCS Plant Materials Centers and other research institutions are working hard to develop genetically appropriate native plants that can be used at restoration sites or for commercial production. This step of producing and developing protocols for growing wild-collected seed is a critical step in getting enough seed available for restoration. Image credit: Valerie Bullard/NRCS

CASE STUDY #9: PRODUCTION – DIVERSITY IS KEY. Maintaining genetic diversity when producing native plant species is critical for eventual restoration success. One recent example is Neches Germplasm splitbeard bluestem (*Andropogon ternarius*), a pre-varietal release by the NRCS East Texas Plant Materials Center in 2019. Neches Germplasm is a composite of 5 accessions from different areas in eastern Texas that were selected from 24 original collections based on germination, growth, and seed production. Neches Germplasm still has a lot of diversity in height, foliage abundance, and timing of seed maturity but has sufficient seed production and seed viability to be successful for commercial producers. Neches Germplasm is appropriate for many different conservation and restoration purposes such as for conservation cover, disturbed areas, and wildlife habitat. The shift by Plant Materials Centers from cultivars to selected class pre-varietal releases reflects a growing need for native seed with more diversity for different conservation purposes. Photo shows harvesting Neches Germplasm splitbeard bluestem at the NRCS East Texas Plant Materials Center. Image credit: Alan Shadow/NRCS

CASE STUDY #10: PRODUCTION – EMBRACING AN ECOLOGICAL PARADIGM. The commercial seed industry is responding to the increasing need for native seed. In 2018, BLM contracted with six private growers to increase source-identified genetically appropriate native seed for multiple ecoregions (see Case Study #12). The six growers are Benson Farms, Inc.; Granite Seed Company; Great Ecology & Environments, Inc.; Oregon Wholesale Seed Company; Pacific Northwest Natives; and S&S Seeds, Inc. According to Jerry Benson of Benson Farms, Inc., the key to native seed production for successful restoration is embracing an ecological paradigm as opposed to an agronomic one. Instead of focusing on maximizing yield, Benson says that the end goal for native seed producers should be the restoration of fully functioning ecosystems. Producing native seeds for functioning ecosystems requires a diverse botanical skillset, from experience with specialized agricultural and seed harvesting techniques to knowledge of native plant community characteristics. Communication between the producer and end-user is also key: growers need to understand the goals of the restoration practitioners, and end-users need to understand the process of converting wildland collected seed to an agricultural seed crop. Photo shows native forbs in production at Benson Farms, Inc. Image credit: Jerry Benson/Benson Farms, Inc. (with permission)

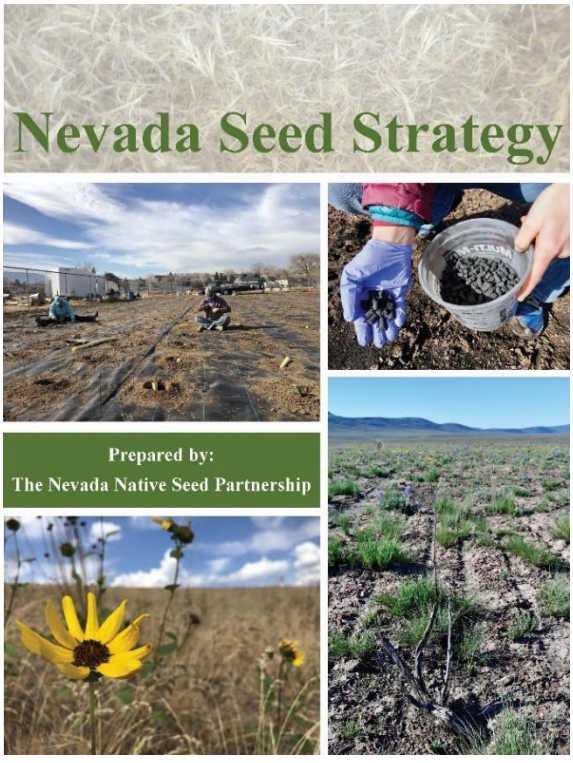
CASE STUDY #11: CERTIFICATION & PROCUREMENT – IDENTIFYING THE SOURCE. Though not required in every state, certification ensures the proper identity and source of native seed. The Southwest Seed Partnership, through the Institute for Applied Ecology (IAE), worked with New Mexico State University's Seed Certification & Noxious Weed Free Program to create the New Mexico Prevariety Germplasm (PVG) Program to meet or exceed the standards set by the Association of Official Seed Certifying Agencies (AOSCA) for 'Source Identified' seed. 'Source Identified' certification can now be obtained for native seed collected and produced following these standards. Seeds are then labeled with an official yellow tag issued by the New Mexico State University Seed Certification & Noxious Weed Free Program. Using source identified seeds improves the ability to select appropriate seed for a restoration site. The added transparency is expected to improve southwest revegetation efforts and increase confidence in seeds in southwest marketplaces. More information can be found on the program website: https://seedcertification.nmsu.edu/pre-varietal-germplasm-d.html. The photo is of a production field of blue grama (*Bouteloua gracilis*) managed in partnership with the Yavapai-Apache Nation's Agricultural Department. Image credit: Gayle Gratop/IAE (with permission)

CASE STUDY #12: CERTIFICATION & PROCUREMENT – SHARING THE RISK. Federal procurement tools can address a barrier to native plant production by supporting development of native seed in collaboration with the private sector. One example is Indefinite Delivery, Indefinite Quantity (IDIQ) contracts for native seed production, which were developed to buy and increase source-identified genetically appropriate native seed for multiple ecoregions. IDIQ contracts reduce production risks for farmers and growers by providing them with a minimum production cost guarantee. In 2018, BLM contracted with 6 commercial growers to increase 41 native grasses and 70 forbs (flowering plants). These seeds are eventually made available through the BLM National Seed Warehouse System for restoration use by BLM, other federal agencies, Tribal Nations, and states. Another example is how BLM's Colorado Plateau Native Plant Program is using the Good Neighbor Authority (GNA) to increase the supply of native species that grow in sparse populations in the wild. The GNA is an agreement mechanism by which USFS and BLM can collaborate with states, municipalities, and tribes to conduct restoration activities across private and public lands. Such procurement tools address a barrier to native plant production by reducing the risk on farmers who grow plants on speculation.

> ***"It is fantastic to have a selection of native, local seed on hand to use following disturbances due to recreation, trespass, and/or smaller fires."***
>
> **– BLM botanist describing successful use of seed procurement contracts in their district**

CASE STUDY #13: STORAGE – KEEPING THE SEED ALIVE.

Seed banks strive to keep seeds alive, but eventually everything ages. Knowing the 'expiration date' after which a sample is no longer viable is critical for planning re-collection, regeneration, and use. There are no guidelines for seed longevity or expiration dates for most of the species in the Seeds of Success (SOS) collections. Therefore, seed banks need to continually monitor viability by testing subsets of the sample, which is labor intensive and consumes precious seeds. In a collaboration between BLM and ARS, researchers at National Center for Genetic Resources Preservation (Fort Collins) are developing a new test that predicts longevity of stored seeds based on the speed that RNA degrades. Using newly collected SOS seeds as well as seeds that have been stored since 2004, the results will allow ARS to predict how long a seed lot survives in storage, including distinguishing seeds that are dormant from those that have died. If successful, this new technology will maximize longevity of SOS seeds, minimize cost for maintenance, and ensure that SOS seeds are always readily available for restoration. Photos show germinating seeds of Virginia iris (*Iris virginica*) (left) and camas (*Camassia quamash*) (right). Image credit: Lisa Hill/ARS



CASE STUDY #14: RESTORATION – STRATEGIES TO COMBAT INVASION AND FIRE. Nevada is the first state to create a state-specific seed strategy, modeled after the National Seed Strategy. In January 2020, the Nevada Native Seed Partnership finalized the Nevada Seed Strategy (front cover at left). This partnership includes federal, state, non-profit, university, and tribal partners. The Nevada Seed Strategy was adopted by and referenced in Nevada's Shared Stewardship Agreement for the Strategy's importance in conserving, protecting, and improving landscape health, supporting agricultural and rural economies, and reducing the risk and mitigating the effects of wildfire. Nevada's Shared Stewardship Agreement is the first to include the USFWS as a signatory agency, along with BLM in Nevada, and the USFS Humboldt-Toiyabe National Forest and the Governor's Office of Nevada. Image credit: Sarah Kulpa/USFWS

CASE STUDY #15: RESTORATION – REGARDLESS OF OWNERSHIP. The passing of a Minnesota state tax benefiting cultural and natural resources led to conservation agencies purchasing land at a faster rate. As a result, the ability to obtain a diverse seed mix for restoration efforts became challenging and agencies were competing against each other for a limited resource. To resolve this issue, the Northwest Minnesota Native Prairie Seed Consortium was established. This public-private partnership co-led by the USFWS, Minnesota Department of Natural Resources, and The Nature Conservancy focuses on providing the highest quality native prairie seed (see photo) through coordinating seed harvest efforts on remnant prairies. Approximately 4,203 acres of high diversity prairie have been restored using seed harvested as part of the Seed Consortium. The Consortium encourages and enables high quality prairie restorations in northwest Minnesota, regardless of land ownership. Image credit: Darren Wheeling/USFWS

CASE STUDY #16: RESTORATION – HURRICANE RESPONSE. In 2015, the Department of Interior awarded the BLM a $3.5 million grant through the Hurricane Sandy Supplemental Mitigation Fund for seed collection in coastal habitats from Virginia to Maine. At the start of the project, Seeds of Success (SOS) East reached out to federal agencies affected by Hurricane Sandy and identified 30 USFWS Refuge projects and 2 NPS projects needing native seed. As of 2018, SOS East teams had made over 2,170 collections of 359 different species spanning 73 plant families, 11 states and 15 ecoregions for restoration projects on DOI lands. Additionally, 35 interns were hired through Chicago Botanic Garden's Conservation and Land Management internship program in partnership with the Mid-Atlantic Regional Seed Bank, The Native Plant Trust, and the North Carolina Botanic Garden (NCBG). This internship program provided hands-on experience to motivated and highly skilled recent college graduates, thus supporting the next generation of botanists and conservation land stewards. Photo shows an SOS East collection of American beachgrass (*Ammophila breviligulata*). Image credit: NCBG/Seeds of Success

CASE STUDY #17: RESTORATION – TEACHING THE NEXT GENERATION. Restoration projects sometimes occur in urban locations, including elementary schools. For example, the USFWS partnered with Brownsburg Community School on a 16-acre native prairie project in Indiana that also serves as the school's cross-country training field. On the Colorado Plateau of Utah, BLM is partnering with schools to teach youth about restoration and native plants by creating pollinator habitat across school campuses. In inner-city Phoenix, BLM partnered with Edison Elementary School to build a native plant and pollinator garden (see photo) where students increase milkweed seed for restoration projects on public lands. Image credit: Natalie Melkenoff/BLM

CASE STUDY #18: RESTORATION – LONGLEAF PINE FORESTS. The longleaf pine ecosystem was the predominate forest type in the southeastern U.S., covering an estimated 90 million acres. Beginning in the 18th century, longleaf pine forests were reduced by commercial logging, altered by fire suppression practices, and converted to other land uses and forest types. Longleaf pine forests—currently at less than 5% of their original extent—are some of the most biologically diverse ecosystems outside of the tropics. The America's Longleaf Restoration Initiative (ALRI; http://www.americaslongleaf.org/) is a coalition of federal and state agencies, non-profit organizations, forest industry, private landowners, and others who have united to restore the iconic longleaf pine forest in the southeastern US. ALRI's 15-year goal is to increase longleaf from 3.4 to 8.0 million acres by the year 2025.

The Department of Defense (DoD) is an active and committed partner in ALRI and is contributing to ALRI's range-wide efforts by sustaining and enhancing longleaf ecosystems both on and off installation. Today, DoD manages over 723,000 acres of longleaf pine habitat on 35 military installations, which constitutes a significant portion of the remaining longleaf pines in the U.S. These military installations have become key refuges for the tree and its unique inhabitants, while at the same time, the remote and open pine savannas provide DoD with an intact habitat for realistic testing and training. DoD invests significant resources to manage longleaf pine forests on its bases. Natural resource activities include prescribed burning, native seed collection, restoration, forest stand improvement, and species management. Outside military installations, the DoD Readiness and Environmental Protection Integration (REPI) Program (https://www.repi.mil) is working with the National Fish and Wildlife Foundation-Longleaf Stewardship Fund (https://www.nfwf.org/programs/longleaf-landscape- stewardship-fund) to expand, enhance, and accelerate longleaf pine ecosystem restoration across the historical range, recently surpassing 275,000 acres of restored or enhanced longleaf pine. Collection and propagation of native seed from across the current range provides a critical foundation for this highly successful, landscape-scale ecosystem restoration partnership.

CASE STUDY #19: RESTORATION – TRIBAL SEED SOVEREIGNTY. The Diné Native Plants Program (DNPP, www.nndfw.org/dnpp/homepage.html) is working to build social, ecological, cultural, and economic resiliency across the Navajo Nation. It is a program of the Navajo Natural Heritage Program with support from the BIA Tribal Resiliency Program, Wildlife Conservation Society, USGS Southwest Biological Science Center, and Tolani Lake Enterprises, a native-owned non-profit. DNPP is building tribal native seed sovereignty where tribal conservation youth corps collect native seed, local farmers grow seed, and ranchers and conservation professionals use seed to mitigate the effects of drought, climate change, and land degradation. Collaborative efforts include training programs (see photo), outreach, and community demonstration sites designed by the Diné people for the Diné people. Image credit: Molly McCormick/USGS

CASE STUDY #20: RESTORATION – NATIVE SEED FOR MINE RECLAMATION. Mining operators expend significant resources reclaiming disturbed areas, yet substantial knowledge gaps exist regarding the use of native seed to achieve reclamation success. The National Seed Strategy increases the use of genetically appropriate seed for successful mining reclamation, so that reclaimed mine sites transform into thriving habitat instead of a scar that never heals. Many regional seed partnerships support mining reclamation seed needs (10% of projects submitted to the Progress Report). For example, BLM has a number of native seed demonstration sites for placer miners in the Fortymile River area of east central Alaska. In California, BLM, USFWS, the mining industry, and commercial growers partnered to increase genetically appropriate seed in support of threatened and endangered species as part of oil and gas reclamation; this work also provided seed for critical habitat areas off the oil field. In the arid Southwest, USGS, BLM, and USFWS in cooperation with oil and gas industry representatives initiated a series of replicated experiments on well pads to identify effective reclamation practices for various arid ecosystems in high-development zones (see photo). This work is important, as reclamation is a big user of native seed. One study by BLM's Colorado Plateau Native Plant Program (CPNPP) estimated that in 2017 alone, reclamation activity on well pads (not pipelines, roads, or related infrastructure) in the Western U.S. used 347,000 pounds of seed, estimated at $3,808,450 (CPNPP 2018). Image credit: Mike Duniway/USGS

Addressing the Nation's Priorities

The National Seed Strategy harnesses botanical expertise from government botanists to non-profit researchers to private growers to restoration ecologists; supports rural, agricultural, minority and tribal livelihoods (farmers, seed cleaning/storage/distribution facilities); and provides training opportunities for the next generation of natural resource professionals (Civilian Climate Corps, interns, etc.) to maintain and preserve our iconic native plant communities. This science-driven national effort is integral to the Nation's conservation priorities, including the commitment to conserve 30% of America's lands and waters by 2030 as outlined in Executive Order 14008, *Tackling the Climate Crisis at Home and Abroad* (2021). Moreover, the National Seed Strategy is recognized in the 2021 DOI Climate Action Plan (DOI 2021, *in progress*) and the 2021 DOI Invasive Species Strategic Plan (DOI 2021) and addresses national priorities such as climate change and tribal engagement.

FOCUS ON: Climate Change

Climate change reduces the resiliency of ecological communities by increasing the frequency and intensity of disturbance regimes, and even drives wholesale ecosystem transformation. These changes are negatively impacting human communities, livelihoods, and lives, costing the American taxpayers trillions of dollars. In 2021, President Biden issued Executive Order 14008, *Tackling the Climate Crisis at Home and Abroad*, to outline the Nation's commitment to increasing climate resiliency. An important strategy to mitigate climate-related threats is to ensure adequate supply of native seed to restore ecosystems degraded by disturbances such as drought, wildfire, invasive species, flooding, hurricanes, and tornadoes. In the long run, such a supply provides the basis for identifying species better adapted to projected future climate scenarios, so that 'restoration' becomes climate-smart adaptation. It has been estimated that 74% of plant species needed for restoration are unavailable from seed vendors (White et al. 2018). Lack of seed biodiversity increases the risk that, in the short-term, ecosystems do not recover from disturbances, and, in the long-term, reduces our options for active, climate-informed adaptation.

As a result of climate change, wildfires are growing in intensity and scale, and this accelerates the need for native seed for post-fire rehabilitation and restoration. Wildfires burned more than 75 million acres in the U.S. and its territories between 2011 and 2020 (National Interagency Fire Center 2021). Not all these acres need to be re-seeded, but if as much as 5% of a burned area needs to be re-seeded, fire specialists at USFS estimate that only 1/5 of total amount of native seed needed is available for procurement and deployment for short- and long-term post-fire recovery.

Climate change impacts ecosystems, lives, and livelihoods. The National Seed Strategy helps meet national priorities for combating climate change, including conserving biodiversity after wildfire. Image credit: NPS

Native seed is needed in strategic locations to promote recovery after fire. Fire management operations such as fire lines and high burn severity areas lead to site conditions that are highly susceptible to erosion and invasion from non-native or undesirable species. Managers require seed to establish vegetation on these sites and other fire-related restoration actions as soon as possible, but this practice is threatened by 1) the lack of appropriate seed available at the right time, and 2) the cost of seed coupled

with increased cost of fire recovery in general (Peppin et al. 2010). For longer-term recovery, seeds are needed in places where heavy equipment is used to create extensive fire lines, safety zones, and drop points. Other critical post-fire areas include rehabilitation after road construction, after maintenance actions such as replacing damaged culverts, or in sensitive areas such as critical wildlife and plant habitats. Restoration efforts require the use of diverse genetically appropriate native grass, forb, and shrub species both immediately after the fire and for long-term recovery (Ott et al. 2019).

It is important to recognize that reforestation and rangeland restoration after fire require more than just planting conifers and grasses. Recovery of ecosystems includes short- and long-term activities that rehabilitate biodiverse understory and overstory plant communities that work together to sustain a functioning ecosystem and increase resiliency after wildfire. Increasing the availability of genetically appropriate native seed for post-fire recovery takes careful planning. Obtaining supply of native seed takes time, a process that needs to start at least five years prior to the time seeds would be available for use. A major barrier to fire recovery is up-front funding to build seedbanks in advance of demand. The National Seed Strategy helps create the infrastructure needed to meet these increasing demands and a common framework for interagency collaboration and leveraging of funds.

FOCUS ON: Tribal Engagement

Tribal Nations have been empowered in a new era of self-determination to take action in adaptive land management and stewardship efforts. Indigenous peoples in the U.S. are often "affected uniquely and disproportionately" by landscape- and community-level environmental impacts due to climate change (Jantarasami et al. 2018). Tribal communities' knowledge systems have been handed down over generations of direct contact with the natural world, putting them in a position to more fully understand the land to which they are intimately connected. As a result of marginalization, displacement, and a subsequent loss of culture that tribal communities have endured, these knowledge systems and their lands have undergone systematic change from traditional lifeways, livelihoods, and land management practices to more Westernized approaches to natural resource management. Examples of this change include shifts in scale and reciprocal relationships with the natural world from small-scale harvesting of traditional foods and a nuanced understanding of stewardship like cultural burning practices, to large-scale exploitation of natural resources and modern agriculture. However, despite the obstacles that tribes may face, many Indigenous and Traditional Knowledge practices are re-emerging today, and tribes are able to set the stage for a new era of adaptation and conservation.

Tribal land stewardship priorities may involve conservation of both biodiversity and culturally relevant plants, which sustain tribal food security and subsistence lifestyles, post-fire restoration activities, invasive species and erosion mitigation, mining reclamation, water security, and other values. Large landscape-level restoration, however, requires a substantial amount of diverse native and genetically appropriate seed that is often not commercially available in the quantities necessary for these various stewardship priorities. For tribes, this dearth of seed and subsequent ecosystem degradation is more than a risk to land health; it has ties to economic prosperity, cultural wellbeing, and tribal sovereignty. Meeting tribal priorities and building resiliency to climate change in the U.S. will require broadscale collaboration. Tribal engagement begins at the foundational level of acknowledgement and respect for Indigenous and Traditional Knowledge systems and continues when these collaborative efforts weave together a variety of knowledge systems and actions that produce enduring, equitable, diverse, fair, and adaptive project outcomes.

With this emerging era of adaptation, co-production of research and other initiatives which involve Tribal Nations and Indigenous communities are more important than ever. Because tribes are self-determining nations with their own governing systems, collaborators have much to consider in terms of respect to tribal sovereignty, and thus the acknowledgment of rights to ancient knowledge systems. For example, the Cause No Harm principle can help guide the motivation, character and intent of collaborative initiatives undertaken by government agencies, research scientists, tribal communities, and Traditional Knowledge holders (Climate and Traditional Knowledges Workgroup 2014). This principle involves identifying and avoiding risks that could ultimately lead to loss of or misappropriation of Indigenous or Traditional Knowledge and intellectual property. The "Cause No Harm" philosophy asks all stakeholders to:

Native Seed and Grassland Restoration Program fellows from the Fort Belknap Indian Community in north-central Montana head off to collect seed in a population that is being monitored using BLM's AIM (Assessment Inventory Monitoring) protocols to study seed collection impacts on the site. Image credit: Cristina Eisenberg/Society for Ecological Restoration (with permission)

1. Define the roles and responsibilities of all partners clearly and carefully;
2. Define what information will be shared;
3. Establish use, ownership, and means to interpret or share information at the outset of the project; and
4. Build and maintain respect, trust, equity, and empowerment.

Other resources like "Free, Prior and Informed Consent" (Mitchell et al. 2019), and the Memorandum on Tribal Consultation (Biden 2021) can provide further assistance when collaborating with tribes. Consideration of important principles should help to form lasting relationships with Indigenous peoples over time, as management decisions are made together with multiple participating entities during collaborative engagement, particularly when making adaptation and conservation decisions.

Plant Conservation Alliance Federal Agency Summaries

All federal agency collaborators of the PCA were invited to summarize their contributions and commitment to the National Seed Strategy. The following summaries demonstrate the critical value of interagency and cross-sector collaboration to ensure the commercial production and availability of native seed to restore resilient plant communities.

The Garden Lounge at the National Museum of Natural History serves as a welcoming interior rest area for visitors, with live plants and a relaxing atmosphere featuring botany content as a frame. The National Seed Strategy is presented as a case study that illustrates the positive aspects of dispersing native seed to restore and rehabilitate lands damaged by hurricanes, fires, and floods. Image credit: Gary Krupnick/Smithsonian

Department of Defense

Mission as it relates to native plants

The Department of Defense's (DoD) Natural Resources Program (https://www.denix.osd.mil/nr/) supports the military's combat readiness mission by ensuring continued access to the ~25 million acres of military land, air, and water resources needed to accomplish vital testing, training, and operational activities.

Implementing the National Seed Strategy

The Natural Resource Program invests significant resources to implement long-term conservation programs that help sustain our nation's priceless natural heritage. DoD uses an ecosystem-based, integrated natural resource management planning approach (or INRMP) to balance our conservation and mission readiness responsibilities—some 342 military installations are currently executing actions in their INRMPs, nationwide. DoD installations closely coordinate with the U.S. Fish and Wildlife Service, state fish and wildlife agencies, and other partners on natural resources management activities.

Many DoD landscapes are unique and becoming increasingly rare. At present, military installations provide habitat for ~490 federally-listed plant and animal species, and over 550 at-risk species—including 75 species that occur only on DoD lands. Healthy natural landscapes are critical to DoD's mission success, as DoD requires high quality lands, free of legal and environmental encumbrances, to conduct readiness activities. It is a core DoD value to be good stewards of our nation's natural heritage and to protect our imperiled species.

DoD's Funding Programs

DoD sponsors several competitive funding programs that support diverse natural resources efforts and address a wide array of environmental challenges:

- *DoD Legacy Resource Management Program* (https://www.denix.osd.mil/legacy/) funds high priority natural and cultural resources projects that have regional, national, and multi-service benefits.
- *Strategic Environmental Research and Development Program* (SERDP, https://www.serdp-estcp.org/) funds basic and applied research and development for resource conservation and resilience, munitions response, environmental restoration, and weapon systems and platforms.
- *Environmental Security Technology Certification Program* (ESTCP, https://www.serdp-estcp.org/) funds demonstration and validation of energy and environmental technology.
- *Readiness and Environmental Protection Integration Program* (REPI, https://www.repi.mil/) funds easements, acquisitions, and stewardship endowments to serve as buffers to installation lands.

DoD's Successful Partnerships

To maximize the effectiveness of management activities and support cooperative conservation, DoD actively supports and participates in many local, regional and national partnership-based conservation efforts and professional organizations. A few examples of key partnerships focused on native plant conservation and habitat restoration, and of particular application for this NSS report include:

Plant Conservation Alliance (PCA) and National Seed Strategy (NSS): DoD serves as a member of the Federal Native Plant Conservation Committee of the PCA and as a member of the NSS Federal Implementation Working Group. These collaborative partnerships provide DoD with a forum for coordination and implementation of a national native plant conservation program, as well as a

framework and strategy to pool resources, tap existing expertise, and work with federal, state, tribal, academic, non-profit, and private-sector partners to restore native plant communities and ensure the availability of native seed.

National Environmental Education Foundation (NEEF, https://neefusa.org), National Public Lands Day (NPLD): DoD has partnered with NEEF for more than 20 years to provide opportunities for people to enjoy, understand, and value native plants and plant communities through volunteer habitat restoration on military installations. DoD-supported NPLD (and more recently, Park Rx) projects have included sand dune restoration, planting native vegetation, invasive plant removal, and pollinator habitat improvements.

Sentinel Landscapes (https://sentinellandscapes.org/): In 2013, the USDA, DoD, and DOI established the Sentinel Landscapes Partnership—a nationwide federal, local, and private collaboration dedicated to promoting natural resources sustainability and preserving agricultural and conservation land uses in areas surrounding military installations. These "Sentinel Landscapes" are places where preserving the working and rural character of key landscapes not only strengthens the economies of farms, ranches, and forests, and conserves habitat and natural resources, but also protects the vital testing, training, and operational missions conducted on those military installations. The current, six Sentinel Landscapes are: Joint Base Lewis-McChord Sentinel Landscape (WA), Fort Huachuca Sentinel Landscape (AZ), Camp Ripley Sentinel Landscape (MN), Middle Chesapeake Sentinel Landscape (MD, DE, VA), Eastern North Carolina Sentinel Landscape (NC), and Avon Park Air Force Range Sentinel Landscape (FL).

North America Pollinator Protection Campaign (NAPPC, https://www.pollinator.org/nappc): Along with 170 diverse partners, DoD is a member of the NAPPC, whose mission is to encourage the health of pollinating animals across North America, and to promote the conservation, protection, and restoration of pollinator habitat.

DoD Native-Plant-Related Projects

DoD has funded hundreds of habitat restoration and native-plant-related projects over the past few decades. DoD believes that partnerships are essential to the success of our military mission and that these synergistic relationships with many state and federal agencies, universities, and non-governmental organizations are crucial to the success of our environmental programs.

DoD has a varied and extensive portfolio of native-plant-related projects. A sample of DoD projects with particular application for this NSS report have focused on:

- seed banking partnerships, and seed banking and seed-source nurseries on DoD lands;
- desert plant ecotypes seed transfer and restoration;
- shortgrass prairie and grassland conservation and management;
- impacts of climate change on tropical and temperate forest ecosystems;
- eastern hardwood forest restoration, forest riparian buffer zone analysis, and tropical forest monitoring techniques;
- invasive plant management and native plant restoration;
- aquatic vegetation restoration and innovative seed-based technology;
- the importance of native plant species for migratory bird habitats; and
- regionally focused native plant research and conservation planning: Chesapeake Bay, Upper West Gulf Coast Plain, Puget Sound, Central Prairie, Hawai'i, Panama Canal Area, Mojave Desert, and California.

Smithsonian Institution

Mission as it relates to native plants

The Smithsonian Institution (SI) is a leader in conducting top-quality research and educating the public about the importance of native plants in everyday life. Scientific research, public outreach, and native plant habitat enhancement take place at six Smithsonian research centers: National Museum of Natural History (NMNH), National Zoological Park (NZP), Smithsonian Conservation Biology Institute (SCBI), Smithsonian Environmental Research Center (SERC), Smithsonian Tropical Research Institute (STRI), and Smithsonian Gardens (SG).

Implementing the National Seed Strategy

NMNH is home to the U.S. National Herbarium, one of the largest and most complete plant collections of North American plants. These specimens represent a 200-year history of plant cover in North America. They paint an incredibly rich picture of biodiversity and, as such, are irreplaceable, unambiguous national records. NMNH's Department of Botany provides curation services and identifications for plant collections made by other federal agencies in support of their own biological mission. Understanding which plant species are appropriate for restoration in specific localities relies on an understanding of plant distributions which in turn depend on collection data and herbarium records. Voucher specimens, including those of the Seeds of Success (SOS) project, are deposited, mounted, prepared, digitized, transcribed, and stored at the U.S. National Herbarium.

Scientists in NMNH's Department of Paleobiology are studying the fossil record to learn more about plants, their surrounding environments, and how those environments changed over time. By uncovering clues about periods of past climate change, they can develop a better understanding of current and future climate change. Museum scientists are working on ways to extrapolate information from past dramatic shifts in global climate and applying it to the faster and more drastic events of today.

Sarah Evans prepares to digitize a specimen in the U.S. National Herbarium. Image credit: Ingrid Lin/Smithsonian

Scientific research on native plants at SCBI and SERC has focused on restoration projects and management methods. These research teams are conducting long-term, large-scale experiments in restoring naturally diverse forests and grasslands. The results from the experimental plots will help generate new information to share with restoration ecologists and landowners about restoring disturbed habitats using native plants. The Smithsonian's Forest Global Earth Observatories, or ForestGEO, provides long-term scientific data about biodiversity, ecological, hydrological, soil, and meteorological processes associated with climate change at local, regional, and global scales. This research platform enables Smithsonian scientists and their university and federal agency partners to better understand the storage and movement of carbon and water in temperate and tropical forests, as well as the impacts of climate change on the relationships of forests with wildlife, the atmosphere, and sources of fresh water. ForestGEO coordinates with the NSF's LTER and NEON programs through multiple shared sites.

The Smithsonian has a strong role in educational outreach and shares with the public information about the importance of native plants and the National Seed Strategy. Smithsonian Gardens maintains 40 urban acres in Washington DC surrounding SI's museum complexes as a Living Museum and Botanical Garden. Native plants are frequently incorporated in the Gardens' displays and interpretive panels. NMNH also uses its educational galleries to educate the public about the importance of the National Seed Strategy.

Department of the Interior

Participants unload seedlings of big sagebrush (*Artemesia tridentata*) in the Great Basin of Nevada. The seedlings were grown as part of the Sagebrush in Prisons Project. The Sagebrush in Prisons Project works toward restoring the habitat of the greater sage-grouse through plant production and environmental education of incarcerated adults in 19 different facilities across 8 states. The program focuses on preparing sagebrush and bitterbrush seedlings for plantings in areas recently affected by wildfire. Since 2014, the program has grown over 1.9 million sagebrush seedlings and over 800 germinated pots for restoration projects on BLM land. Image credit: BLM

Bureau of Indian Affairs

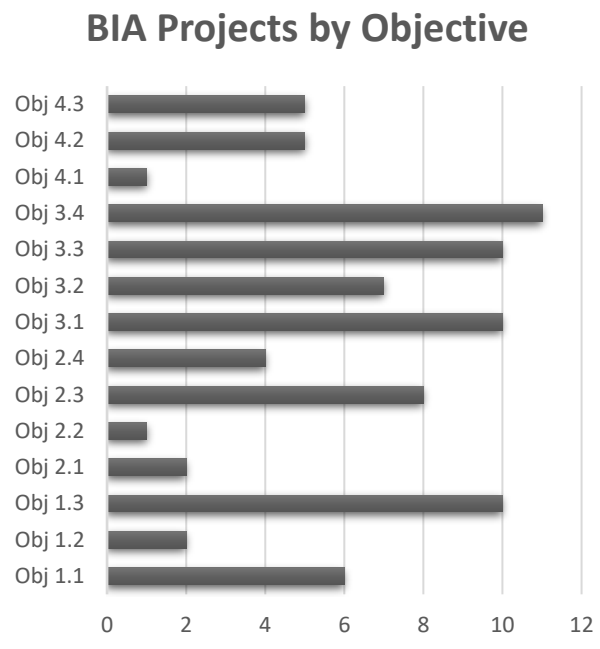
Mission as it relates to native plants

The mission of the Bureau of Indian Affairs (BIA) is to enhance the quality of life, to promote economic opportunity, and to carry out the responsibility to protect and improve the trust assets of American Indians, Indian tribes, and Alaska Natives. BIA is responsible for the administration and management of nearly 56 million surface acres and 59 million acres of sub-surface minerals estates held in trust by the United States for American Indians, Indian tribes, and Alaska Natives, and provides assistance to 574 federally recognized tribal governments to help protect water, natural resources, and land rights.

Implementing the National Seed Strategy

Organizational Structure

The Bureau of Indian Affairs Office of Trust Services-Central Office oversees all headquarters activities associated with management and protection of trust and restricted lands, natural resources, and real estate services. Native plant projects are primarily funded in the organization through various programs in the Office of Trust Services: the Division of Forestry and Wildland Fire Management, the Division of Natural Resources, and the Tribal Climate Resilience Program. Federally recognized tribes are eligible for funding, and certain programs may also fund authorized tribal organizations. The Division of Forestry and Wildland Fire Management funds many types of programs and projects. Forestry Projects funding (recently ~$26.9M) is broken down into four sub-activities: Forest Development, Forest Management Inventory and Planning (FMI&P), Woodlands Management, and the Timber Harvest Initiative. The Division of Natural Resources has four funding programs for federally recognized tribes that may fund native plant projects: Agriculture Program Tribal Priority Allocation (TPA) (recently ~$24.4-25.5M), Invasive Species Program (in recent years ~$6.7-9.7M) to include Noxious Weed Management, Endangered Species Program (in recent years ~$2.6-3.6M), and Tribal Youth Initiative. The Tribal Climate Resilience Program (TCRP) funding (in recent years ~9.9-14.4M) is designed to support tribes preparing for climatic events and environmental trends that impact treaty and trust resources, economies, infrastructure, and public health and safety. There are several funding Categories in TCRP that could be relevant to native plant conservation activities. Climate Adaptation Planning, Trainings and Workshops, and Internships play primary roles in funding for native plant conservation and restoration-related planning projects. Since 2015, TCRP has funded approximately over $2.7M in awards to tribes and authorized tribal organizations for adaptation plans that highlight native plant projects.



National Seed Strategy Reporting

Ten projects were identified representing tribal work consistent with the goals of the National Seed Strategy. All these projects originated with other federal partners, and while BIA partners with the tribes on each project, BIA reported zero projects directly. Each of these projects address one to four National

Seed Strategy Goals. The BIA was either a primary or a partial source of funding for two of the projects. Goal 3, *Developing tools for land managers,* represents the greatest strength for tribes since most reported projects contributed to training, assessments, and decision support system tools. There is broad access and use of tools created by partners, and co-production of other tools to address restoration projects on tribal lands. Three of the reported activities are: training opportunities in restoration practices using native seed, an assessment and monitoring program, and species-specific tools that are important for examining management of ecoregions in the Western U.S. in a changing climate. For Goal 4, *Developing internal and external communications*, three notable communication networks involve informal partnerships with tribes and the BIA: the Colorado Plateau Native Plant Program, the Plant Conservation Alliance Federal Committee, and the Plant Conservation Alliance Federal Implementation Working Group. For Goal 1, *Identifying and quantifying seed needs*, the Mojave Desert Native Plant Program serves as an example of a region-specific partnership, where the Colorado River Indian Tribes and other partners are performing seed increase grow outs in addition to seed increase and harvest protocol development. A BLM Medford Native Seed Collection project aims at collecting rare species for long-term germplasm storage. For Goal 2, *Undertaking research and improving technologies for seed production and use*, the RestoreNet project is a co-produced field trial network for dryland restoration, led by the USGS Southwest Biological Science Center. This network includes sites in ecosystems of the Southwestern U.S., for which research is critical and may have potential to help drought-prone regions that struggle with restoration. Despite this success in research, it appears that Goal 2 has had the least success for BIA-partnered reporting, implying a potential lack of shared research in Indian Country. More research is needed for characterizing species-specific and genetic-variation data for restoration activities, delineation of seed zones, seed transfer guidelines, etc.

Agency Needs

The BIA does not have a national committee to address native seed data and tools, seed collection and storage, or restoration and other implementation activities. Because tribes are sovereign nations, there are no national standards that apply to reporting, unless required by a federal grant authority for a specific native seed or plant project. Despite this, tribes use both Traditional Ecological Knowledge and western science to support National Seed Strategy goals, likely without awareness or use of the National Seed Strategy. It may be beneficial for BIA to have a formal committee at the national level with regional representation to coordinate these efforts, to raise awareness among tribal land managers of the National Seed Strategy as a useful decision-making tool, and to support tribes in accessing and maintaining genetically appropriate native plants. For BIA, not enough information is currently reported to accurately determine existing gaps in the procurement and deployment of native seed, but with a survey of regional representatives, a better picture of native seed use and needs on tribal lands may be determined.

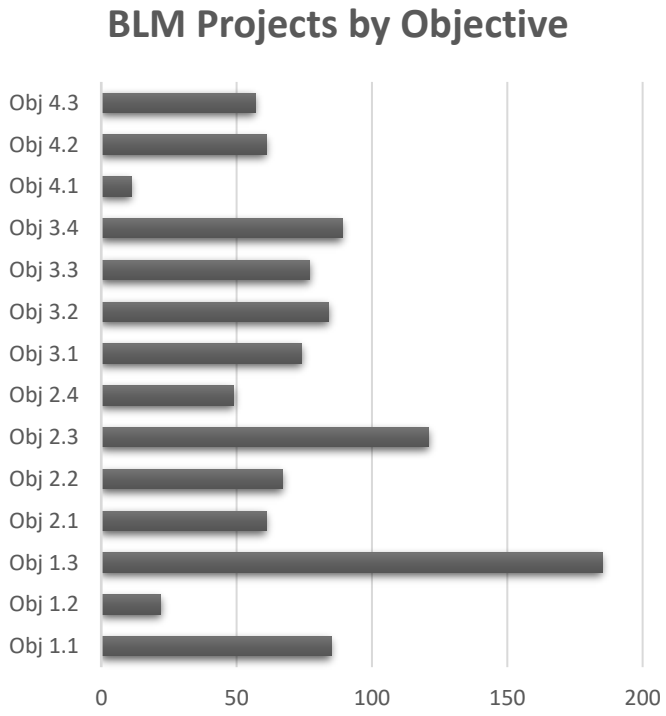
Bureau of Land Management

Mission as it relates to native plants

The Bureau of Land Management (BLM) manages 245 million acres of public land, which represents 38% of all federally managed land and 10% of the entire U.S. land mass. Most BLM land encompasses dryland ecosystems of the western U.S., which are increasingly impacted by drought and wildfire. BLM sustains the ecological and economic health, diversity, and productivity of these public lands for the use and enjoyment of present and future generations. Because native plants are the true green infrastructure we rely on for healthy, resilient, biodiverse ecosystems, BLM is dedicated to the conservation and restoration of native plant communities on its public lands.

Implementing the National Seed Strategy

As the largest public land manager in the U.S., BLM plays a significant role in the implementation of the National Seed Strategy. BLM was a partner in nearly half of all projects submitted for the Strategy's five-year progress report. These projects covered a wide range of issues, including fire rehabilitation, active restoration, invasive species treatments, wildlife habitat and corridors, rare or threatened and endangered plants or animals, mine reclamation, and recreation.



Though BLM-partnered projects supported all goals of the National Seed Strategy, the agency took the lead in implementing Goal 1, *Identifying and quantifying seed needs*. BLM sponsored the National Academies of Sciences' *Assessment of Native Seed Needs and Capacities* (interim report available now; final report anticipated Fall 2021) and continues to play a lead role in the national native seed collection project Seeds of Success (SOS)—a public-private partnership between multiple federal agencies and many non-federal collaborators. SOS is primarily focused on dryland ecosystems of the western U.S., but BLM has helped facilitate the expansion of SOS into the eastern and southeastern states, which are becoming increasingly susceptible to tropical storms and hurricanes. In 2015, the Department of Interior awarded BLM a $3.5 million grant through the Hurricane Sandy Supplemental Mitigation Fund for seed collection in coastal habitats from Virginia to Maine. As of 2018, more than 125 of these SOS East collections had been used for Hurricane Sandy restoration projects.

In addition to seed collection, roughly half of all BLM-related projects involved native seed production or scientific research. BLM is the largest purchaser of native seed in the U.S., with most seed used for post-fire rehabilitation and restoration, restoration after invasive species treatments, and reclamation of abandoned mines and orphaned wells. However, the current supply of native seed is insufficient to meet BLM's needs, especially with the increasing intensity of climate-driven events like wildfires, droughts, and severe storms. To help meet the increasing need for native seed, in 2018 BLM established the Indefinite Delivery, Indefinite Quantity (IDIQ) Contract for Native Grass and Forb Seed Increase—a

venture that reduces the risk to commercial growers by providing a minimum cost guarantee. To date, BLM has spent about $4 million through the IDIQ on the initial increase and production of 94 taxa of native seed from 40 unique seed transfer zones. BLM has also funded research to develop climate-based seed transfer zones, as well as empirical seed zones for certain restoration "workhorse" species, and to better predict seed longevity—invaluable when seed-banking for conservation and restoration.

Seeds of Success crew member collects wildland seed from a population of smooth desertdandelion (*Malacothrix glabrata*) in California. Image credit: BLM CA170/Seeds of Success

BLM-supported projects span sectors and scales. Between 2015 and 2020, BLM partnered with at least 232 non-federal collaborators, including over 30 private growers, 10 botanical gardens, 44 universities, 7 water and conservation districts, 21 state agencies, and 6 Tribal Nations. Notable partnerships include the Sagebrush in Prisons Project—a collaboration between BLM and the Institute for Applied Ecology that engages state prison systems to produce sagebrush seedlings for habitat restoration projects on BLM lands and to provide educational training for participating inmates. Since 2014, the Sagebrush in Prisons Project has worked with 19 prisons in eight western states and grown nearly 2 million sagebrush seedlings for BLM restoration projects. BLM has also entered a five-year agreement with north-central Montana's Fort Belknap Indian Community and the Society for Ecological Restoration (SER) to implement a Native Seed and Grassland Restoration Program. Initiated in 2019, the Program combines BLM protocols, SER best practices, and Traditional Ecological Knowledge for seed collection of restoration species and culturally important plants as determined by Tribal Elders. Additionally, the project provides education and job opportunities for the *Aaniiih* and *Nakoda* Tribes.

Projects involving BLM were predominately local or regional in scale, but BLM was also a partner in statewide, national, and even international projects. Because the U.S. National Seed Strategy was the first of its kind in the world, BLM is sometimes called upon to advise international seed-based restoration efforts. For example, in 2020, BLM offered guidance to an Australian group charged with developing their own national seed strategy. Also in 2020, the BLM partnered with the Society for Ecological Restoration's International Network for Seed-based Restoration to publish the first international principles and standards for using native seeds in ecological restoration. Printed in a special open access issue of the journal Restoration Ecology, the standards outline a series of best practices for each of the key steps in the native seed supply chain.

Through these projects and others, BLM is helping to forge the path forward for the National Seed Strategy, facilitating success through effective collaboration and implementation of the Strategy's goals.

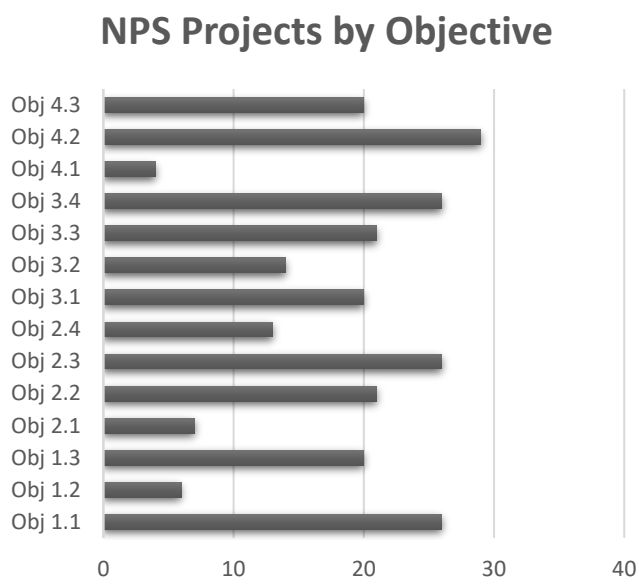
National Park Service

Mission as it relates to native plants

The National Park Service preserves unimpaired the natural and cultural resources and values of the 85 million acres of land across 419 units of the national park system and conserves the scenery, the natural and historic objects, and the wildlife of these special places for the enjoyment, education, and inspiration of current and future generations.

Implementing the National Seed Strategy

National Park Service (NPS) Management Policies emphasize the use of native species and local ecotypes in restoration projects. Although not formally tracked, NPS has implemented hundreds of native plant revegetation projects, in campsites and trails, facilities, and a wide range of disturbed lands. NPS achieved one of the earliest restoration successes in the country when park rangers collected native sod as it was plowed on farms in Nebraska to restore tallgrass prairie at Homestead National Monument in the 1930s. More recent examples include revegetation of areas disturbed during the construction of the new visitor center at Grand Canyon National Park, a prairie restoration using local ecotypes of 65 species along the St. Croix National Scenic Riverway, and the use of locally collected genetic material to restore Whitebark pine in Grand Teton and Glacier National Parks.



Park staff acquire native seed and other plant materials by way of in-park collection and development, partnerships with government and private sector nurseries, or direct purchase from seed companies. Methods are based on restoration goals and rarity of the species in question. For the most part, park staff work with general concepts of plant genetics and ecology to make decisions on seed sources. Development of the National Seed Strategy (NSS) is timely as the scope and complexity of native seed needs has increased. Invasive plants have altered significant areas of many parks and species selection needs to include competitive ability with the non-native species. And, as seen so clearly in 2020, wildfires have moved beyond historical patterns leaving uncharacteristic levels of high burn severity areas with natural recovery processes altered by global change. For example, Bandelier National Monument has experienced multiple fires across the same areas, and native Ponderosa pine woodlands cannot recover in the novel climate envelope in the northern New Mexico mountains. Post-fire seeding needs to be assessed for species or sources of species that are better suited for projected climate regimes.

The NPS Transportation Program has been a leader in the use of native plants in parks. In 2019 the program used over 7,000 lbs of native genetically appropriate seed in restoration projects to revegetate and restore over 400 acres of disturbed NPS lands including roadside disturbances, converted sagebrush lands, and degraded prairies. This program will be critical to the implementation of projects funded through the Great American Outdoors Act of 2020. This bill brings resources for NPS to upgrade facilities, roads, and other park assets. Many of these projects will require revegetation. Another

exciting initiative has grown from more than 50 historic sites east of the Mississippi seeking to increase the diversity of open fields to support biodiversity.

NPS does not have a centralized program to manage native seed needs. Few parks can afford dedicated facilities or staff to support seed collection, propagation, and seed increase, making the common and expensive practice of developing project-specific products with a local producer using park seed unsustainable. Slowly, park staff are supporting the use of ecotypes of "workhorse" species advocated in the NSS to address soil erosion and other disturbed land needs. For example, several parks have joined the Southwest Seed Partnership for seed collection, research, and production. NPS engagement will increase with the increase in ecotype development and product availability.

In addition to being a customer for seed developed through the NSS, NPS can also increase its contributions to the NSS by providing source material for ecotype development. This is increasingly important as NSS programs move into eastern states where smaller areas are managed for native biodiversity. Also, with nearly 330 million visitors a year and strong social media and internet presence, the NPS has a great capacity to educate the public about native plants and the pressures they face through its interpretive programs.

The NPS will benefit from continued development of the National Seed Strategy. Local ecotype seed often has the best overall potential for success in restoration projects. Greater availability of local ecotype seed will help NPS needs be met and help the agency become a strong partner, customer, and supporter of suppliers offering local ecotype seed. The NSS will also promote a much broader range of species available for projects, particularly forbs and shrubs. Science and ecotype source and availability tracking will inform decisions for seed—even species—selection as novel approaches are tested in the context of global stressors such as climate, biological invasions and landscape fragmentation.

Native plants are important for our rivers. Genetically appropriate native plant materials were recently used for prairie restoration along the St. Croix National Scenic Riverway, managed by NPS. Image credit: NPS

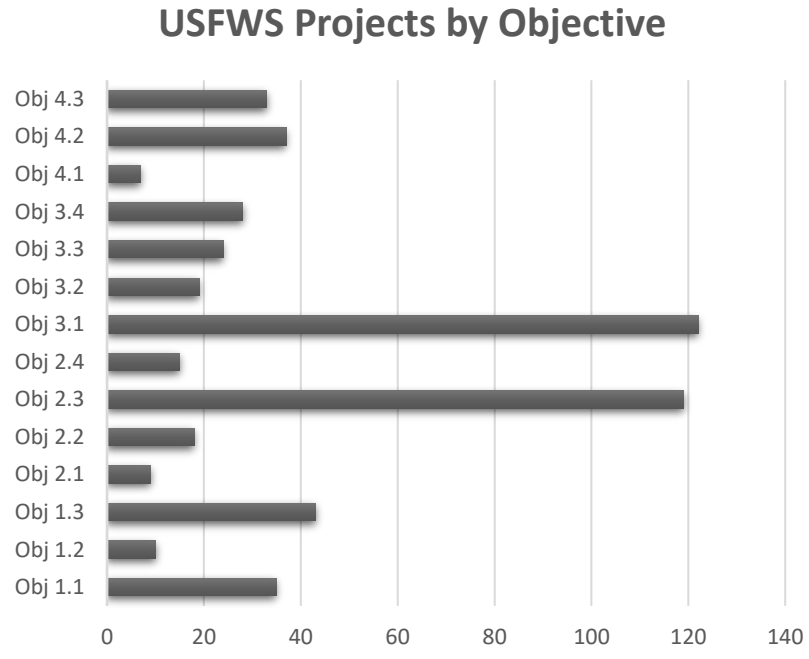
U.S. Fish and Wildlife Service

Mission as it relates to native plants

The mission of the U.S. Fish and Wildlife Service is to work with others to conserve, protect, and enhance fish, wildlife, plants, and their habitats for the continuing benefit of the American people. The USFWS manages over 95 million acres of land and waters within 568 National Wildlife Refuges, nearly 760 million acres of marine monuments, and 38 wetland management districts for the continuing benefit of the American people, while also providing primary trusteeship for migratory birds, anadromous fish, and over 2,000 threatened and endangered species.

Implementing the National Seed Strategy

As the oldest federal conservation agency in the United States, the U.S. Fish and Wildlife Service (USFWS) has a long history of ensuring a healthy environment while providing opportunities for Americans to enjoy the outdoors and our shared natural heritage. Restoration is key to this effort and the science-based collaboration fostered by the National Seed Strategy to improve the use and availability of genetically appropriate native plants for restoration aligns with our agency mission priorities and goals. Healthy, resilient native plant communities are critical to addressing some of our biggest conservation challenges, such as catastrophic drought, hurricanes, wildland fire, pollinator decline, and encroachment of invasive species.



At USFWS, a National Seed Strategy Implementation Team is working to ensure we have the essential plant species needed to maintain and restore our refuge lands, support the needs of private landowners enrolled in our voluntary conservation programs, and meet the habitat needs of our imperiled native animal and plant species. With its unveiling in 2015, the National Seed Strategy provided an opportunity to take a broader view of the many ways our agency depends on and supports the use of native plants for ecological restoration. In addition to managing 95 million acres of land across a full range of habitat types in all States and Territories, we work beyond our boundaries with private landowners, and local, state, and federal agencies, tribes, and conservation groups to sustain healthy working landscapes. At least eight programs across USFWS regions manage, enhance, or restore native plant habitat.

The NWRS goal to conserve a diversity of fish, wildlife, and plants and their habitats for the benefit of current and future generations is informed by a policy to conserve and restore habitat to pre-settlement vegetation with a focus on native species. The NWRS has substantial experience collecting, storing, and

growing genetically appropriate native seed and plants to ensure availability of these vital components of Refuge ecosystems for restoration. At least thirteen Refuges have collected native seed on their lands, and many others have done so on a Refuge-by-Refuge basis. The regional collaboration envisioned under the Strategy, using coordinated collection, seed banking, and grow-out protocols, has accelerated ecological restoration of Refuges impacted by landscape-scale devastation, described in Case Study #15. The Partners for Fish and Wildlife Program (Partners Program) and Coastal Program assist thousands of private landowners across the Nation with financial and technical assistance to restore and enhance habitat on their lands. Since 2015, we have restored over 170,000 acres of native habitat for pollinators on both refuge and private lands, ranging from small gardens to larger restoration projects, including the conversion of 5,124 acres of improved pasture, haylands, or non-productive croplands to native grassland habitat in Texas through a successful partnership among private landowners, the Texas Parks and Wildlife Department, and the Partners Program.

The ES Program works with partners to protect and recover the more than 657 animals and 876 plants listed under the ESA and foster proactive conservation that may eliminate the need to list additional species. In 2016, the ES Program collaborated with BLM to lead our first Seeds of Success collecting teams in support of our multi-regional effort to restore sagebrush habitat, providing integrated advanced planning vital to this monumental project. The ES Program was also an integral partner in developing the Nevada Seed Strategy, described in Case Study #14. Just as the response by species to changes in habitat can take years to manifest, positioning our agency and our Nation to have the right seed in the right place at the right time is a work in progress.

Sarah Kulpa, USFWS, and Sophia Heston, Great Basin Institute, collect year 2 data from a native seeding experiment on the 2018 Martin fire. Image credit: Cathy Silliman/UNR

We are proud of our contributions over the past five years, but much more needs to be done under each of the four broad Strategy goals. USFWS co-leads the interagency Federal Implementation Working Group with the BLM to facilitate coordination and implementation on the ground and at the national level. We encourage continued collaboration and coordination with the partners that implement the Strategy, building toward a sustained, well-informed, and integrated national effort to restore resilient habitats. The progress made during the first five years of the Strategy will help to conserve native plant communities and the ecosystem services they provide: clean air, clean water, species habitat, and carbon storage, along with the benefits they provide to the economy and society as a whole by restoring resiliency to our landscapes and reducing the risk of wildfire, droughts, floods and invasive species.

Note regarding data tables: The USFWS has contributed projects under each goal of the strategy and our contribution represents 30% of total projects submitted.

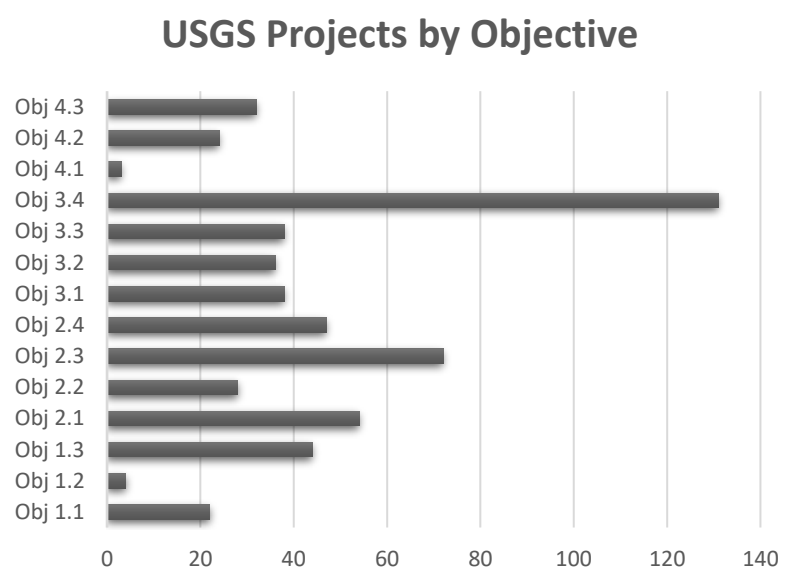
U.S. Geological Survey

Mission as it relates to native plants

The mission of the U.S. Geological Survey (USGS) is to monitor, analyze, and predict current and evolving dynamics of complex human and natural Earth-system interactions and to deliver actionable intelligence at scales and timeframes relevant to decision makers.

Implementing the National Seed Strategy

The USGS supports the National Seed Strategy, including efforts that support stewardship of public lands; protect public safety, health, and American economic prosperity; sustain healthy fish and wildlife populations; improve resilience to natural hazards like wildfire, drought, and hurricanes; and enhance community safety and well-being. The National Seed Strategy (NSS) provides valuable opportunity for the USGS Ecosystems Mission Area to connect with land managers pertaining to species management, land management, biological threats and invasive species, and climate adaptation science. The NSS provides valuable opportunity for the USGS Ecosystems Mission Area to connect with land managers pertaining to species management, land management, biological threats and invasive species, and climate adaptation science.



Research and activity at USGS support all four goals of the NSS, and our expertise is focused on meeting research needs (Goal 2, *Undertaking research and improving technologies for seed production and use*, and Goal 3, *Developing tools for land managers*). This work supports the needs of DOI and USDA agencies, tribal governments, state agencies, universities, industry, and non-profit organizations. According to the sample of projects reported in the 2020 NSS Progress Report, almost 1/3 (28%) of projects listed the USGS as a partner. This work is funded through partnerships and grants, with other funding coming from USGS programmatic funding; nearly half (43%) of projects used more than one funding source. This sample of projects alone generated over 100 research publications and reports, advancing knowledge of native seed production, improving restoration outcomes, and helping land managers make science-informed decisions.

<u>Example USGS Science Centers, partnerships, and projects:</u>

- Climate Adaptation Science Centers (CASC) help managers of fish, wildlife, and ecosystems understand climate change impacts and strategically adapt to changing conditions. There are 8 regional CASCs providing cutting edge solutions for new and evolving challenges to support our nation's resource managers and communities. This work includes understanding climate impacts to native plant communities and developing climate adaptation plans to increase resilience of native habitats.
- USGS Science Centers: Forest and Rangeland Ecosystem Science Center (FRESC), Southwest

Biological Science Center (SBSC), and Western Ecological Research Center (WERC) provide direct research support for BLM Plant Conservation & Restoration Program and Regional BLM Native Plant Programs. This work develops seed transfer guidance, identifies native species suitable for restoration, improves restoration techniques, and supports strategic planning for restoration and reclamation. Many USGS Science Centers provide science that meets NSS goals.

- The USGS is restoring the Sagebrush Steppe in the face of invasive annual grasses. USGS scientists integrate multiple scientific disciplines to evaluate approaches for soil stabilization, control of invasive grasses, and restoration of native plant communities, including providing restoration handbooks and seed transfer guidance to support decisions at local to landscape scales.
- Restoration Assessment and Monitoring Program of the Southwest (RAMPS) connects science and land management to improve degraded dryland ecosystems of the iconic American Southwest on the frontlines of climate change. RAMPS provides outreach and communication, scientific research, and decision-support. Specific projects include evaluation and research on genetically appropriate native plants and restoration techniques in an increasingly hotter and drier region.
- The Genetics for Western Restoration and Conservation research group investigates how organisms are influenced by historical and contemporary events (e.g., land use, climate change, management activities), which may guide policy and management given future challenges. Examples of research aligned with NSS goals include developing seed transfer zones; determining how restoration affects biodiversity; understanding the effects of production on native seed; and assessing questions surrounding taxonomy and hybridization.
- USGS engages in long-term collaborative work with other DOI, DoD, botanic gardens, and private Conservancy partners to recover 14 listed plants species of the California Channel Islands through surveys, seed banking, demographic and life history studies, recovery planting trials, and strategic planning for sustained conservation and recovery. This project addresses the urgent conservation and recovery needs of 14 endemic listed species across >100 populations on seven of the Channel Islands.
- USGS Native Bee Inventory and Monitoring Laboratory designs and develops bee surveys, including accurate and detailed identification tools important for plant reproduction and healthy native habitats. The lab also develops techniques for converting lawns and old fields with genetically appropriate native plants in the Southeast Plains ecoregions.
- USGS is reducing extinction risk caused by invasive species in the Pacific Islands. This includes investigating restoration techniques that combat loss of Ohi'a (*Metrosideros polymorpha*), a native tree that is experiencing rapid death due to an emerging disease.

USGS scientists develop new methods and tools to supply timely, relevant, and useful information about the Earth and its processes. Collaboration with stakeholders is critical for our research to make the biggest impact, and the NSS provides a platform for agencies to express research needs. USGS is working with diverse stakeholders to provide science support for every step in the native seed development process so that resources of money, time, and personnel are put to the best use for enhancing and improving degraded ecosystems.

U.S. Department of Agriculture

In 2001, the NRCS E. “Kika” de la Garza Plant Materials Center in Kingsville, TX, teamed up with the Caesar Kleberg Wildlife Research Institute at Texas A&M University-Kingsville, and the South Texas Natives project to develop and promote native seed sources for restoration and reclamation activities was born. Now in its 20th year, the effort has evolved into Texas Native Seeds (TNS) with many more partners, including the addition of the NRCS James E. 'Bud' Smith (Knox City) and East Texas (Nacogdoches) Plant Materials Centers, and has multiple focus areas for Central, West, and South Texas as well as the Permian Basin and Panhandle. Since its inception, this effort has released over 30 new pre-varietal releases to commercial growers for use across conservation, reclamation, and restoration projects for livestock production, wildlife habitat establishment, and increased diversity in prairie plantings, and for use by the transportation and energy sectors. Above photo shows successful prairie restoration at Caddo Mounds State Historic Park in Texas. Image credit: Alan Shadow/NRCS

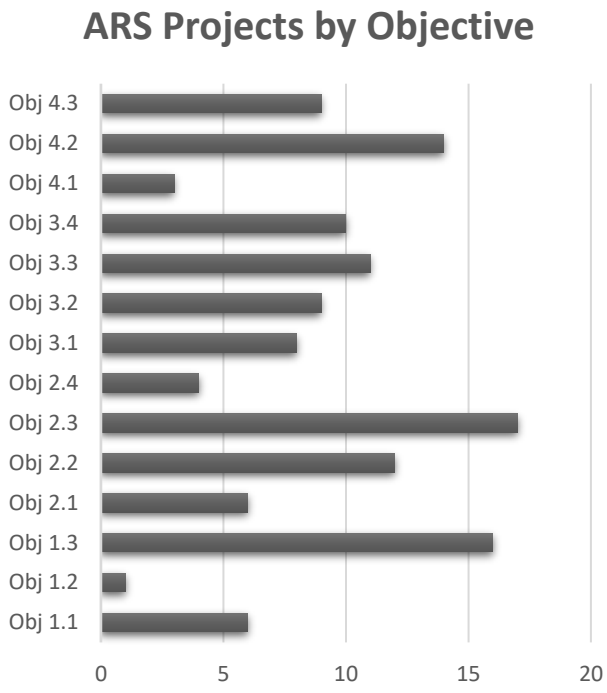
Agricultural Research Service

Mission as it relates to native plants

The Agricultural Research Service (ARS) is the U.S. Department of Agriculture's chief scientific, in-house research agency. The ARS mission is to find solutions to agricultural problems that affect Americans every day from field to table. The development and use of native plants are priorities in ARS research programs, ranging from conserving and facilitating the use of native germplasm, to providing an array of seeds and other plant materials for stakeholder use, to developing the management practices and decision-aid tools for successful use of natives for land conservation, land restoration, and animal forage production. ARS research and technology transfer support the four goals of the National Seed Strategy, especially in western rangelands where producers and land managers need tools to prevent wildfire, battle invasive weeds, restore degraded lands, and provide forage for livestock.

Implementing the National Seed Strategy

Examples of recent ARS research related to the National Seed Strategy include:



- ARS in Pullman, WA, is the entry point for Seeds of Success (SOS) collections into the National Plant Germplasm System (NPGS). A portion of SOS seed also goes into long-term storage at the ARS in Fort Collins, CO. Requested germplasm is made available publicly. In addition to research on seed preservation and regeneration, scientists study where native species occur, if they are endangered, and what their priority status is for collection.
- ARS in Logan, UT, focuses on broadening the biodiversity of forage germplasm and providing seed and sustainable management practices for semi-arid land uses, including conservation, reclamation, recreation, and forage production.
- Research in Boise, ID, is characterizing the field response of perennial grass seeds and using this information to improve methods to restore native plant communities. Scientists have developed a website for managers to download microclimatology for their field sites to better understand weather effects on seeding success (greatbasinweatherapplications.org).
- Research in Fort Collins, CO, is establishing parameters for local adaptation of the common rangeland species bottlebrush squirreltail (*Elymus elymoides*), including consideration of drought resistance and use of tools to match plant ecotype traits to climate.
- Research in Burns, OR, is developing seed coatings for use in the northern Great Basin: one to delay germination and reduce winter mortality of fall-sown seeds, and one to deactivate herbicides in the vicinity of desired seeds so herbicides can be applied at seeding to control invasive grasses. Scientists are also testing the use of periodic burning of production fields to enhance seed quality in bottlebrush squirreltail (*Elymus elymoides*) and bluebunch wheatgrass (*Pseudoroegneria spicata*) and modeling the range of soil moisture and temperature conditions needed to successfully restore native grasses across the Great Basin.

The National Seed Strategy also provides ARS a framework to coordinate with other federal agencies and non-federal stakeholders responsible for land management and make sure that research gaps are being addressed and research results are getting to the right customers when they need them. ARS actively engages with the Plant Conservation Alliance and the Federal Implementation Working Group of the National Seed Strategy. ARS research locations consistently collaborate with the Bureau of Land Management, the US Geological Survey, the US Forest Service, the National Park Service, the US Fish and Wildlife Service, and the Natural Resources Conservation Service.

While there has been much progress in the development and use of native seed and plants for ecologically sound land management, there remain many challenges, which seem to be only exacerbated by changing climate. ARS continues to dedicate its talent and resources toward achieving the goals of the National Seed Strategy and solving the related problems of the agricultural community.

Successful restoration of rangeland after the Martin Fire in northern Nevada. Restoration by ARS, BLM, and Nevada Department of Wildlife used innovative seed mixes and strategies. Image credit: Charlie Clements/ARS

National Institute of Food and Agriculture

Mission as it relates to native plants

The National Institute of Food and Agriculture (NIFA) is the extramural funding agency within USDA's Research, Education, and Economics mission area. NIFA provides leadership and funding for programs that advance agricultural research, education, and extension to help solve national challenges in agriculture and food. The agency's competitive grant programs support research, education, and extension activities. To ensure science is put into use, NIFA's integrated approach includes the three components of the agricultural knowledge system: a) research to provide answers to the complex issues facing the nation and world; b) education to strengthen schools and universities to train the next generations of scientists, educators, producers, and citizens; and c) extension to provide the knowledge gained through research and education to the agricultural workforce and to enable them to put theory into practice. Meeting agency mission and goals, NIFA's projects are engaged in finding innovative ways to: 1) meet the growing global food demand; 2) fight hunger and food insecurity in vulnerable populations; 3) help farmers and ranchers adapt to changing climate; 4) ensure that safe and nutritious foods are available at affordable prices; 5) reduce greenhouse gas emissions from food production; 6) enhance youth and family development; 7) develop bioenergy to build energy independence; 8) strengthen educational capacity to prepare the next generation of scientists, agricultural producers, and educators; 9) restore and sustain soils and forests as well as natural resources needed for or impacted by food and agriculture; and 10) ensure the health of delicate ecosystems.

NIFA supports research of native plants, including crop wild relatives like this American wild carrot (*Daucus pusillus*). Image credit: BLM OR090B/Seeds of Success

Implementing the National Seed Strategy

NIFA coordinates with ARS and USDA's National Plant Germplasm System, as well as with the SAES-NIFA-ARS National Plant Germplasm Coordinating Committee (http://escop.info/committee/national-plat-germplasm-coordinating-committee-npgcc/). Although NIFA's Agriculture and Food Research Initiative (AFRI) plant breeding priority (Program Code: A1141) does not specifically mention the National Seed Strategy, the request for applications (RFA) does accept research proposals relevant to its goals. Examples of projects funded by NIFA supporting the National Seed Strategy:

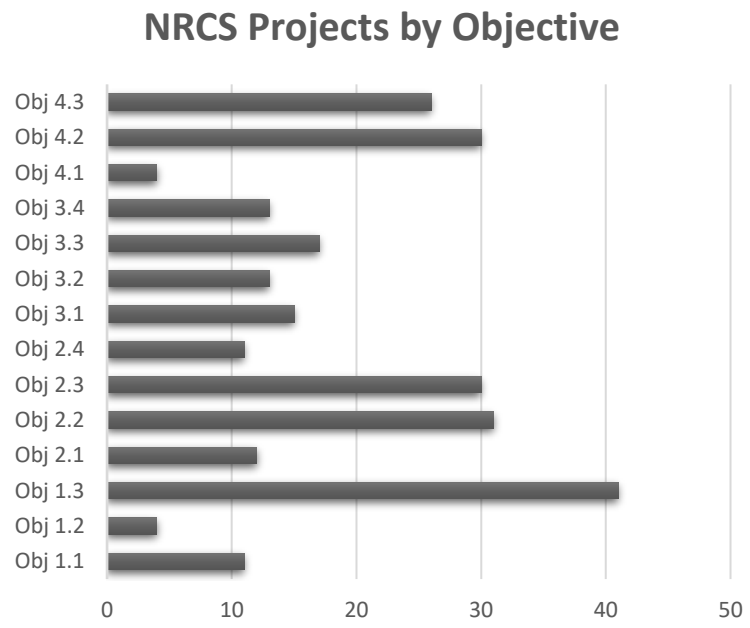
- **Ecological Restoration, Seed Sourcing and Climate Change (University of Wyoming)**: The main goal of this project is to increase seed availability and improve restoration outcomes on western rangelands. Field and greenhouse studies assessed intraspecific variation and seed germination characteristics of cultivar and wild sources of native grasses and sagebrush ecosystem plant species.

- **Native Plant Materials Development Program at the State Botanical Garden of Georgia (University of Georgia):** The goal of this project is to advance the native seed development process by identifying priority species, collecting germplasm of local ecotypes, developing supplies of high-quality seed, and sharing knowledge with growers concerning efficient propagation and production protocols for native plants.
- **Management and Utilization of Plant Genetic Resources (University of California [UC] Davis, Colorado State University, Washington State University):** This project addresses preservation of a diversity of plant genes through the collection, maintenance, evaluation, and enhancement of plant germplasm of economically important crops and their wild relatives. Researchers involved in this project collect information about germplasm distribution in the US and advise the National Plant Germplasm System (NPGS) regarding issues involving germplasm collection, preservation, and distribution.
- **Conservation, Management, Enhancement and Utilization of Plant Genetic Resources (Iowa State University):** This project supports the development, conservation, maintenance, and utilization of high-quality plant genetic resource collections and associated information. Research is conducted to improve germination protocols, optimal seed processing and seed storage technology, as well as detection and elimination of seed-borne pathogens. Its goal is to improve seed health and viability in storage conditions over extended periods of time.
- **Northeast Organic Seed Conference: Strengthening the Regional Organic Seed Sector (University of Vermont):** This project focuses on strengthening the organic seed sector in the U.S. Northeast, which is essential given that extensive activities related to organic seed production and distribution in the region are largely disconnected.
- **Does Source Climate or Genotype Better Predict Early Pine Seedling Performance in Restoration Projects (UC Merced and US Forest Service):** This study aims to test whether the number of genetic variants predicted to do well in the planting site predicts growth and survival of seedlings better than the difference in climate between the source and planting site. The results will help develop tools managers may use to select seed sources for restoration or tree breeding efforts.
- **Climate change and fuel wood harvesting impact on pinyon and juniper: Patterns of change and methods for re-establishment (Navajo Technical College):** Pinyon pines are a culturally and ecologically important species across much of the southwestern US, including the Navajo Nation. This project will collect and store seed from many sites to ensure the availability of seeds for future restoration as well as to develop techniques for germination, growth, and inoculation with beneficial soil microbes so that trees can be replaced where they have been lost.
- **Enhancing educational outcomes for plant genetic resources (PGR) conservation and use (Colorado State University):** This project will develop an organized series of learning resources (videos, e-book chapters, images, etc.) including three 1-credit graduate-level course modules on PGR conservation and use in plant breeding and genetics. The learning resources will also be used by ARS, private companies, and non-governmental organizations to improve the abilities of their employees to conserve and use PGR.

Natural Resource Conservation Service

Mission as it relates to native plants

The mission of the Natural Resource Conservation Service (NRCS) is to deliver conservation solutions so agricultural producers can protect natural resources and feed a growing world. NRCS provides America's farmers, ranchers, and private landowners with financial and technical assistance to voluntarily put natural resource conserving measures on the ground. The use of appropriate seed, in most cases native plants, is an integral part of conserving our nation's natural resources.



Implementing the National Seed Strategy

Plant Materials Used by NRCS:

NRCS provides technical assistance to private landowners to address resource concerns including soil erosion, soil health, reduced water quality, degraded plant conditions, and reduced wildlife and pollinator habitat. A suite of conservation practices is tailored to address every scenario. Each of these practices require genetically appropriate native seed, both native and introduced, to address the resource concerns. Practices that establish vegetation for wildlife and pollinators, vegetative buffers, and natural areas typically require native plants. More than 1.5 million acres are planted with native plants annually. NRCS conservation practices are available at https://www.nrcs.usda.gov/wps/portal/nrcs/main/national/technical/cp/

Plant Development Efforts at Plant Materials Centers**:**

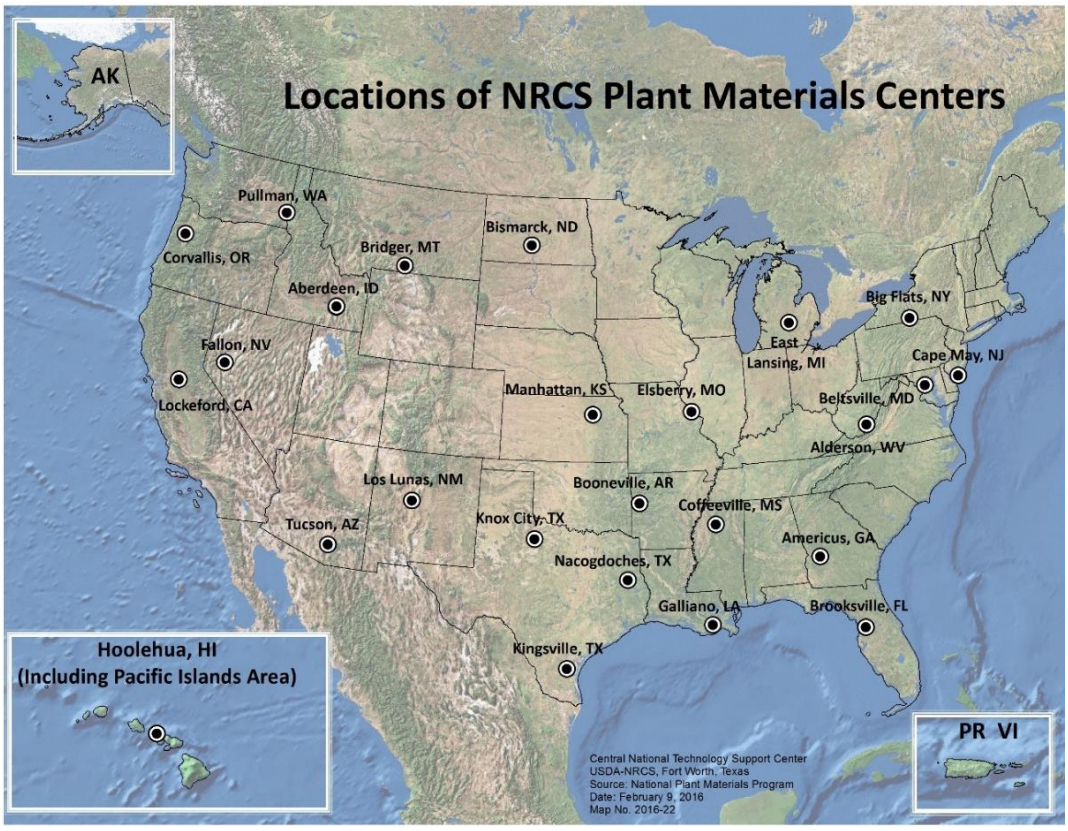
NRCS's 25 Plant Materials Centers (PMCs) are the agency's in-house program to develop vegetative solutions to critical natural resource concerns. Products from the PMC program include 1) new plant materials to support NRCS conservation practices and developed and released to the public for commercial production and to protect and conserve natural resources, and 2) technical information for the effective establishment, use, and maintenance of plants for a wide variety of natural resource conservation purposes. PMC program information is available at https://www.plant-materials.nrcs.usda.gov

PMCs have selected and released 751 conservation plants over the past 80 years, of which 578 are active and commercially available today. All PMC plant releases support NRCS conservation activities on private lands, and many benefit public land efforts. For the past 25 years, PMCs have focused primarily on native plant species released under pre-varietal germplasm guidelines. The 19 new plants released by PMCs since 2015 support the National Seed Strategy Objective 1.3, *Increase the supply and reliable availability of genetically appropriate seed*.

PMCs annually prepare and post to the program's website hundreds of documents with details on the use, selection, establishment, and management of plant materials for natural resource conservation.

These efforts support National Seed Strategy Objective 2.2, *Conduct species-specific research to provide seed technology, storage and seed production protocols for restoration species*, and Objective 2.3, *Conduct research on plant establishment, species interactions, and ecological restoration*.

Native plants are a critical component to the work NRCS does to improve the health and resilience of ecosystems and the sustainability of agriculture. The efforts of PMCs, often in cooperation with other agencies participating in the National Seed Strategy, ensures that NRCS, other federal agencies, and the public have access to appropriate commercially available plant materials for revegetation and restoration efforts.

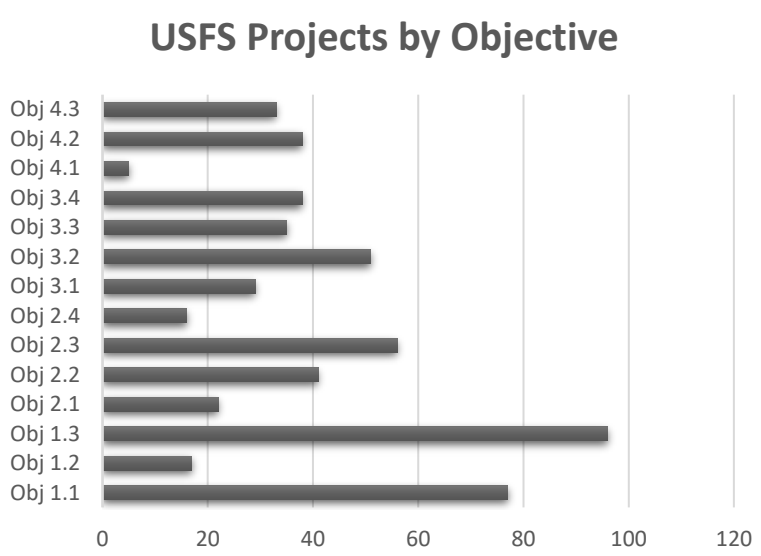


Top: NRCS has 25 Plant Materials Centers located across the U.S. Map credit: Central National Technology Support Center/NRCS. Left: Amethyst Germplasm hoary tansyaster (*Machaeranthera canescens*) was released in 2014 by the Aberdeen, ID, PMC for use in wildlife habitat and pollinator plantings in the Intermountain West. Image credit: Derek Tilley/NRCS

U.S. Forest Service

Mission as it relates to native plants

The USDA U.S. Forest Service (USFS) requires a steady supply of genetically appropriate native seed to implement the agency mission to sustain the health, diversity, and productivity of the nation's forests and grasslands to meet the needs of present and future generations. There are 154 National Forests in 41 states and Puerto Rico and 15 National Grasslands in 12 states covering over 192 million acres of land. The diverse array of species and plant communities occurring on these lands makes the task of supplying native seed a daunting one, especially when seed needs are increasingly driven by large unplanned disturbances such as wildfires, hurricanes, and floods. Often, after large-scale events, the USFS cannot meet its need for genetically appropriate seed, including the need for post-fire restoration in Oregon in 2020.



Implementing the National Seed Strategy

USFS works with partners on native seed projects to help ensure that sufficient quantities of the appropriate species and provenances are available. Expertise and capacity are often provided by USFS facilities and programs for seed research, conservation, germination, storage, and propagation, including six nurseries, two stand-alone seed extractories, and a national seed laboratory. USFS also includes State and Private Forestry and Research and Development organizations that further contribute to the development and effective use of native seed for “all lands” restoration activities.

USFS participates in projects that help meet all four goals of the National Seed Strategy. Eighty-nine of those projects are included in this first Plant Conservation Alliance report. Many of the projects are designed to meet more than one of the four strategy goals and cover a variety of uses and needs of the Forest Service multiple-use mandate. Project scale varied from local to regional to national. Examples of a few of these projects are highlighted below.

- Researchers at the Pacific Northwest Research Station developed the Seedlot Selection Tool (SST) to help managers match seedlots with planting sites based on climate information. The SST can map current or future climates based on selected climate change scenarios. It provides linkages to seed inventories and streamlined spatial analyses for determining if there are gaps or shortfalls in seed sources for a species or geographic area. The analyses help prioritize out-year seed collections and coordination efforts to ensure the availability and use of native seed that are adapted to current as well as future climates.
- Partners in the Intermountain Region led by the Rocky Mountain Research Station identified 80 species as a core list of native forbs and shrubs beneficial to pollinators while also providing a high likelihood of success for development under the Region’s native plant program. The species are suitable for enhancing and improving existing pollinator habitat pollinator habitat in

disturbed areas in need of revegetation. Common garden studies are underway on several of these species.

- In the Eastern Region, at the Midewin National Tallgrass Prairie, native seed is produced in long beds of a single species. Over the last five years, seed production beds have been replanted using techniques to maximize seed harvest and control invasive species. Species include violet wood sorrel (*Oxalis violacea*) and yellow star grass (*Hypoxis hirsuta*), neither of which are currently available from commercial sources.

Volunteers weeding and planting Prairie Sundrops (*Oenothera pilosella*) during the seed production bed renovation at the Midewin National Tallgrass Prairie in 2018. Image credit: Jennifer Durkin/USFS

- In the Pacific Northwest Region, the Olympic National Forest restored 520 acres of habitat for Taylor's checkerspot butterfly. Tasks included controlling small trees and shrubs using mechanical control methods, piling slash in thinned areas, preventing non-native plant invasion, and planting and seeding genetically local native plant species. Staff also monitored revegetation effectiveness.
- Partners in the Colorado Plateau region conducted genetic analysis of commercially available seed versus natural seed sources of blue grama (*Bouteloua gracilis*) to inform seed transfer and native plant materials development. Patterns of genetic diversity and adaptation are being investigated, along with ploidy levels across the species' range in the region to help ensure that genetically appropriate seed is available and used for restoration work with this important species in the Southwest.

Besides implementing the National Seed Strategy, these projects and many more are part of USFS effort to implement our 2012 Native Plant Materials: A Strategic Framework plan and our 2008 Native Plant Policy as we manage for integrity of our National Forests and Grasslands.

Plant Conservation Alliance Non-federal Cooperators Summary

"Most importantly, successful implementation of this Strategy will require the active participation of a diverse set of public and private partners. Increased coordination is vital to accelerate the pace and scale of restoration and provide native plant materials when and where they are needed."

– National Seed Strategy for Rehabilitation and Restoration

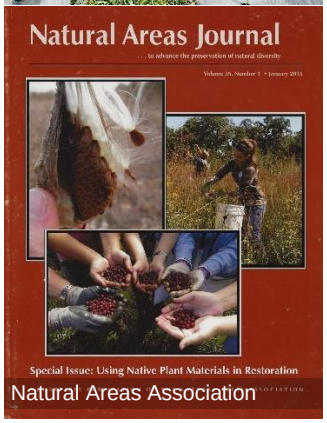
More than 300 National Seed Strategy implementation projects (roughly 70% of all projects submitted to this Progress Report) included at least one non-federal partner. About 360 non-federal partners were represented in these projects, including tribal agencies, state and municipal programs, private seed producers, nurseries, regional seed cooperatives, universities and community colleges, oil and gas companies, private landowners, botanic gardens, and other non-profit and non-governmental organizations.

EXAMPLES OF NON-FEDERAL IMPLEMENTATION PROJECTS

PROJECT	NON-FEDERAL PARTNER
Native seed and grassland restoration using a combination of best western science and Traditional Ecological Knowledge	Fort Belknap Indian Community
Restoration practitioner training course development	Society for Ecological Restoration (SER)
Publication of first international principles and standards for seed-based restoration (tinyurl.com/seedstandards)	SER's International Network for Seed-Based Restoration
Bulk production of genetically appropriate native seed for restoration and research	BFI Native Seed LLC
Research into the effectiveness of seed boxes and planting depth using seed drills	TRUAX Company, Inc.
Native seed collection by interns and contract collectors (Chicago Botanic Garden is the biggest provider of Seeds of Success collectors)	Chicago Botanic Garden
Technical planning support for using native seeds in conservation	The Xerces Society for Invertebrate Conservation
Meetings to support a native sustainable seed market and develop recommendations for policymakers	Tallgrass Prairie Center (University of Northern Iowa)
Native plant outreach and programming	Natural Areas Association


North Carolina Botanical Garden


Southwest Seed Partnership



Natural Areas Association

State, regional, and taxon-based Plant Conservation Alliances (PCAs) are a subset of the non-federal collaborators implementing the National Seed Strategy. With a broad spectrum of local partners from governmental and non-governmental agencies to scientists, educators, and volunteers, these collaborations have formed an alliance to leverage expertise and resources for the common goal of conserving native plants and their habitats at the state, regional, or taxonomic level. As of March 2021, 11 such PCAs have been established and another 6 PCAs are being formed. Using targeted conservation and habitat restoration, these alliances embody the PCA axiom, "Think Globally, Act Locally."

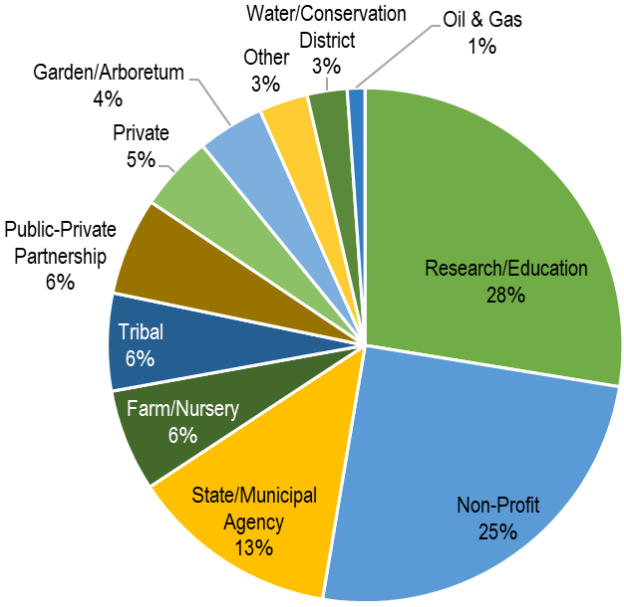
EXAMPLES OF STATE AND REGIONAL PCA IMPLEMENTATION OF THE NATIONAL SEED STRATEGY


Mullins/Institute for Applied Ecology

PCA	IMPLEMENTATION
Indiana Plant Conservation Alliance (INPCA)	The primary goal of the INPCA is to act as an educated resource and advocate for responsible restoration of native rare plants, and the use of natural habitat-specific seed choices during restoration.
Laukahi: Hawai'i Plant Conservation Network	Laukahi is engaged in establishing ex-situ conservation networks of rare native plants through building capacity, quantity, and quality of collections at native seed banks, nurseries, and botanical gardens as well as maintaining a network of researchers and database of publications on Hawaiian native plants.
Southeastern Plant Conservation Alliance (SE PCA)	Action items on the SE PCA strategic plan include securing southeastern rare plants in seed banks and other collections; implementing restoration projects; and supporting the National Seed Strategy.

Continued collaboration among federal and non-federal stakeholders is essential for successful implementation of the National Seed Strategy. Cross-sector involvement is demonstrated by the 2015-2020 projects reported here, emphasizing the importance of the National Seed Strategy to the health, prosperity, and resilience of America's people and lands. The combination of national coordination and local action is vital to informing place-based restoration efforts and success, ensuring we get the right seed in the right place at the right time.

IMPLEMENTATION TAKES ALL TYPES. The figure at right shows categories of non-federal partners as a percent of total number of non-federal partners named in the 2015-2020 National Seed Strategy Progress Report.



For more information on non-federal implementation of the National Seed Strategy:
PCA Non-Federal Cooperators Committee, PlantConservationAlliance.org

The Path Forward: Investing for the Future

As demonstrated by the case studies and summaries above, the Plant Conservation Alliance continues an unprecedented level of interagency collaboration and public-private partnerships to catalyze joint problem-solving for natural resource challenges. Success is being achieved through the establishment of nationwide networks of botanists, seed collectors, researchers to develop seed; farmers to grow native seed; nurseries and seed storage facilities to supply adequate quantities of appropriate seed; and restoration ecologists to study and implement restoration techniques. These collaborations are producing plants, tools, and techniques that sustain native ecosystems; assisting in recovery of threatened and endangered plant and animal species; improving wildlife habitat; promoting recovery from natural hazards and other disturbances; and sustaining multiple types of land use.

Plants are an integral part of our ecosystems and should also be an integral part of public land management.

However, implementation of the National Seed Strategy has only just begun. Producing native seed is a lengthy process that requires stable funding and ongoing collaboration from diverse stakeholders, including land managing, agricultural, and research partners. Genetically appropriate seed is not currently available for most restoration projects. Procurement tools, methods for predicting future seed needs, and research that fills critical knowledge gaps on selecting, growing, and deploying seed are still in development. Commercial availability and cost continue to hinder use of genetically appropriate plants, despite changes in policy to promote the use of genetically appropriate natives (NASEM 2020; Tangren & Toth 2020; Baughman et al. 2019; Peppin et al. 2010). However, as more native plants are made available, costs of native seed should decrease (Ott et al. 2019). Finally, federal agencies have a "severe shortage" of botanical capacity needed for planning and implementing restoration projects (Kramer & Havens 2015). The NASEM seed assessment will elucidate and provide suggestions for solving these issues and more (NASEM 2020). Additionally, the National Seed Strategy is a living document, and mechanisms for revising and improving the strategy are built into Goal 4, *Developing internal and external communications*; revision efforts for the National Seed Strategy are currently underway.

The task to sustain America's ecosystems is large and so is the vision of making plants a more integral part of public land management. As such, the National Seed Strategy is a cross-cutting effort that meets federal priorities. Executive Order 14008, *Tackling the Climate Crisis at Home and Abroad* (2021), outlined a call to action for national conservation and restoration efforts that the National Seed Strategy is supporting in numerous ways (Table 2). Through continued efforts and collaboration, we can develop a reliable supply of locally adapted, genetically appropriate native seed to combat the climate and extinction crisis and overcome the barriers to getting the right seed in the right place at the right time.

Carrizo Plain National Monument in California, during 2017 super bloom. Image credit: Bob Wick/BLM

Table 2: Executive Order 14008, *Tackling the Climate Crisis at Home and Abroad* (2021), identified many priorities related to conservation and ecosystem restoration. Because plants form the foundation of healthy, resilient ecosystems, the National Native Seed Strategy helps to meet conservation and climate-change-related objectives in many ways, from creating jobs in the restoration economy to developing tools for climate-smart restoration.

Areas of emphasis in EO 14008, *Tackling the Climate Crisis at Home and Abroad*	**How the National Seed Strategy helps to meet national priorities outlined in EO 14008**
Creating jobs	Seed collectors, seed researchers, farmers, seed analysts, seed certifiers, seed equipment manufacturers, restoration practitioners
Addressing national and economic security impacts of climate change	Seed banking for germplasm preservation, food security (crop wild relatives); wildfire and drought
Integrating climate considerations into international work	UN Decade on Ecosystem Restoration; International interest in National Seed Strategy: Australia, Brazil, Canada, China, European Native Seed Producers Association, France, Germany, Kuwait
Leveraging federal government's footprint and buying power to lead by example and support robust climate action	Consolidated seed buys, seed production contracts to increase availability of locally adapted native seeds
Increasing resilience to the impacts of climate change and improving climate forecast capabilities	Plant community restoration using climate-smart practices (e.g., USFS Climate-Smart Restoration Tool, USGS Climate Distance Mapper)
Building sustainable infrastructure	Native plant communities are the true green infrastructure
Conserving at least 30% of lands and waters by 2030	Federal land management agencies manage approximately 28% of US land mass; more than 2,000 rare plant species occur on federally managed lands
Creating a Civilian Climate Corps Initiative (new generation of Americans working to conserve public lands and waters)	Seed collectors, seed banking, seed researchers, cadre of restoration ecologists, rare plant monitoring
Conserving and restoring public lands, and increasing reforestation	10+ million acres impacted by National Seed Strategy projects, 2015-2020
Protecting and conserving biodiversity	Rare plant conservation; focus on diverse plant communities
Improving access to recreation and revitalizing recreation economies	Plant communities are the foundation of landscapes that draw visitors to natural places: "super bloom" in California, fall colors in woodlands across the U.S.
Delivering environmental justice	Engagement with historically marginalized rural, tribal, and agricultural communities
Making science-based decisions	Research supports benefits of using locally adapted native plants in restoration

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BUREAU OF LAND MANAGE


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Appendix 1: Publications Submitted to the Progress Report

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Appendix 2: Funding Contributors

The list below shows entities that were listed as having contributed funds to support projects submitted for this Progress Report. The list is a sample and used to show the diversity of partners who use native seed. The list is limited to federal projects that were submitted for the Progress Report. Inclusion in this list does not equal endorsement.

FEDERAL

Army Corps of Engineers
Bureau of Indian Affairs
Bureau of Land Management
Department of Defense Legacy Program
Department of Energy
Department of Interior
Department of the Interior Office of Wildland Fire
Joint Fire Science Program
National Aeronautic and Space Administration
National Park Foundation
National Park Service
National Science Foundation
Smithsonian Institution
U.S. Bureau of Reclamation
U.S. Department of Agriculture
U.S. Environmental Protection Agency
U.S. Fish and Wildlife Service
U.S. Geological Survey
USDA - Agricultural Resource Service
USDA - Farm Service Agency
USDA - National Institute of Food and Agriculture
USDA - Natural Resources Conservation Service
USDA - U.S. Forest Service

NON-FEDERAL

American Public Gardens Association
California Conservation Corps
California Deer Association
California Muledeer Foundation
California Native Plant Society
Canyon Country Discovery Center
Chicago Botanic Garden
Curtin University's Australian Research Council Centre for Mine Site Restoration
Desert Botanical Garden
Friends of Verde River
Grand Canyon Conservancy
Great Basin Institute
High Mountain Nursery
Honey Bee Health Coalition
Lomakatsi Restoration
Mattole Restoration Council
McDowell-Sonoran Conservancy
National Fish and Wildlife Foundation
Native Plant Society of New Mexico
NatureServe
New Mexico State University
Northern Arizona University
Private donors
Public volunteers
Rim to Rim Restoration
Rocky Mountain Elk Foundation
Selberg Institute
Texas Native Seed
The Arboretum at Flagstaff
The Nature Conservancy
Timber companies
Uncompahgre Partnership
University of Arizona
University of Nevada - Las Vegas
University of Nevada - Reno
University of Utah
University of Wyoming
Upper Colorado Environmental Plant Center
Wildlife Conservation Society
Wyoming Excellence Fund
Yale University

STATE & MUNICIPAL

California Department of Fish and Wildlife

California Off-Highway Vehicle grants

California State Office

El Dorado County Planning Department

El Dorado Irrigation District

Jackson Soil and Water Conservation District

Natural Resource Conservation Districts

Nevada Department of Wildlife

Oregon Department of Fish and Wildlife

Oregon Department of Forestry

Oregon Parks and Recreation Department

Oregon State Parks

Oregon Watershed Enhancement Board

Washington Department of Fish and Wildlife Service

Washington State Department of Transportation

Appendix 3: Organization Acronyms

AMS – Agricultural Market Service (USDA)

ARS – Agriculture Research Service (USDA)

BIA – Bureau of Indian Affairs (DOI)

BLM – Bureau of Land Management (DOI)

DoD – Department of Defense

DOI – Department of Interior

EPA - Environmental Protection Agency

FSA – Farm Service Administration (USDA)

NASEM – National Academies of Sciences, Engineering, and Medicine

NASA – National Aeronautics and Space Administration

NIFA – National Institute for Food and Agriculture (USDA)

NPS – National Park Service (DOI)

NRCS – National Resource Conservation Service (USDA)

SI – Smithsonian Institution

USFS – U.S. Forest Service (USDA)

USACE – U.S. Army Corp of Engineers

USBG – U.S. Botanic Garden

USDA – U.S. Department of Agriculture

USFWS – Fish and Wildlife Service (DOI)

USGS – U.S. Geological Survey (DOI)

Appendix 4: Glossary

This glossary describes terms referenced in the "National Seed Strategy Progress Report, 2015-2020." These terms are defined with the intent of providing clarity for their use in this Progress Report. These terms were taken from the National Seed Strategy for Rehabilitation and Restoration (PCA 2015).

adaptation (adapted): a change or the process of change in structure or habits by which a species or organism becomes better suited to its environment.

common garden study: an experiment where different genotypes, populations, or varieties are grown together in the same environment such that environmental effects on trait expression are minimized and genetic differences are more readily observed.

ecological genetics: the study of how ecologically relevant traits evolve in natural populations.

ecology: the study of relationships of organisms to one another and their environments.

ecological restoration: See restoration in glossary.

ecoregion: areas of general similarity in ecosystems and in the type, quality, and quantity of environmental resources. They are designed to serve as a spatial framework for the research, assessment, management, and monitoring of ecosystems and ecosystem components.

ecosystem: the biota (plants, animals, microorganisms) within a given area, the environment that sustains it, and their interactions.

ecosystem services: the benefits people and wildlife obtain from ecosystems. These include provisioning services such as food, water, timber, pollination, and fiber; regulating services such as the regulation of climate, floods, disease, wastes, and water quality; cultural services such as recreation, aesthetic enjoyment, identity, and spiritual fulfillment; and supporting services such as soil formation, photosynthesis, and nutrient cycling.

empirical seed zone: empirical seed zones are developed for individual species across their distribution through the following steps: (1) Researchers collect seed from diverse geographic and climatic areas of the targeted region; (2) Researchers evaluate plantings from collected seeds in common gardens for production, morphology, phenology, and physiological traits; (3) Researchers develop regression models that link genetic variation across the landscape with collection location environments to delineate seed zones for the collected species. (See also provisional seed zone in glossary.)

establishment (establish): the stage at which the seedling has exhausted the food reserves stored in the seed and must grow, develop, and persist independently.

ex situ conservation: the technique of conserving all levels of biological diversity outside their natural habitats through such means as botanical gardens, zoos, or seed banks. gene flow: the transfer of alleles or genes from one population to another.

genetically appropriate native seed: native plant materials environmentally adapted to a restoration site that are likely to establish, persist, and promote community and ecological relationships. Such plants would be: sufficiently genetically diverse to respond and adapt to changing climates and environmental conditions; unlikely to cause genetic contamination and undermine local adaptations, community interactions, and function of resident native species within the

ecosystem; not likely to become invasive and displace other native species; not likely to be a source of nonnative invasive pathogens; and likely to maintain critical connections with pollinators.

genotype: the genetic makeup of a cell, an organism, or an individual. The genetic code of an organism. germination: events beginning with water uptake by a seed and ending with the beginning of elongation of the embryonic axis through the surrounding structures.

germination: events beginning with water uptake by a seed and ending with the beginning of elongation of the embryonic axis through the surrounding structures.

habitat: the dwelling place of an organism or community that provides the requisite conditions for its life processes.

invasive species: a species that is nonnative to the ecosystem under consideration and whose introduction causes or is likely to cause economic or environmental harm or harm to human, animal, or plant health.

locally adapted plants: plants from an area geographically near a planting site that are environmentally adapted and likely to establish and persist.

maladaptation: a species that has traits that are poorly suited or adapted to a particular situation or set of conditions.

native plants: indigenous terrestrial and aquatic species that have evolved and occur naturally in a particular region, ecosystem, or habitat. Species native to North America are generally recognized as those occurring on the continent prior to European settlement. Native plant species represent a number of different life forms, including conifer trees, hardwood trees and shrubs, grasses, forbs, and others.

native plant communities: recurring assemblages of native plant species associated with local substrates and natural dynamic processes. Their composition varies in space and time in response to changes in climate and species dispersal.

nonnative species: an organism is considered nonnative (alien, foreign, nonindigenous, exotic) when it has been introduced by humans to a location(s) outside its native or natural range. This designation applies to a species introduced from another continent, another ecosystem, another seed zone, and even another habitat within an ecosystem. With respect to a particular ecosystem, this includes any species, including its seeds, eggs, spores, or other biological material, capable of propagating that species, that is not native to that ecosystem. This definition of nonnative will vary depending on the scope and context of projects.

protocol: a standardized method containing detailed steps.

provenance-specific: geographic-based seed source; synonym to “genetically appropriate.”

provisional seed zone: provisional seed zones are based on climate data and used for species for which empirical seed zones have not been developed. Provisional seed zones in combination with established ecoregions can be used to guide movement of plant materials for restoration. (See also empirical seed zone in glossary.)

reciprocal transplant studies: studies using plants from multiple populations of a species that are planted in a set of sites that represent local and nonlocal climates to test questions of adaptation of the populations to their local environments. Such studies are useful for evaluating the effectiveness of seed transfer guidelines and seed zones. When sites represent extreme environments, these studies

have been used effectively to predict how plants will respond to future climate change as climates shift toward new extremes.

reclamation: actions to stabilize the terrain, assure public safety, improve aesthetics, remove contaminants, and usually to return the land to what, within the regional context, is considered to be a useful purpose. Reclamation projects that are more ecologically based can qualify as rehabilitation or even restoration.

rehabilitation: rehabilitation emphasizes the reparation of ecosystem processes, productivity, and services, whereas the goals of restoration also include the reestablishment of the preexisting biotic integrity in terms of species composition and community structure.

resilience: the capacity of an ecosystem to regain structural and functional attributes after it has suffered harm from stress or disturbance.

restoration: the process of assisting the recovery of an ecosystem that has been degraded, damaged, or destroyed.

seed reserve: a national network of storage facilities for seed that can be used by land managers for restoration projects. Seed reserves will include seeds of pollinator-friendly plants.

seed transfer guidelines: recommendations for protecting the integrity of the natural pattern of adaptive variation of wild populations by restricting seed transfer to areas within which seed can be moved about freely with the expectation that they will grow and reproduce successfully and will produce no adverse genetic effects.

seed zone: a mapped area with fixed boundaries in which seeds or plant materials can be transferred with minimal risk of maladaptation.

stabilization: to determine the need for and to prescribe and implement emergency treatments to minimize threats to life or property or to stabilize and prevent unacceptable degradation to natural and cultural resources resulting from the effects of disturbances.

stakeholder: individuals, organizations, and intergovernmental partners who are involved in or contribute valuable knowledge to and support for implementing the actions outlined in this Strategy, or who may be directly or indirectly impacted by the actions of the Strategy. Those who have an interest in the Strategy's outcome.

treatment: an action or actions taken to ameliorate or repair ecosystem damage. These activities vary with objectives but occur along the repair continuum, which includes restoration, rehabilitation, and reclamation.

workhorse species: species that are locally adapted native plants that are abundant across a wide range of ecological settings, establish quickly, and produce high ground cover on disturbed sites.

Captions for full-page photo spreads (photos clockwise from top left)

Front cover: Handful of native prairie seed, Northwest Minnesota Native Prairie Seed Consortium, Darren Wheeling/USFWS; Indian ricegrass (*Achnatherum hymenoides*) production at NRCS Great Basin Plant Materials Center, NRCS; member of Shoshone-Paiute tribe planting sagebrush seedling in Idaho, BLM; seed storage in BLM National Seed Warehouse, BLM; endangered Kearney's blue-star (*Amsonia kearneyana*) seedlings at Desert Botanical Garden, Natalie Melkonoff/BLM; seed collection from soaptree yucca (*Yucca elata*) in Chihuahuan Desert, Laura Shriver/BLM

Page ii: Demonstration meadow with black-eyed susan (*Rudbeckia hirta*) and narrowleaf mountain mint (*Pycnanthemum tenuifolium*) in full bloom, Janine Pollack/NASA Goddard Space Flight Center; Conservation Corps of New Mexico intern carrying box of native seed collected for Seeds of Success, Ella Samuel/BLM; volunteers planting showy milkweed (*Asclepias speciosa*) in native plant demonstration garden, Maria Mullins/Institute for Applied Ecology (with permission)

Page 4: Monarch butterfly larva on woollypod milkweed (*Asclepias eriocarpa*) planted from seed, Valerie Bullard/NRCS; empty playa near restoration research sites in Lordsburg, NM, Melanie Gisler/Institute for Applied Ecology (with permission); Great Valley Phacelia (*Phacelia ciliata*) population for wildland seed collection in California, BLM CA930D/Seeds of Success

Page 59: BLM project crew lead, Chris Otahal, during restoration of Afton Canyon Area of Critical Environmental Concern, Kyle Sullivan/BLM; endangered Gentner's fritillary (*Fritillaria gentneri*) growing at J Herbert Stone USFS Nursery in Central Point, OR, Bryan Wender/BLM; demonstration meadow with educational signage in front of building 33 at NASA Goddard Space Flight Center, Sara Tangren/University of Maryland Extension Service (with permission)

Back cover: Forest Bound Youth Outdoor Education Program participants making seed balls, Southwest Seed Partnership/USFS; Pineywoods germplasm thickspike gayfeather *(Liatris pycnostachya*) seed increase field at NRCS East Texas Plant Materials Center, Alan Shadow/NRCS; monarch caterpillar on swamp milkweed (*Asclepias incarnata*) in demonstration meadow, Janine Pollack/NASA Goddard Space Flight Center; Rocky Mountain bee plant (*Cleome serrulata*) population for wildland seed collection in Utah, BLM UT080/Seeds of Success; boxes of Wyoming big sagebrush (*Artemisia tridentata* Nutt. ssp. *wyomingensis*) wildland-collected seed, BLM OR134/Seeds of Success