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Introduction

California is embarking on ambitious efforts to create resilience in a changing world, with 30x30 and other climate and biodiversity initiatives positioning it squarely as a global leader in this work. Numerous ecological restoration projects are underway or planned to help meet resiliency goals and ensure that all residents benefit from a healthy environment. Catastrophic wildfires and other natural disasters are greatly expanding the need for ecological restoration throughout California.

Native seeds are a critical piece of these and other nature-based solutions that focus on climate change, drought, extreme wildfire, and other stressors. However, current seed stock is insufficient to meet growing needs. For these efforts to be successful, the state must invest in the core infrastructure necessary to support the escalating demand for native seed.

Today, restoration practitioners are faced with a difficult decision: use whatever seed they can get (local or not), or don’t seed at all. California faces an urgent and growing need to coordinate efforts to ramp up supply to meet demand, set standards of practice, and build capacity to meet those standards. Improving coordination will affect every stage of the native seed production process, including collection; processing; increase; certification; storage; and, ultimately, use for ecological restoration (Figure 1).

With ambitious work ahead, we must look to how we set ecological restoration projects up for success with the use of native seeds adapted to local site conditions. Using appropriate, source-identified (SI) seed intentionally collected to capture local genetic diversity helps preserve characteristics that allow a population to be well-adapted to its local conditions and bolsters the species against climate change and other environmental stressors. Preserving genetic diversity also helps maintain biodiversity at all levels, from individual genes to entire ecosystems (Mishler & Baldwin, 2021). Thus, a greater volume of seed, more available species, and additional localized species or ecotypes are needed.

Currently, however, native seed producers face the challenge of preserving genetic diversity while also producing enough seed to meet demand. The need to meet demand presents a risk of selecting for certain traits such as high yield (Schoen & Brown, 2001; Dyer et al., 2016) at the expense of the overall genetic diversity that may be crucial to survival in a restoration context (Holl et al., 2022; Pizza et al., 2021; Dyer et al., 2016). Native seed producers also face institutional barriers. For example, much of the funding for seed used in restoration comes from short-term, post-fire emergency sources, which leaves little time for planning and creates an unstable market for producers.
Figure 1. The California Native Seed Strategy addresses all facets of native seed planning, production and use. The cycle of native seed production and use includes many steps that need increased capacity and coordination as described in this Strategy.

Graphic adapted from Great Basin Native Plant Project.
Lupinus microcarpus var. densiflorus contract grow for Klamath dam removal restoration project at Heritage Growers Native Seed Amplification Fields in Colusa County California.

Photo credit: Michele Ranieri, Heritage Growers Operations Manager
This California Native Seed Strategy (Strategy) offers a pathway for increasing the availability of native seed and its use in ecological restoration\(^1\). The Strategy is a state-specific version of the National Native Seed Strategy, informed by the Nevada Native Seed Strategy (PCA, 2015; NNSP, 2020), that addresses the policy, grants and contracts, capacity (personnel and infrastructure), collaboration, and science and technology needed to get the right seed in the right place at the right time. Its objectives and actions are aimed at increasing the availability of native seeds for ecological restoration and the related guidelines and standards needed to preserve genetic diversity. These objectives and actions are intended to achieve the following four goals over the next five years (2023–2028):

**GOAL 1** Identify Native Seed Needs and Ensure the Reliable Availability of Genetically Appropriate Seed.

**GOAL 2** Improve Guidelines and Identify Research Needs for Native Seed Production and Use.

**GOAL 3** Develop Tools that Enable Native Seed Producers and Users to Make Timely, Informed Decisions.

**GOAL 4** Develop Strategies and Tools for Internal and External Communication.

Successful implementation will require collaboration between agencies, Tribes, industry partners, and other interested parties. As the original and current stewards of native plants, Indigenous peoples cultivate and use these valuable cultural resources in ways that are critical to understand and include. Tribal perspectives, needs, and seed- and data-sovereignty concerns have been integrated throughout this Strategy and will be a part of its implementation. This Strategy provides opportunities for collaborative community-based knowledge-building and industry growth. Finally, this Strategy aims to advance equity in the field of native seed production and use by including actions that focus on historically underserved communities.

\(^1\)Species-specific rare plant seed collection as well as long-term conservation storage and seedbanking (ex situ conservation), while essential to biodiversity preservation, are outside the scope of this plan.
Background

California’s complex climate, topography, and geology make it home to more native plant species than any other state; a third of these species are endemic (naturally occurring in only one geographical area). The state’s flora falls within a range of vegetation types, from wildflower-rich oak woodlands and grasslands to the tallest and oldest conifers, fire-dependent coastal sage scrub, and chaparral. Much of the state lies within the California Floristic Province, one of 36 global biodiversity hotspots. The rest of the state represents portions of the Great Basin Floristic Province in the northeast, and the Desert Province in the southeast.

Fire—a stewardship tool used by California’s Indigenous peoples as well as lightning-caused blazes—has also played an important role in maintaining this biodiversity from time immemorial. Today, climate change and land use policies, including more than a century of fire suppression, contribute to fires that are often dramatically larger and more severe. This, in turn, has led to a much greater demand for native seed for large-scale post-fire restoration projects.

California is leading the way with ambitious environmental initiatives that will require restoration and ongoing habitat stewardship using native plants. In addition, 2021–2030 is the United Nations Decade on Ecosystem Restoration; dams are coming down and habitats are being restored. To support the growing demand for native seeds for ecological restoration, several critical and interconnected challenges must be addressed.
Policy

The use of native seed in California is currently unregulated by the state. The absence of policies, in addition to a native seed supply shortage, pressures some land managers to use seed that may not be appropriate for a given area. Using non-native seed, out-of-state seed, or seed from different climatic conditions or habitat types, has the potential to reduce the resiliency and biodiversity of that area. Using genetically appropriate seed is crucial to preserve biodiversity and increase success of restoration projects. Both SI native seed availability and market stability would benefit from additional state policies, particularly those that regulate and mandate the use of native seed.

The California Crop Improvement Association (CCIA) requires testing be done at a lab that follows Association of Official Seed Certifying Agencies (AOSCA) rules for agricultural seed quality, yield, genetic purity, percent weed seed, and other factors. Developing a similar requirement for the Quality Assurance Pre-Variety Germplasm Program, tailored to native seed, will help increase the efficacy, quality, and integrity of
ecological restoration. Currently, SI seeds are not required, and the capital required to meet those standards is a major disincentive for producers. Therefore, development of new policies and requirements should be paired with programs that provide producers with financial and technical assistance to incentivize compliance.

Finally, some public agencies devoted to biodiversity protection may prohibit the collection of native seed that is not intended to be directly returned to those lands. After appropriate assessments of the species needed and source-population distribution, permits and interagency agreements could support collections that are meant to serve a broad public good (e.g., restoring diverse plant populations) while maintaining agency resource-protection mandates.

Given biodiversity’s tremendous benefits to ecosystem and human health, a case could be made that the wealth of stock seed, production protocols, and other resources held by native seed producers should be accessible to the public. However, this would have to be done while trying to avoid unintended negative consequences to the native seed production industry. One approach is to ensure that native seed stock, related information, and other resources generated from public funding remain accessible to everyone. In addition, building institutional capacity would enable agencies to generate and house even more publicly available resources.

**Grants & Contracts**

Native seed, which is often used to prevent post-fire erosion and the establishment of non-native species, is not always available or seen as logistically or financially desirable compared to using a non-native seed source. However, as California experiences more erratic weather due to climate change, producers predict an increasing need for locally sourced native seed—a demand existing systems and infrastructure are incapable of meeting.

Currently, much of the native seed used in restoration is funded by emergency-driven post-fire money, which arrives in bursts and has very short availability windows. The constricted timeframes of both grant-based and disaster-recovery funding do not provide adequate lead times for seed planning and production. Restoration work that is not time-constrained would allow longer-term contracts and provide stable funding to build regional seed stock that could be repurposed in emergency situations. For example, a relatively modest investment of $3.6 million in 2019 to California Plant Rescue enabled it to double its collections in five years. While the need across the state is orders of magnitude larger, this result demonstrates how funding an organized coalition with clear goals can rapidly increase seed supplies for restoration.
A greater number of flexible, long-term contracts would allow producers to grow and store large amounts of native seed with assurances that there would be buyers for it. In 2018, the Bureau of Land Management’s (BLM’s) Plant Conservation and Restoration Program began to address the issues of production timeframe, and native seed stock availability using indefinite delivery, indefinite quantity (IDIQ) production contracts with producers. These contracts typically last five years and are awarded to three to five vendors, with a price-per-pound bid as a task item.

With reliable funding, the BLM was able to partner with six non-federal seed banks to store native seed collected from numerous seed zones across different ecoregions in the western United States (NASEM, 2023). This enabled them to increase the number of native seed types that were specific to transfer zones that were not readily available on the commercial market. Although seed-production IDIQ contracts are not a new tool, the focus on seed production by seed-transfer zone is a novel approach for the BLM. The seed given to producers came from the Seeds of Success (SOS) program, which the BLM initiated in 2001. Although the quantity increases are small and the funding for the new program is modest, IDIQ is proving to be a significant new approach to meeting native seed needs.
Capacity

Increased personnel and infrastructure are needed across participating organizations and agencies at each phase of the native seed planning, production, and use cycle (Figure 1) to expand the availability of genetically appropriate native seed. Bringing additional producers online and certifying wild collections and subsequent generations in production will require investing in individuals knowledgeable about the native seed process. Similarly, SI seed documentation requires personnel to collect and verify species, location, and growing conditions. CCIA has indicated that their current annual maximum is 50 certifications, which is well under the source location and species diversity necessary to meet restoration needs, if the state were to require SI quality assurance. Many federal agencies use SOS trained staff for wild collections, and California Plant Rescue partners have been collecting rare plant seed across public lands. Both programs have agreements and documentation in place that allow them to scale-up source seed collection if CCIA recognizes this documentation as equivalent to theirs for wild populations. (AOSCA accepts SOS collection documentation in a few states.)

As is done in other states, California needs cooperative extension personnel who can support native seed farming. These individuals, along with the farmer-trusted expertise of University of California Agriculture and Natural Resources or Natural Resource Conservation Service (NRCS) personnel, will be essential for facilitating native seed farming on agricultural lands for ecological restoration projects.

Lastly, there is a shortage of equipment and space to process and store native seed. Cooperative extension projects could help meet this need, as could state, federal, and private facilities. These facilities could be shared through collaborative regional working groups.

Collaboration & Coordination

As previously stated, a coordinated community-based effort is needed to implement this Strategy. Regional working groups made up of state, federal, Tribal, private, and non-governmental organizations involved with seed production and use in ecological restoration will play key roles in sharing seed, personnel, infrastructure, resources, and information. A central organization should coordinate these regional working groups and facilitate communication with the steering committee. Several groups across the state that are already working together—including the Mojave Desert Native Plant Program, the Great Basin Native Plant Project, and the Orange County Native Seed Partnership—can serve as examples. Regional working groups can also highlight
policy, contractual, and scientific and technical barriers that need attention, such as policies limiting native seed collection across jurisdictions, sharing resources, and promoting a viable seed industry.

Science & Technology

Both the native seed industry and public agencies would benefit from clear guidelines around where and what kinds of native seed are required. Seed analysts would benefit from species-specific standard information (percent pure seed, percent inert matter, etc.). Among the questions such standards and guidelines would address: What does it mean for seed to be native? Do out-of-state genetics count as California native? What are minimum seed zones and transfer guidelines? How many generations can be produced in a farming environment before stock must be refreshed from wild seed? What is the acceptable germination rate for each species?

A tremendous amount of research has been conducted on native seed increase and use in restoration, especially during the first five years of the National Native Seed Strategy (2015–2020). Studies included in the August 2020 special issue from the Society for Ecological Restoration, “Standards for Native Seeds in Ecological Restoration,” provide a foundation for setting best management practices (BMPs) to improve efficiency and integrity in the native seed production process, including seed sourcing, germination, production, harvest, storage, and use in the field.

In 2020, CNPS hosted the symposium Protecting California’s Diversity: Genetic Considerations for Native Planting and Restoration. This symposium, research from the Society of Ecological Restoration’s special issue, and other resources contributed to Goal 2 of this Strategy. This goal differs from the National and Nevada Seed Strategies in that it does not directly call for research to be conducted, but rather relies on existing research to inform the guidelines and protocols to meet its objectives. However, identifying knowledge gaps where research is needed is still included. Goals 2 and 3 are similar in that they organize new and existing information related to native seed production and use to make it more readily available and usable. As described in Goal 3, a number of these databases already exist.
**Goal 1:**
Identify Native Seed Needs and Ensure the Reliable Availability of Genetically Appropriate Seed

**Background**
A survey and gap analysis of native seed supply and demand is needed to set a clear path for this Strategy. New policies are also needed to establish standards and ensure reliable access to SI seeds across jurisdictional boundaries. Some of the gaps identified between supply and demand will likely be closed through stable, long-term funding and contracts that would give native seed producers the necessary lead time to meet demands. Collaboration between producers, users, and others involved in this process would also increase seed availability and allow practices to be standardized to ensure diversity and quality. Lastly, additional staffing for native seed producers, certifiers, processors, and collectors, among others, is essential to scale up the process to meet current demands for genetically appropriate seed.
Objective 1.1: Understand native seed supply and demand.

The first step in closing the gap between current capacity and the long-term need for ecological restoration is to understand the scope and scale. A broad range of parties are involved in native seed production and use, and understanding all of their needs will set the Strategy on the right course. Of particular importance are those of underserved communities where we lack information about both the likely restoration need as well as ongoing work to produce native seed.

Action 1.1.1: Conduct a needs assessment of California native seed users.

Conduct a broad survey of small and large native seed users, including cooperatives; councils; collectives; Tribal, federal, and state governments; private landowners; and non-governmental organizations (NGOs) throughout California. Combine the results with reviews of past assessments to help gauge demand. Organize results (species, quantity in pounds ordered/received, and barriers to meeting needs) by bioregion.

Action 1.1.2: Conduct a needs assessment of California native seed producers.

Conduct a broad survey of small and large native seed producers, including cooperatives; councils; collectives; Tribal, federal, and state governments; private landowners; and NGOs throughout California and surrounding states with reviews of past assessments and research to understand current industry capacity, barriers to participation, and the economic and logistical prerequisites for a stable future market.

Action 1.1.3: Conduct a gap analysis of the needs between producers and users.

A gap analysis would provide direction for where to allocate resources. It should identify the quantity of seed needed, the regions where needs are highest, and the types of species, or blends of species, most needed. It should also identify what barriers need to be addressed to meet those needs (e.g., infrastructure).

Objective 1.2: Create policy to improve the availability of genetically appropriate native seed.

Without any policies to ensure the use of genetically appropriate native seed, seed used for restoration projects may be ecologically inadequate. Agencies are increasingly adopting the BLM’s SOS protocols to wild-collect native seed for use on federal lands;
something similar would be beneficial for non-federal partners as well. For example, agreements or policies to support appropriate collection on state lands could provide a mutually advantageous solution for increasing wild seed sources while protecting public resources.

Currently, native seed is not regulated like other seed types (e.g., crops and noxious weeds) and is not required to have SI quality assurance. Additional staffing capacity and financial support would be required to expand CCIA requirements for native seed production and avoid production bottlenecks. (See Action 1.5.4: “Create additional positions to support SI Quality Assurance Programs and consider additional seed quality assurance methods”; Action 3.1.1, “Provide training on CCIA Quality Assurance processes.”; and Action 1.3.2, “Fund the transition to SI native seed.”)

Finally, native seed producers possess information with immense public value, but there is currently little incentive to share trade secrets. Nevertheless, there are ways to make this information more widely available as an incentive for much-needed new producers to enter the market.

Action 1.2.1: Re-evaluate native seed collection and use policies.
Work with agency leaders and policymakers to examine policies around wild seed collection on state-owned lands. Establish SOS collection protocols as a standard and encourage non-federal land managers to participate. Carefully consider evaluating tradeoffs between percent seed collected in a population and the time it takes to increase to scale, especially for perennial crops.

Action 1.2.2: Develop a state policy to regulate SI native seed.
Bolster native-seed markets and support CDFA regulation through enacting policies that require native seed for restoration, regulate SI seed, and incentivize the use and/or production of native seed.

Action 1.2.3: Establish stewardship of native seed as a public good.
Secure investments from state agencies to ensure that seed sourced for restoration from and for public lands, as well as information (e.g., techniques, research, etc.) generated by these activities, remain accessible to the public. This would allow native seed users to access seed within ecological boundaries and across jurisdictional boundaries, and provide protocols for more producers to produce more species. (See Action 1.5.5, “Create more infrastructure for native seed increase, processing, and storage.”)
Objective 1.3: Increase long-term, stable funding for native seed production and use.

Both grant-based restoration and disaster recovery funding lack sufficient lead times to ensure adequate planning and production. Providing sustained restoration funding would help create a reliable demand that could be aligned with regionally forecasted natural-disaster likelihoods. (See Objective 3.4, “Enable native seed users to spatially forecast needs.”) Furthermore, funding is needed to back many of the policy actions laid out in Objective 1.2. This includes the capital required for native seed producers to obtain SI quality assurance, produce new species, and share species-specific protocols to improve seed production and restoration practices. Finally, funding should be made accessible and available to underserved communities, which often lack access to these resources.

Action 1.3.1: Secure reliable funding through federal and state budgets.

Explore using existing funding programs to support native seed production. These include:

- State funding from initiatives such as 30x30 that support restoration for climate change, wildfire resiliency, or biodiversity and could contribute to more stable demand for native seed.

- A new federal Farm Bill that could help fund native seed production, as it may be considered a small-market crop.

- California’s Sustainable Groundwater Management Act could fund crop transitions from non-native crops with high water needs to native seed production.
A block grant, administered with the assistance of the Bureau of Indian Affairs and/or the Intertribal Agriculture Council, that could be set up to support current and future Tribal seed production efforts.

**Action 1.3.2: Fund the transition to SI native seed.**

Provide a financial incentive to help native seed producers overcome cost-prohibitive barriers to transitioning to SI quality assured native seed.

**Action 1.3.3: Fund cultivation of species not yet in production.**

Pursue creation of subsidies for the cultivation of species not currently produced to alleviate the financial risk associated with creating a greater diversity of available native seed.

**Action 1.3.4: Set aside funding for underserved communities and community-based solutions.**

Establish grants and specific state funding set-asides for Tribes and underserved communities to support community-based native seed production and use in restoration projects.

**Objective 1.4: Coordinate long-term, stable contracts between native seed producers and users.**

The lack of advance planning for large projects is a major barrier to increasing reliable native seed supply and stabilizing commercial pricing. Having more flexible, long-term contracts would allow producers to grow and store large amounts of native seed with assurance that there will be buyers.

One example of this is IDIQ native seed production contracts utilized by the BLM (see Background). Although vendors are not guaranteed task orders, this approach allows seed producers to better anticipate the species needed and price per pound. Similar contract structures would help producers meet native seed demand. Other changes that would help increase both native seed production and diversity include advance contracts, including seed development as an allowable expense, guaranteed purchase volume/price, contracts for specialized species, and contracts for underserved communities.

**Action 1.4.1: Create more IDIQ or similar contracts for seed production.**

Use IDIQ or similar contracts between seed producers and users. Note, navigating the IDIQ process may be more difficult for smaller and underserved producers and
is only administered by federal agencies; however, it can still serve as a template for other organizations. (See Action 3.1.2, “Provide training on IDIQ and other contracting procedures.”)

**Action 1.4.2:** Create advance contracts to help cover initial production costs.

Establish advance contracts that provide the capital required to start production, as opposed to requiring producers to wait for post-delivery compensation.

**Action 1.4.3:** Include native seed development costs as an allowable expense in large-scale restoration planning grants.

Provide producers with better lead time by including seed development in planning grants. Similar to Action 1.3.2: “Fund the transition to SI native seed”, this provides critical support earlier in the production process.

**Action 1.4.4:** Include guaranteed purchase volume and/or price in contracts.

Ensure a guaranteed purchase volume or price per pound to reduce risk to producers.

**Action 1.4.5:** Create contracts for specialized collection and increase.

Develop specific contracts for native seed that is not currently commercially available to reduce risk to producers and help increase the variety of seeds available. (See Action 1.3.3, “Fund cultivation of species not yet in production.”)

**Action 1.4.6:** Create contracts specifically for underserved communities.

Establish contracts specifically for underserved communities to eliminate the burden of competition.

**Objective 1.5:** Increase personnel and infrastructure capacity to support Strategy implementation.

Meeting this Strategy’s objectives to increase production, on-board new producers, issue certifications, and use SI native seed will require more staff. For example, required SI documentation needs personnel to collect and verify native seed species, location, and growing conditions. Wildland seed collection certification is also time-intensive and logistically challenging, as collections occur simultaneously at multiple locations. More
facilities are needed across the state to increase, process, and store native seed as well as develop new stock, and move towards a “California Sourced, California Grown” model.

**Action 1.5.1: Ensure that restoration seeding decisions are made by a restoration specialist, botanist, or a professional with similar expertise.**

Establish guidelines that place restoration seeding decisions under the purview of a staff botanist, local Indigenous practitioner, restorationist, ecologist, or restoration specialist at the local or regional level. In the absence of in-house capacity, hire additional permanent staff, or find a source similarly qualified to provide technical support (e.g., a consultant or staff from other organizations).

**Action 1.5.2: Encourage new producers and hire additional native seed collection crews.**

Increase supply by bringing on additional producers and seed-collection crews. Explore community and nature-based solutions such as partnering with local organizations and repurposing fallow fields.

**Action 1.5.3: Create additional technical service positions to support native seed producers.**

Hire additional farmer-trusted technical service personnel to help onboard new producers.

**Action 1.5.4: Create additional positions to support SI Quality Assurance Programs and consider additional seed quality assurance methods.**

Add staff capacity to provide quality assurance to native seed producers transitioning to SI seed. Accept SOS data-collection protocols for quality assurance to help alleviate staffing, quality assurance program costs, and other logistical challenges.

**Action 1.5.5: Create more infrastructure for native seed increase, processing, and storage.**

Investigate the capacity of state and federal nurseries to provide space for seed increase, processing, and storage. Explore the approach other states have used where university cooperative extension institutions participate in seed collection, foundation-stock storage and maintenance, and seed growing (including propagation testing, genetics, and other research). Explore other community-based approaches to onboard new growers and increase infrastructure.
Objective 1.6: Support regional collaboration.

California includes portions of three floristic provinces and thirteen Jepson Level III ecoregions. Bioregions such as these are useful for delineating seed transfer zones and population genetics, but each agency has its own way of organizing them.

Jepson ecoregions (e.g., Figure 2 northwest [NW], Sierra Nevada [SN]) loosely correspond to many bioregions used by agencies. Therefore, these would also be useful geographic subdivisions for regional collaboratives involving agencies, Tribes, producers, researchers, and other interested landowners and NGOs. The 2023 National Academies report, *An Assessment of Native Seed Needs and the Capacity for Their Supply*, (NASEM, 2023) includes thorough recommendations regarding a structure similar to the National Interagency Fire Center that would bring cross-agency coordination.

These regional collaboratives could develop banks of locally sourced seed as well as climate-controlled storage, seed cleaning equipment, labeling machines, and growing equipment. Several such partnerships are already active in California, including the Mojave Desert Native Plant Program, the Great Basin Native Plant Project, Orange County Native Seed Partnership, and Seed L.A..

![Figure 2. Jepson ecoregions. (Jepson 2023).](image)

Action 1.6: Facilitate regional working groups.

Establish regional working groups based on bioregions such as Northwestern (NW) and Cascade Ranges (CaR) combined, Central Western (CW), Great Central Valley (GV), Sierra Nevada (SN), and Southwestern (SW), and coordinate with already existing collaboratives, such as those in the Great Basin (GB) and Desert (D) regions (Figure 2). Engage a wide range of regional participants through surveys, emails, symposiums, websites, and other marketing and outreach opportunities. Conduct virtual and/or in-person meetings to share resources, information, and needs. Include features such as recording virtual meetings with closed captioning and providing travel funding to increase accessibility.
Goal 2:
Improve Guidelines and Identify Research Needs for Native Seed Production and Use

Background

The following objectives address guidelines and research needs for each step of the native seed production process, including seed zones, transfer, collection, processing, storage, increase, testing, and certifications. They also include guidelines and research needs for seeding methods and establishment monitoring. Goal 2 actions will be informed by existing research, and as appropriate, consultation with underserved and local communities and incorporation of Traditional Ecological Knowledge.

For details on the storage and use of information described in this goal, see Goal 3, “Develop Tools to Enable Native Seed Producers and Users to Make Timely, Informed Decisions”; information dissemination is described in Goal 4, “Develop Strategies and Tools for Internal and External Communication.”
Objective 2.1: Improve and develop use of native seed zones and transfer guidelines for current and projected future conditions.

Organizations differ in their definitions of “native,” requirements for native seed use, seed zones, and transfer guidelines. Improving existing seed transfer guidelines and establishing them for species not already covered will provide a minimum standard for everyone involved in California native seed development and, in turn, facilitate increased collaboration amongst seed producers and users. Improved guidelines and a minimum standard will also help maintain the genetic variation needed for populations to adapt to stressors and changing climate conditions (Armstrong et al., 2019). Genetic testing and/or experiments that reveal whether a species is a generalist or specialist can be used to create appropriate seed zones and transfer guidelines. Species with evidence of local adaptation differences within seed zones, life-history traits with low potential for gene flow, ploidy variation, hybridization, or taxonomic uncertainty should also be prioritized for study. This research may reveal that some of these species should receive defined subzone or exclusion zones (Ward et al., 2008).

Action 2.1.1: Define “native seed.”

Define what plants are native to specific regions and establish practical guidelines for using appropriately native seeds based on established biotic regions, such as those provided by the Jepson Herbarium at the University of California, Berkeley (Figure 2). Native seed can be defined using the following (or similar) language:

“Native seed” means seeds sourced from California plant taxa that occur naturally in the Jepson Region associated with a specific California location (as defined and updated by the University of California, Berkeley Jepson eFlora).

Action 2.1.2: Compile information for already-established native seed zones and transfer guidelines by species and bioregion.

Organize established native seed zone information by species and bioregion, including related research to inform decision-makers as they define seed zone and transfer criteria for target species. Compile information from scientific literature and existing databases such as Reforestation, Nurseries, and Genetic Resources (RNGR) and the Society for Ecological Restoration (SER), among others.
Action 2.1.3: Set standard native seed zone and transfer guidelines.

Delineate species-specific genetic (empirical) seed zones and transfer guidelines when sufficient information is available. For species without established genetic seed zones, refer to ecoregions with similar geology, climate, soil, hydrology, vegetation, and other geographic features (Erickson & Halford, 2020). Notably, provisional seed zones used by some practitioners are based on climate data (winter minimum temperature and aridity) along with ecoregional boundaries (Bower et al., 2014) and need refinement. This is intended to be only one of the tools used to make seed-transfer decisions.

Action 2.1.4: Conduct research on species that need native seed zone and transfer guidelines developed for California bioregions.

Conduct research to characterize the genetic variation of species used in restoration that are not included in the compiled information from Action 2.1.2 to help native seed users and producers improve seed integrity and long-term ecological restoration success.
Objective 2.2: Improve species-specific protocols for native seed collection, production, processing, testing, and storage.

Agricultural crops have been selected and bred for uniform traits and genetics to make germination, harvest, storage, and other elements of production easier. However, when working with native seeds, the opposite approach is required to maintain genetic diversity. For example, native species differ in dormancy and germination traits more than agricultural species do. And, while this may have advantages in the wild, slow or erratic germination poses challenges in seed production. In addition, different seeds require different harvesting, processing, and storage techniques. This differentiation between native species also poses a challenge to seed analysts. Unlike agricultural crops, seed analysts lack species-specific standards to perform their lab tests.

Improving species-specific protocols and BMPs will help producers, analysts, and users manage the complexities of producing native seed while maintaining genetic integrity and limiting the spread of pests and pathogens. Seed producers, analysts and users should be given information on species-specific production protocols in the form of a user-friendly guide. Additional research is also needed to fill current knowledge gaps. Information should be open access, drawing from existing protocols when available, and have a process for vetting. The Oregon Plant Materials Center (ORPMC) (Corvallis) has a Native Seed Production Guide for the Pacific Northwest that can serve as an example.

Action 2.2.1: Develop BMPs to limit pests and pathogens during collection and production.

Create BMPs to ensure that the correct species are collected; material on or near the ground or from diseased plants is not collected; people, tools, and equipment are inspected and cleaned between sites; and native seed cleaning and drying are implemented in a manner to avoid pathogens while preserving viability.

Action 2.2.2: Compile and develop information on species-specific germination protocols.

Provide species-specific germination protocols to help seed analysts test and producers grow a greater number of species and a larger volume of native seed. Utilize existing seed germination databases and literature (RNGR Database; Kildisheva et al., 2020; Emery, 1988) as well as seek out and develop additional reference material.
Action 2.2.3: Compile and develop information on native seed production to maintain genetic integrity.

Provide species-specific protocols to help producers with the complexities of native seed production. Also ensure that local genetic diversity is preserved through guidelines that include the number of generations of seed that can be produced beyond the wild collection, how to prevent hybridization, and how to prevent unintentional selection of traits, among other important considerations (Conrady et al., 2023; Pedrini & Dixon, 2020; Dyer et al., 2016; Ward et al., 2008). Seek out and compile additional reference material.

Action 2.2.4: Compile and develop information on native seed germination, field establishment, and maintenance.

Gather information such as site preparation (e.g., weed control, soil seedbed), and establishment (e.g., timing of seeding, irrigation, plant materials [seed versus transplants], weed control, fertilization, and management of pests and diseases) (NRCS, n.d.). Make this information available in a centralized location, such as the Strategy website (see Action 4.1.2: “Develop and maintain the Strategy website to organize information for external communication”). Seek out and compile additional reference material.

Action 2.2.5: Compile and develop information on native seed harvesting.

Aggregate existing and seek new information on harvesting equipment and techniques based on variables such as location, native seed traits, operation scale, and harvest frequency and volume (RNGR Database; Pedrini et al., 2020 NRCS, n.d.) as well as BMPs for avoiding unintentional selection during harvest.
**Action 2.2.6:** Compile and develop information on species-specific native seed processing.

Assemble existing and seek additional information on native seed processing (RNGR Database; Bonner & Karrfalt, 2008; Wall & Macdonald, 2009) to ensure that seed is clean and healthy for optimal propagation success and greater storage longevity.

**Action 2.2.7:** Compile and develop information on species-specific native seed storage.

Collect existing and seek additional information on native seed storage (Seed Information Database; RNGR Database; De Vitis et al., 2020; Pedrini & Dixon 2020; Walters et al., 2018; Walters, 2015; Wall 2009; Walters et al., 2007). Include both short-term storage for near-term restoration project use and long-term storage for conservation banking.

**Action 2.2.8:** Conduct research on species-specific native seed processing, storage, and germination for species that lack technical guidelines.

Focus research on filling in knowledge gaps on species-specific native seed processing, storage, germination, and harvest to help seed analysts and producers expand the number of species available and the quantity of each. Have a process for vetting this information, and share it in a centralized, open-access location.

Photo credit: CNPS
Objective 2.3: Improve seed germination and plant establishment at restoration sites through shared seed plans.

Numerous factors influence the success of native seed germination and plant establishment, among them, species, seed stock, local climate (rainfall, soil moisture, air temperature), soil conditions (depth, texture, nutrients, salinity), competition (weeds), and herbivory (Armstrong et al., 2019). A seed plan tailored to a project’s specific objectives and habitat type(s) provides restoration practitioners with critical guidance on site preparation, seed-mix development, sowing rates, maintenance, monitoring, and communication to maximize their chances of success (Shaw et al., 2020; Stromberg et al., 2007; Griggs, 2009; Jackson et al., 2015; Gornish & Shaw, 2017; Armstrong et al., 2019).

Action 2.3.1: Compile and develop site-preparation strategies based on an initial restoration site assessment.

Identify barriers to plant establishment using an initial site assessment that includes disturbance history, degradation level, soil erosion or compaction, slope and aspect, and existing vegetation (including invasive plants) (Armstrong et al., 2019). Compile and share information on various site preparation measures to help land managers facilitate successful plant establishment. Categorize information by bioregion.

Action 2.3.2: Compile and develop workhorse native seed mixes, sowing rates, and sowing techniques.

Establish “workhorse” native seed mixes that incorporate species that perform well together over a broad range of site characteristics and increase successful seed germination and plant establishment to reach restoration goals. “Workhorse” native mixes avoid the introduction of non-native species and increase diversity compared to single-species broadcast seeding. To avoid decreasing genetic diversity, create local or regional mixes that reflect the genetic diversity of that area. Determine the elements of these seed mixes by objective, habitat type, and seed zone. Include recommended seeding rates, sowing techniques (e.g., broadcast, drilling, and hydroseeding), and aftercare/soil amendments (e.g., composting and mulching) to help land managers facilitate successful plant establishment and community diversity (Stromberg et al., 2007; Jackson et al., 2015; Gornish & Shaw, 2017).
Action 2.3.3: Compile and develop maintenance strategies to ensure successful seed germination and plant establishment at restoration sites.

Assemble and share species-specific information on effective maintenance techniques and timing to help land managers ensure successful seed germination and plant establishment and anticipate maintenance requirements when creating their initial restoration plans.

Objective 2.4: Improve monitoring of seed germination and plant establishment at restoration sites for adaptive management.

Monitoring is critical for adaptive management and is often a project requirement, yet the results of that monitoring are largely unavailable. Improving and standardizing monitoring techniques will ensure that this information is being collected in more consistent and comparable ways. More reliably collected and shared information will not only help increase seed germination and plant establishment success rates, but also strengthen the restoration field as a whole.

Action 2.4.1: Develop and improve guidelines for monitoring techniques.

Adapt monitoring techniques from Elzinga et al. (1998) or other resources. Use monitoring results to determine whether current native seed production and use strategies are successful, detrimental, or neutral and if changes should be made to achieve seed production and use goals. Share results as discussed in Goal 3.

Action 2.4.2: Conduct long-term monitoring and use the information gained to improve native seed use in ecological restoration.

Conduct long-term monitoring at native seeding sites and share data amongst the native seed community. Establish long-term monitoring sites in each bioregion to determine seeding BMP success.
Goal 3:
Develop Tools that Enable Native Seed Producers and Users to Make Timely, Informed Decisions

Background

Native seed producers and users would benefit from technological tools and trainings to increase and improve the use of native seed in ecological restoration. A native seed inventory database and forecasting tools need to be developed for both users and producers to utilize in their planning. Training in how to use these tools will also be necessary. Information from Goals 1 (“Identify Native Seed Needs and Ensure the Reliable Availability of Genetically Appropriate Seed”) and 2 (“Improve Guidelines and Identify Research Needs for Native Seed Production and Use”) should be organized and made available on the Strategy website (see Goal 4). Training should also be provided on how to use the information provided from Goals 1 and 2. Data sensitivity, including Tribal data sovereignty, will need to be included throughout Goal 3.
Objective 3.1: Educate native seed producers and users on policies, procedures, and protocols.

Native seed producers and users would benefit from training on many of the objectives and actions described under Goals 1 and 2. Combined with materials available on the Strategy website (see Goal 4), this training would permit participants from around the state easy access to ongoing education. Closed captioning and translation into at least Spanish (or, ideally, as many languages as possible) would also increase accessibility. In-person trainings held in various parts of the state could be tailored to share regionally specific information and materials in locally important languages.

Action 3.1.1: Provide training on CCIA Quality Assurance processes.

Train producers on both how to achieve quality assurance standards and how to go through the CCIA quality assurance process. Train Registered Seed Technicians on native seed standards and identification to increase seed lab capacity.
Action 3.1.2: Provide training on IDIQ and other contracting procedures.

Offer training on IDIQ and other contracting procedures—including how to navigate the federal procurement system and its contracting criteria (i.e., awarding the lowest bid)—to encourage new entrants into the industry, simplify the process for existing producers, and help remove barriers to using native seed BMPs. Consider providing training on non-IDIQ contracting topics, including sample language around genetically appropriate native seed, seed testing, and risk (e.g., as described in Objective 1.4 (“Coordinate long-term, stable contracts between native seed producers and users”).

Action 3.1.3: Provide training on best management practices.

Conduct BMP training for various aspects of native seed production and use, especially how to avoid pest and pathogen introduction, as described in Action 2.2.1 (“Develop BMPs to limit pests and pathogens during collection and production”).

Action 3.1.4: Provide training specifically to underserved communities.

Increase access to training for underserved communities, including by developing both local and online learning opportunities as previously described.

Objective 3.2: Make both new and already established guidelines and databases easily accessible to seed producers and users.

Housing information in a centralized location ensures that practitioners have access to the most current policies, procedures, and best available science to apply to their project planning. A shared set of protocols and best practices around all phases of the process—selection, collection, propagation and growing, harvest and storage, planning, seeding, and monitoring—will ensure that practitioners have similar knowledge and expectations as well as an ability to make decisions that get the right seed in the right place at the right time.

Action 3.2.1: Centralize information developed via Goals 1 and 2.

Provide the following information on the Strategy website:

- A needs assessment that seed producers and users can submit at any time, as well as a summary of results (Objective 1.1).
- Results of gap analysis between seed supply and demand (Objective 1.1)
• Up-to-date information on native seed zones, transfer guidelines, and SI quality assurance policies (Objective 1.2 and 2.1).

• Funding opportunities (Objective 1.3).

• Contracts out for bid (Objective 1.4).

• Job and training opportunities (Objective 1.5).

• Regional working group meeting information, including dates, agendas, and minutes (Objective 1.6).

• BMPs to limit pests and pathogens during collection and production (Action 2.2.1).

• List of seed testing labs with staff trained in AOSCA methods.

**Action 3.2.2: Create and expand existing databases to organize information developed via Goal 2.**

Provide the following information by species and bioregion in a database housed on the Strategy website:

• Seed zone and transfer guidelines (Objective 2.1).

• Seed collection, processing, storage, and production protocols (Objective 2.2).

• Seeding plans (Objective 2.3).

• Monitoring for seed germination and plant establishment at restoration sites (Objective 2.4).

**Action 3.2.3: Provide links to already-established guidelines and databases identified in Goal 2.**

Link the following databases, among others, on the Strategy website:

• RNGR Database

• Seed Information Database

• Seed Selection Tools

• Restoration Resource Center Resource Database

• USDA Plants Database Plant Guides
Objective 3.3: Make it easier for native seed users to find a source of genetically appropriate native seed.

A native seed inventory database is needed to coordinate transactions among producers and seed users and provide information such as taxon name, source, amount available, price, and transfer zone. Several existing websites, including the Institute for Applied Ecology, Calscape, and Calflora, currently list available seed and have container species lists for various nurseries. However, no site provides the proposed database functionality.

Action 3.3: Develop a native seed inventory database that enables buyers to find seed.

Create a seed inventory database as an extension of Calscape and linked on the Strategy website (see Objective 4.1) that allows buyers to see native plant ranges, native seed zone and transfer guidelines, and seed availability.
**Objective 3.4: Enable native seed users to spatially forecast needs.**

Better forecasting of where and when restoration is planned would help ensure that native seeds are available when they are needed. Multiple tools—many with overlays of biodiversity information as well as fire, climate, and other data—exist to help forecast restoration needs. Among them: Planscape focuses on where interventions can reduce fire intensity. California’s 30x30 initiative has compiled climate, biodiversity, and other layers on their California Nature site. CNPS has highlighted Important Plant Areas throughout the state, which may help prioritize areas in need of restoration. Alternatively, new tools could be developed, with related training provided to native seed users. These resources would ideally enable seed users to issue a five-year needs forecast and provide a regularly updated central database that aggregates these forecasts.

**Action 3.4.1: Assess existing tools for forecasting native seed needs and expand the capabilities of the most suitable tool.**

Determine which existing tools should be extended with a seed forecasting function, or if a new tool should be developed.

**Action 3.4.2: Invest in tools and trainings that improve native seed demand forecasting.**

Prepare a tool and training module for the Strategy website on how to assess lands for restoration and cross-reference with areas of potential severe disturbances. This tool could also include known sites awaiting restoration planning and implementation.
Goal 4: 
Develop Strategies and Tools for Internal and External Communication

Background

For this Strategy to be adopted and implemented, broad collaboration and engagement across and among native seed producers and users is essential. Prioritizing feedback, creating a framework for evaluation, and reporting progress will ensure that it remains relevant as needs and approaches evolve over time. Targeted, intentional, and meaningful Tribal consultation as well as communication with underserved communities will be important throughout this process.

Objective 4.1: Conduct external education and outreach.

Developing and implementing a communications plan and tools to share this Strategy will help generate support and inspire action. Messaging about the needs it meets as well as its benefits to people and the environment should be designed to resonate
with target audiences such as agencies, legislators and decision-makers; native seed producers and users; and interested members of the public, including Tribes and underserved communities.

**Action 4.1.1: Develop a communications plan.**

Create a communications plan that includes target audiences (e.g., underserved communities, people in the native seed industry) as well as motivating messages and trusted messengers for each. Include how to use communications tools such as press releases, social media, mailing lists, publications, etc., to reach these audiences.

**Action 4.1.2: Develop and maintain the Strategy website to organize information for external communication.**

Build a California Native Seed Strategy website with evergreen content, updated as needed (see Objective 3.2 for suggested website content and applications). Include a streamlined process for partners to submit edits and make changes to ensure the site is kept current.

**Objective 4.2: Distribute and implement the Strategy internally across partners and regions and provide feedback mechanisms.**

California’s size and complexity necessitates having its own structure for more localized, frequent, and targeted communication, separate from that used by the Plant Conservation Alliance for the National Seed Strategy. It will be informative to have a two-way communication channel for regional working groups to update the steering committee with their progress towards achieving the goals set out in the Strategy and to share lessons learned.

**Action 4.2.1: Facilitate communication between Strategy regional working groups and the steering committee.**

Assign one organization responsibility for coordinating the steering committee/central convening group and hosting or maintaining regional groups. This should include regular meetings to share resources, information, and needs within each region, and coordination with the steering committee for oversight and support.
Action 4.2.2: Develop and maintain the Strategy website to organize information for internal communication.

Utilize the California Native Seed Strategy website described in Action 4.1.2 to provide (or link to) information and tools outlined in Goal 3 for the benefit of internal audiences.

Objective 4.3: Determine how to measure progress and revise the Strategy.

Mechanisms for measuring progress toward goals and revising, as needed, are key components of any strategy.

Action 4.3.1: Create agreed-upon metrics to measure progress.

Develop one or more key metrics for each objective and action and determine how and how often they will be measured.

Action 4.3.2: Review and revise the Strategy.

Reassess and update this Strategy based on the metrics developed in Action 4.3.1, initially tracking and making small adjustments annually, and then every five years.
As is done in other states, California needs cooperative extension personnel who can support native seed farming.
References


List of Acronyms and Other Abbreviations Used in Text

AOSCA  Association of Official Seed Certifying Agencies
BLM    Bureau of Land Management
BMPs   Best Management Practices
CAL FIRE California Department of Forestry and Fire Protection
CCIA   California Crop Improvement Association
CDFA   California Department of Food and Agriculture
CDFW   California Department of Fish and Wildlife
CNPS   California Native Plant Society
IDIQ    Indefinite Delivery, Indefinite Quantity
NGOs   Non-Governmental Organizations
NPS    National Park Service
NRCS   Natural Resource Conservation Service
PCA    Plant Conservation Alliance
RNGR   Reforestation, Nurseries, and Genetic Resources
SER    Society for Ecological Restoration
SI     Source-Identified
SOS    Seeds of Success
UC     University of California
UC-ANR University of California Agriculture and Natural Resources
USDA   United States Department of Agriculture
USFS   United States Forest Service
List of Websites Used in Text

California Plant Rescue  
www.caplantrescue.org

Calscape  
www.calscape.org

Calflora  
www.calflora.org

California Nature  
www.californianature.ca.gov/pages/ca-nature

Great Basin Native Plant Project  
www.greatbasinnpp.org

Important Plant Areas  
www.cnps.org/conservation/important-plant-areas

Institute for Applied Ecology  
www.appliedeco.org

Mojave Desert Native Plant Program  
www.blm.gov/blog/2022-04-19/planting-seeds-success

National Native Seed Strategy  
www.blm.gov/programs/natural-resources/native-plant-communities/national-seed-strategy

Native Seed Production Guide  

Planscape  
www.planscape.org

Protecting California’s Diversity: Genetic Considerations for Native Planting and Restoration  
www.cnps.org/genetics-symposium-2020

Reforestation, Nurseries, and Genetic Resources (RNGR)  
www.rngr.net

Restoration Resource Center Resource Database  
www.ser-rrc.org/resource-database

RNGR Database  
www.rngr.net/npn/propagation/protocols

Seed Information Database  
www.ser-sid.org

Seed L.A.  
www.seedla.org

Seed Selection Tools  
www.appliedeco.org/nativeseednetwork/seed-selection-tools

Society for Ecological Restoration (SER)  
www.ser.org

Standards for Native Seeds in Ecological Restoration  
Planting plugs of *Asclepias californica* in the Demonstration Garden at Heritage Growers Native Seed Amplification Fields in Colusa County California.

Photo credit: Joan Bosque, Heritage Growers Demonstration Coordinator