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"America's Natural Solutions:
The Climate Benefits of Investing in Healthy Ecosystems"

Questions for the Record

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The Honorable Kathy Castor

1. **In your testimony you referred to "ecocultural" restoration. Can you define what this means and say a little more about the impact you are seeing on how your ecological restoration work is also generating cultural and climate resilience for the Fort Belknap community? How can Congress ensure ecocultural restoration is integrated in Federal decision-making?**

Definition of Ecocultural Restoration:

Ecological restoration is the process of assisting the recovery of an ecosystem that has been degraded, damaged, or destroyed.[1] *Ecocultural restoration* acknowledges and honors Indigenous peoples' contributions and traditional wisdom. Defined as the process of restoring key historic pre-contact, pre-industrial ecosystem structures, processes, and functions, and the Indigenous cultural practices that helped shape ecosystems, ecocultural restoration (also referred to as biocultural restoration) increases resiliency to climate change and other stressors, while supporting Indigenous ecosystems and their cultures.[2]

Ecocultural restoration is based on Traditional Ecological Knowledge (TEK; also known as Indigenous Traditional Knowledge—ITEK), defined as knowledge and practices passed from generation to generation informed by cultural memories, sensitivity to change, and values that include reciprocity. TEK land-care practices include using prescribed fire and seasonal flooding to modify vegetation, conserving culturally significant species such as beaver (*Castor canadensis*) and bison (*Bison bison bison*), or adjusting timber use to create more sustainable communities of traditional plants that provide wildlife habitat, and in turn, food for humans. These processes increase biodiversity and ecological resilience by creating fine-grained, landscape mosaics that function within an ecosystem's range of natural variability. Further, TEK acknowledges that change is constant in an ecosystem. Because Indigenous people see the world as always changing, their TEK is designed to observe and acknowledge these changes, and act

[1] Gann, et al. 2019.
[2] Kimmerer 2011; Zedler, and Stevens 2018; Martinez 2019; Dickson-Hoyle, et al. 2021.

on them rapidly by adjusting Indigenous land stewardship and subsistence practices. In this manner, TEK can optimize climate resiliency, as a form of adaptive management that has been use for millennia globally.[3]

Ecocultural Restoration and Cultural and Climate Resilience:

Established in 1888, the Fort Belknap Indian Reservation (FBIR) is homeland of the *Nakoda* (Assiniboine) and *Aaniiihnen* (Gros Ventre) Tribes. It lies in north-central Montana, north of the Missouri River, on the Northern Great Plains, comprising 263,000 ha. FBIR lands are primarily used for grazing, agriculture, ceremonies, hunting, gathering traditional plants for food and medicine, recreation, natural resource extraction, and conservation. Adjacent Bureau of Land Management (BLM) lands are used for grazing, natural resource extraction, hunting, recreation, and conservation.

On the FBIR, the ecocultural restoration work we are doing will help generate cultural and climate resilience for Fort Belknap Indian Community (FBIC) and BLM. Specifically, in partnership with BLM, Oregon State University (OSU), and Society for Ecological Restoration (SER), we are developing an ecocultural restoration plan based on FBIC TEK, with the guidance and participation of the Tribal Council, the Tribal Historical Preservation Office, Tribal elders, youth, natural resources staff, and educators, applicable to multiple-use FBIR and BLM lands in this region. Because the plan will be built on Indigenous stewardship practices in this grassland used for millennia (e.g., prescribed burning, conserving culturally significant plants that also function as soil-stabilizing plants and carbon sinks) that have always included adaptation to changes in the climate, it will build climate resilience and increase what today we refer to as the *ecosystem services* on which humans rely for survival, such as fertile soil, plants, pollination, and clean water.[4]

Additionally, because we are engaging the FBIC with jobs and training for youth, including creating a Tribal youth conservation corps that provides income and natural resource training, and because the youth involved in this program will be the lead authors of the ecocultural restoration plan we are developing, this work is also very directly building capacity within FBIC. By engaging Tribal youth, we are creating a STEM pathway for them in higher education at institutions such as OSU, helping them develop into future leaders in natural resource management and conservation. Collectively this is generating cultural resiliency—by empowering youth to use their culturally traditional relationships with the natural world to find nature-based climate solutions that are also firmly grounded in Western science. This strategy is called Two-Eyed Seeing. By combining the empirical strengths and logic of Western science and the insights and wisdom of TEK, one gains binocular vision that enables people to find solutions to challenging natural resource problems, such as global warming. The ecocultural restoration plan we are co-creating will be based on cultural competency (e.g., understanding the FBIC culture), and will go beyond that to cultural humility (e.g., self-assessment and accountability, openness, and equitable relationships with all involved).[5]

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[3] Kimmerer 2000; Roos, et al. 2018; Eisenberg, et al. 2019 ; Reyes-Garcia et al. 2019.

[4] Food and Agriculture Organization (FAO) of the United Nations. 2021.

[5] Bartlett, et al. 2012.

How Congress Can Ensure Integration of Ecocultural Restoration into Federal Decision-Making:

According to the White House Office of Science and Technology Policy, TEK could and should improve understanding of climate change and environmental sustainability. TEK also could help in the development of comprehensive climate adaptation and natural resources management strategies, aimed at achieving mutually beneficial outcomes for Tribal Nations and US Federal agencies.[6] However, the US Federal government tends to implement top-down strategies using one-size-fits-all approaches. Such approaches will not be effective in incorporating ecocultural restoration into Federal decision-making. This is because ecocultural restoration, which is informed by TEK, is strongly place-based, and comes from Indigenous cultures, with each Tribal Nation having a unique culture.[7]

Co-management is a partnership whereby the government shares power with resource users, with clearly specified rights and responsibilities for each actor relating to management and decision-making. In the US, Federal co-management efforts that incorporate ecocultural restoration via TEK and uphold treaty rights are one of the foundational principles in addressing initiatives such as Presidential Executive Order 14008 on Climate Change.

With Tribal Nations, co-management typically includes a Memorandum of Understanding (MOU). Such partnerships convey economic benefits to Tribes and government agencies, with mutual respect and reciprocity, and can function as stepping-stones to self-determination. However, in practice, co-management can be an imperfect alliance, because its roots lie in settler colonialism. Successful co-management acknowledges and supports self-determination and natural resources treaty rights, with clear understanding of what TEK means to the specific Tribal Nation involved in the partnership.

Ecocultural restoration has huge potential for co-management of public lands. In order for it to succeed in its application, it must be place-based and part of a partnership based on inclusive, equitable, and respectful interactions. It must include relationship building that leads to government-to-government policy actions that honor Tribal sovereignty and self-determination rights, via formal agreements (e.g., MOUs).[8]

Congress can ensure that ecocultural restoration is incorporated into Federal decision-making by implementing policies and providing secure, dedicated funding to enable development of the trust-based relationships described above. In doing so, it is important to consider that it takes time to build relationships between Tribal Nations and Federal agencies that lead to collaboration to partner in natural resource ecocultural restoration. Building this trust means beginning to overcome 175 years of genocide, breaches of treaties, and exploitation of Tribal Nations. Note that the Indian Self-Determination and Education Assistance Act of 1975, 25 U.S.C. §§ 450 et seq. and the 1994 Tribal Self-Governance Act, 25 U.S.C. § 458aa et seq. passed fairly recently. These acts acknowledged and reinstated Indigenous peoples' sovereignty rights and empowered them to manage their lands. Nevertheless, securing such rights in practice

[6] White House Council on Environmental Quality (CEQ); 2021a. White House Council on Environmental Quality (CEQ). 2021b.
[7] Reyes-Garcia 2019.
[8] Usher 200; Houde 2007; Nadasdy 2007; Nie 2008; Kenney 2012; Casson 2015; Reid et al. 2018; Grey and Kuokkanen 2019.

continues to challenge many Tribal Nations, particularly regarding natural resource and subsistence treaty rights.[9]

2. **In your testimony, you noted the differences you saw in the condition of the grasslands on Tribal lands as compared to the BLM lands. Please describe what these differences indicate, and why healthy grasslands are so important.**

Differences between FBIC Tribal lands and BLM lands:

Global warming is leading to increasingly frequent severe and extensive drought and wildfires. Warmer temperatures, below-average winter precipitation, earlier snowmelt, and drier summers are creating longer wildfire seasons. Ecosystems managed for agriculture often lack the resiliency to recover from these disturbances and other environmental stressors (e.g., insect outbreaks), because such management involves plowing the soil, planting non-native agronomic species for harvest, and eliminating or disrupting processes with which these ecosystems co-evolved, such as intermittent intensive grazing by herds of bison, low-severity fires set by Indigenous people, and mixed-severity wildfires.[10]

We are working to address the above issues in our grassland restoration project, which began in 2019 in the Northern Great Plains Biome of Montana, on BLM and FBIR lands. I am the Lead Principal Investigator (PI) of this project, and Dr. Thomas H. DeLuca is the co-PI. In addition to the FBIC and BLM, project partners consist of OSU and SER. Our grassland restoration project goals are to:

a) Help the BLM Plant Conservation and Restoration Program (PCRP) ensure a stable commercial supply of native plant materials for restoration and rehabilitation efforts on public lands
b) Help BLM inventory and quantitatively assess the condition and trend of natural resources on the nation's public lands

We are meeting these goals by surveying US Federal and adjacent Tribal lands using Assessment, Inventorying and Monitoring (AIM) protocols, and then applying BLM Seeds of Success (SOS) protocols to collect the seeds of target species for conservation. Target species include those known to stabilize soils after a severe fire or other disturbance, such as Junegrass (*Koelaria macrantha*), which can rapidly resprout and help prevent erosion. Seeds go to the National Seed Repository to eventually be used for ecological restoration of public lands that have been degraded by catastrophic fire, drought, or intensive conventional agriculture.[11] An additional goal is to co-create an ecocultural restoration plan with the FBIC, based on TEK (described in the response to Q1), to increase resiliency to drought and other environmental stressors.

During the summer of 2021, much of the Western US experienced an extreme drought. Per National Oceanic and Atmospheric Administration (NOAA) and State of Montana data, our study site on the FBIR and surrounding BLM lands was in D3 (Extreme) and D4 (Exceptional) drought. In D3 conditions, crops are not harvestable, winter pasture is opened for grazing, the soil has large cracks in it, and the fields are bare. Cattle have very little water and producers must

[9] US Congress. 1975. Indian Education and Self-Determination Act of 1975; Deloria, and Lytle 1983; US Congress. 1994. Tribal Self Governance Act of 1994; Wilkins, and Lomawaima 2001; Treuer 2012; Treuer 2019.
[10] Bond, et al. 2004; Fuhlendorf, et al. 2008; Allred, et al. 2011 ; Grimm, et al. 2013; Polley, et al. 2013; Lark, et al. 2020; Hessburg, et al. 2021.
[11] BLM 2021a; BLM 2021b.

import water and supplemental feed. Fire restrictions increase. In D4 conditions, pasture loss is widespread, crops are destroyed, fire risk is extremely high, and fires are widespread.[12] Given that most of our study site (both FBIC and BLM land) is used primarily for some form of agriculture, and that for residents of north-central Montana, agriculture is a leading occupation and income source, D3 and D4 drought can have devastating economic impacts on human communities in this region.

In June-August, 2021, when we surveyed FBIR and BLM lands, which consist of mixed-grass prairie communities, I received one of the most powerful lessons of my career as an ecologist. In keeping with expected D3-D4 drought conditions, our field crew and I found that in late spring on BLM lands, which were dominated by exotic (e.g., non-native/invasive) grass species (primarily crested wheatgrass, *Agropyron cristatum*), with some native grasses (Sandberg bluegrass, *Poa secunda,* and Western wheatgrass, *Pascopyrum smithii*), these grasses grew approximately six inches tall. On adjacent FBIC land that had the same drought conditions, climate, elevation, geomorphology, and other ecological characteristics, but contained mostly native plant species (primarily Western wheatgrass, Sandberg bluegrass, and green needlegrass, *Nassella viridula*), the same grasses grew up to four feet tall. On BLM land, in the few places where native plants, such as bluegrass, had bloomed, their seed pods were hollow, lacking a cotyledon, because the plant had suppressed growth to survive. This stark difference in plant drought resiliency was unattributable to cattle; both Tribal and BLM lands are multiple-use lands, subject to cattle grazing, which we documented with trail cameras. Further, because of the drought response described above, on FBIR land we were able to collect 23 pounds of seeds of target species for conservation. On neighboring BLM land we were only able to collect 3 ounces (0.19 pounds or 0.8%) of seeds of target species, despite scoping those Federal lands really thoroughly for several weeks, working in Blaine and Phillips Counties.

Dr. DeLuca, an eminent soil scientist, and I hypothesize that this difference between FBIR and BLM land is at least partly related to differences in soil ecology between the two systems. Charcoal (also known as pyrogenic carbon, PyC) legacies in the soil created by the low-severity fires historically set by Indigenous people were deposited in mineral soils on a frequent and in some cases annual basis. The recalcitrant nature of PyC results in its accumulation over time, thereby increasing the scale and function of the soil carbon pool, resulting in increased nutrient availability and drought resiliency.[13]

Indigenous burning is a key TEK land stewardship practice used globally to improve soil health.[14] In what is today the US, Indigenous use of fire to improve habitat for wildlife and productivity of culturally significant species of plants harvested as part of the hunter-gatherer lifeway has been widely documented. On the Northern Great Plains, Indigenous people used fire to manage plant communities to improve availability of culturally significant plants used for medicine and subsistence, such as Indian turnip (*Pediomelum esculentum*), and improve bison habitat. These prescribed fires were typically of low severity.[15]

In the 1800s, when Tribal lands were stolen and settled by Euro-Americans throughout the US, fires were suppressed. As part of colonization, the Indian Appropriations Act of 1871 placed Native Americans on Indian Reservations and ended Tribal sovereignty rights.[16] Yet,

[12] NOAA, NRCS, State of Montana 2022.
[13] DeLuca et al., 2020.
[14] Bond, et al. 2005 ; Kimmerer, and Lake 2001.
[15] Boyd 2022; Lake, et al. 2017; Roos, et al. 2018.
[16] Indian Appropriations Act of Mar. 3, 1871.

despite strong encouragement to assimilate into Euro-American culture, Native American people did not completely cease their cultural traditions regarding grassland, forest, and wildlife stewardship. On reservation lands, in keeping with TEK, Native Americans continued to set some prescribed fires, even though they were discouraged from doing so by the US Federal government. On non-Tribal lands, fire exclusion post-Euro-American colonization changed soil biogeochemical properties significantly, in ways that created plant communities far less resilient to drought and other environmental stressors.

Pyrogenic carbon (PyC) is a fire legacy formed through the thermal decomposition of organic matter during fires. PyC can increase nutrient cycling in soils and the carbon budget in an ecosystem. PyC is highly stable and can be preserved in mineral soils for decades to centuries. Recent studies have shown that the presence and content of soil PyC explains a significant amount of variation in soil function (e.g., water infiltration, carbon microbial cycling, nutrient availability and dynamics).[17]

The quantity and quality of PyC in soils is related to fire severity and frequency. Low- and mid-severity fire improves soil properties and processes, by stimulating nutrient release and depositing PyC in the topsoil (O and A soil layers, called "horizons"). Low- to mid-severity fire will retain much of the soil seedbank and nutrient capital, simply losing some of the topsoil to volatilization. After such events, microbial activity rebounds quickly and nutrient availability actually increases. In contrast, the sort of high-severity wildfires we have been experiencing globally, linked to climate change, result in complete combustion of the topsoil, loss of key species from the seedbank, mortality of shallow plant roots, reduced resprouting of herbs, and loss of carbon and nitrogen from surface mineral soil.[18]

Soils on the FBIR and adjacent BLM lands are predominantly moderately fertile, high-clay soils derived from glacial till.[19] Surface soils are susceptible to wind erosion and loss of soil organic matter under conditions of limited vegetative cover. Frequent fire and deposition of degradation-resistant PyC created a more fertile and higher tilth soil condition, which is more resilient to drought. On BLM lands, exclusion of fire and decades of heavy grazing pressure by cattle likely led to slow, consistent loss of soil carbon due to mineralization and erosion losses, with only modest returns of fresh organic matter from the resident plant community. Differences in plant community composition also influence ecosystem carbon stocks, with exotic plant species often resulting in a net decline in soil carbon.[20]

Understanding how different management practices and fire history influence soil PyC stock, dynamics, and soil biogeochemical properties at various spatial scales will be of great importance in designing nature-based solutions and strategies to improve the resilience of all grasslands. To be effective, such solutions must incorporate TEK, including ethnobotany.[21] While soil characterization (e.g., measuring the depth of the various soil horizons) is part of AIM protocols, in 2022 and beyond, we will be taking a more detailed look at soils. It is possible that the difference we observed between BLM and FBIR lands may be related to the legacy of PyC on FBIR lands, a legacy that as part of TEK cultural burning practices on this grassland created the landscapes and plant communities more resilient to climate change we observed in summer

[17] Bird 2015; Bowring, et al. 2022.

[18] DeLuca, et al. 2020; Gao, and DeLuca 2018; Gao, and DeLuca 2020; Michelotti, and Miesel 2015; Adkins, and Miesel 2021; Landry, and Matthews 2017; Hart, et al. 1994; Merino, et al. 2019.

[19] Hilts 1986.

[20] Lesica, and DeLuca 1996; Zouhar 2021.

[21] Lake 2021; Gann, et al. 2019; Turner 2015.

of 2021. Nevertheless, relationships in the natural world are far from simple, which Indigenous people have acknowledged since time immemorial as part of their TEK. We also expect that a variety of site-specific environmental factors will have bearing on the drought resilience of FBIR and BLM lands.[22]

Many factors have degraded grasslands and continue to threaten them, including increasing agricultural development and drought. Restoring grasslands for the ecosystem services they provide is a global priority. Maintaining ecologically resilient, productive grassland and forest ecosystems that can reliably and sustainably supply the ecosystem services on which humans rely for survival will help us address the climate crisis and create a more sustainable future for humanity.[23]

Why Healthy Grasslands Are so Important:

Grasslands are critically important to humanity as we respond to the climate crisis because they are one of the most stable and reliable terrestrial carbon sinks, providing 12% of terrestrial carbon stocks globally. During photosynthesis, plants draw carbon dioxide from the atmosphere and store it in their leaves, stems, and roots. Unlike forests, grasslands store the majority of their carbon (~81%) belowground, in their roots and soil. In fact, the roots of prairie grasses such as Western wheatgrass often extend belowground as far as twelve feet. Because most of a grassland's carbon is stored in the soil, when a grassland burns, it does not release much carbon into the atmosphere, the way a forest does when it burns. Additionally, prairie grasses typically grow as "bunchgrasses," sprouting from near-surface root crowns or rhizome mats. These grasses are highly adapted to fire, because they co-evolved with regular Indigenous cultural burning. When burned lightly, they can resprout within 48 hours, and grow back with increased vigor.

Overgrazing combined with introduction of exotic species reduces soil organic matter storage. Our data suggest that BLM lands have a far higher proportion of exotic species such as crested wheatgrass and cheatgrass (*Bromus tectorum*) than Tribal lands. Part of this is an artifact of the Homestead Era, during which semi-arid lands in the Northern Great Plains were settled and developed for agriculture. Attempts to stabilize soils in the 1920s involved planting exotic grass species. Many of these lands have not recovered from the ecological degradation caused by over a decade of drought that culminated in the 1930s Dust Bowl. Even with reintroduction of prescribed low-severity fire that replicates Indigenous traditional burning, on BLM lands these exotic species will influence fire behavior and post-fire responses. In grassland ecosystems comprised primarily of native grass species, with a small proportion of exotic species, prescribed burning and mixed-severity wildfire do not cause a sharp increase (known as an *irruption*) in exotics. However, as the proportion of exotics increases in a prairie, some, such as cheatgrass, will irrupt in response to fire, out-competing native grass species.[24]

All of this means that as the climate continues to warm and wildfires continue to increase in frequency, size, and severity, grasslands provide a highly stable and important carbon sink that is more resilient than forests as a source of carbon. In general, native grass species, which are perennial, long-lived plants, are the most effective at sequestering carbon. This is because many of the exotic agronomic species, which come from Europe or the Middle East, do not grow roots

[22] Roos, et al. 2018.

[23] Havstad, et al. 2007; Bedunah, et al. 2012 ; Augustine, et al. 2021.

[24] Briggs, et al. 1995; Strassburg, et al. 2000; Libecap, and Hansen. 2002; Ontl, and Janowiak 2017; Dass, et al. 2018; Eisenberg, et al. 2019 ; Lark, et al. 2020; Nagy, et al. 2021.

as deeply into the soil as North America's native grasses. Since Montana's Northern Great Plains provide a unique combination of grasses and forbs of high conservation value, establishing and maintaining a native seed conservation program here that incorporates TEK and ecocultural restoration is crucial to meeting US Federal plant conservation and climate resiliency objectives.[25]

3. **Can you describe the importance of a stable, economical supply of native plants and seeds? What programs are needed to ensure this supply is available to local communities and local landscapes?**

Importance of Supply of Native Plants and Seeds:

As wildfires and other climate-driven disasters continue to devastate the US, ecological restoration has become a national and global priority. Having a stable, economical supply of native plants and seeds is critical to restore ecosystems in the aftermath of these crises. Currently the availability of native seed of a sufficient range of species and of appropriate genetic provenance for ecological restoration does not match the need locally, regionally, or nationally. Federal agencies, such as the BLM, US Forest Service (USFS), US Fish and Wildlife Service (USFWS), National Park Service (NPS), Tribal nations, and the US Department of Defense (DoD) are the largest purchasers of native plant seeds in the US.[26] The use of genetically-appropriate native plants (rather than non-native species or native species from a different locality) in restoration is required or encouraged in policy documents by some agencies, like the NPS and USFS. BLM policy strongly encourages the use of native plants used for restoration on federal land, and BLM alone buys hundreds of thousands of pounds of seed annually in response to wildfires.

Although BLM and other agencies have large stores of native seeds, and are actively working to increase their supply, large disasters create a reactive demand on what is already a limited supply, driving up the cost of native seeds, and in some cases, leading to the use of non-native species in plantings and seed mixes. State and local authorities are also users of native seeds, frequently sourcing them for roadside revegetation, invasive species control, landscape beautification, soil and water conservation, and pollinator and wildlife habitat restoration. However, these proactive state and local restoration efforts contend with the same supply chain limitations as the Federal agencies that dominate the market. This lack of appropriate native plant material generally strongly constrains ecological restoration. To that end, there exist several programs which, with additional support, are well positioned to address this increasing need, as well as opportunities to create new programs.

Existing Programs and Needs:

The **BLM Plant Conservation and Restoration Program (PCRP)** is working to ensure that land managers across our nation can buy the native seed that will work to restore native plant communities that provide wildlife habitat, ecosystem services, and recreational opportunities for all Americans to enjoy. Seed collection is the first step in native plant materials development.[27] Seeds of Success (SOS; https://www.blm.gov/programs/natural-resources/native-

[25] Lavin, and Seibert 2011. Oldfield, et al. 2019.
[26] National Academies of Sciences, Engineering, and Medicine 2020.
[27] Oldfield 2019.

plant-communities/native-plant-and-seed-material-development/collection) is the national native seed collection program housed under the BLM's PCRP. The mission of SOS is to collect wildland native seed for research, development, germplasm conservation, and ecosystem restoration. Established in 2002, SOS has made over 26,000 seed collections of over 5,800 unique taxa, from 43 states. Additional SOS accomplishments include:

- Over 2,500 seed collectors trained in over 140 collecting teams
- In 2015, the DOI 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, over 125 SOS East collections have been used for Hurricane Sandy restoration projects.

To continue the success of the PCRP, we need more:

- Botanical Expertise – As of 2021, there were 32 botanists in the BLM. The BLM manages 245 million acres. This means, there is only one botanist for every 7.656 million acres of public lands.
- Restoration Ecologists – As the availability of locally adapted native seed increases, we need restoration practitioners who know how to best leverage this national investment back onto the landscape.
- Seed cleaning and testing facilities – In the 20 years that the PCRP has existed, the infrastructure available to clean, test, and store 20 years' worth of seed collections has remained stagnant. More seed cleaning facilities like the USFS Bend Seed Extractory are needed for the PCRP and SOS to continue to grow and provide a stable supply of native seeds for increase and use on public lands.

To address the urgent need for native plant materials for restoration, the **Plant Conservation Alliance** Federal Committee (https://www.blm.gov/programs/natural-resources/native-plant-communities/national-seed-strategy/pca), which includes representatives from twelve Federal agencies, developed the **National Seed Strategy** (NSS; https://www.blm.gov/programs/natural-resources/native-plant-communities/national-seed-strategy). The vision of NSS is to provide the right seed in the right place at the right time. Successful establishment and survival of seedlings depends on where and how seeds are collected. Research suggests that it is important to use locally adapted seeds. Local populations often show a home-site advantage and non-local genotypes may be maladapted to local environmental conditions. Furthermore, intraspecific hybridization of local and non-local genotypes may have a negative impact on the genetic structure of local populations through mechanisms such as outbreeding depression. Additionally, many species show a strong, small-scale genetic differentiation between different habitats so that matching habitats of the restoration and donor site can be more significant than minimizing geographical separation. In sum, locally adapted seeds have a far higher germination and survival rate, leading to more effective ecological restoration efforts, than do seeds obtained from other geographical areas.[28]

The mission of NSS is to ensure the availability of appropriate seed to provide healthy and productive plant communities in a changing climate. 2015-2020 NSS accomplishments (https://www.blm.gov/sites/blm.gov/files/docs/2021-02/NSS%20Progress%202020%20Fact%20Sheet.pdf) include:

[28] Vander, et al. 2010; Baughman, et al. 2019.

- 17 Federal Agencies, 20+ Tribal Nations, 52 States & Territories, 380 total partners, $167 million invested
- Almost 9,000 seed collections
- 170+ scientific reports & articles on native seed research and development
- National Academies of Science national seed needs study underway
- 1000s of native seed crops developed by local and regional efforts in over 32 ecoregions
- 65+ nurseries, farms, growers, and botanic gardens engaged, 21+ regional seed partnerships
- 2 facilities increased seed storage capacity to 2.1 million pounds
- 250+ types of seed available for large-scale restoration
- 10+ million acres impacted

Largely because of global warming, wildfires and storms are becoming increasingly frequent and severe. Warmer temperatures, below-average winter precipitation, earlier snowmelt, and drier summers are creating longer wildfire seasons.[29] Hurricanes are also becoming increasingly frequent and severe, also linked to global warming. These natural disasters increase our need for native plant materials for restoration. Accordingly, next steps for the NSS are:

- 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 Hubs" with partners who develop, store, and deliver locally adapted native seeds
- Increase research to enhance decisions based on science for every step, from seed collection to restoration
- Increase public education and awareness on the importance of locally adapted native seed in ecological restoration

Continuing to support the above programs in a manner that can meet our nation's needs for native plant material for restoration requires stable, dedicated Federal funding. Such support would fund:

- SOS seed collecting efforts, and analysis of such efforts under the Justice40 Initiative, of which SOS is a pilot program
- Genomic studies on seeds to be used for restoration
- Education of specialists (e.g., botanists) and employment opportunities, particularly from underserved communities such as Tribal Nations
- Seed-growing enterprises and training and opportunities
- Community and public outreach

[29] Grimm, et al. 2013; Polley, et al. 2013; Hessburg, et al. 2021.

Future Programs:

A stable, enduring native seed supply must include a diversity of voices and autonomy of community groups that builds equitable participation in social, economic, and environmental benefits. In the US, supporting Tribal Nations in developing seed-growing enterprises will create a participatory, community-based seed supply approach that will:

- Address social and environmental justice
- Honor TEK, because seeds are sacred in most Indigenous cultures
- Help achieve the goals of the US Federal government in creating ecosystems more resilient to fire, drought, and other ecological disasters
- Address the goals of the UN Decade for Ecosystem Restoration

Meeting large-scale restoration goals requires connection between local seed production and collaborative platforms to negotiate roles, rights, and responsibilities between all partners. When partnering with Tribal Nations, this will require government-to-government negotiations that fulfill sovereignty and self-determination rights.[30]

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[30] Reyes-Garcia 2019; Fernandez, et al. 2021; Urzedo, et al. 2022;

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