Seed Selection Tools to Enhance Sagebrush Restoration

Adrienne Pilmanis, BLM Ecologist and Colorado Plateau Native Plant Program Coordinator

2019 Utah All Lands All Hands Summit
Salt Lake City, UT, February 6, 2019
• Consideration of Seed Source is Important
• Seed Sourcing Approaches and Seed Transfer Zones
• Three Sagebrush-applicable Seed Sourcing Tools using Seed Transfer Zones:
  • Climate Smart Restoration Tool - North America
    • Based on USFS’s Seedlot Selection Tool platform with Great Basin Native Plant Program (GBNPP) to include Sagebrush research results
    • Bryce Richardson & colleagues
  • Seed Selector and Climpart Tools - North America
    • USGS Southwest Biological Science Center (SBSC) with BLM’s Colorado Plateau Native Plant Program (CPNPP) and N. AZ University
    • Kyle Doherty & colleagues
  • Climate Distance Mapper – four Southwest Ecoregions incl. So. GB and CP
    • USGS Western Ecological Research Center (WERC) with Mojave Desert Native Plant Program (MDNPP)
    • Dan Shryock & colleagues

• Tool Comparison & Resources
Underlying Concept: Genetic variation adapts to ranges of environmental conditions over time, so seed source is a key influence on restoration outcome*. 

Positive project outcomes due to seed source:
- Seed is genetically adapted to current & future biophysical site conditions, including extremes & episodic events and/or management objectives (resilient)
- Seeded plants compatibly breed with themselves and local plants (Project set up for success)

Negative project outcomes due to seed source:
- No germination or establishment
- Inbreeding depression (low fitness from genetic relatedness)
- Outbreeding depression (poorly compatible with locals)
- Lack of sufficient genetic variety to be resilient now, later, and under extreme conditions or other stressors (Project not set up for success)

Sourcing (Provenance) Methods

Where do I get the seed for my restoration project?

1. Local provenance seed
   - Collection on- or near-site of project or use
   - Can use collections from within a Seed Transfer Zones (STZ), which indicates the areal extent from which sources of seed can “safely” be used

2. Admixture provenance seed
   - Maximize genetic diversity by including a range of genotypes to increase adaptive potential (likelihood of suitability to site conditions and compatibility with locals) (seed chosen from > one site or zone)

3. Predictive provenance seed
   - Sources are chosen based on ability to cope with future site conditions
   - Requires some type of modeling, such as Global Climate Models

Three Provenance methods list adapted from Shryock et al 2018
Seed Transfer Zone (STZ)s are used to increase chance of seeding success; avoid negative outcomes related to seed source.

1. “Provisional Seed Transfer Zones”
   - Environmental factors, “climate similarity” partitioned geospatially into zones
     - Climate variables (temperature, precipitation) are used as proxies for genetic relatedness over time
     - PSTZs can be for species in general, or
     - Species-specific, e.g. if using a Species Distribution Model, better

2. “Empirical Seed Transfer Zones”
   - Genecological Adaptation evidence used to derive partitions
     - Results from common gardens and/or molecular studies allow a strong species-specific inference of adaptation to environment across space

- Can use both types predictively – couple with models of future conditions
Figures of STZ types

Provisional

No data on specific species correlated with climate
*Bower et al, 2014*

Empirical

Indian ricegrass ~ 5 STZs

Correlates plant performance or genetics with climate data
*Johnson et al, 2012*
Current Geospatial Tools

Climate Smart Restoration Tool - based on Seedlot Selection Tool platform to include range species

- North American extent (coming soon)
- Helps guide seed collection & find locations where specific sources of seed may do well
- Incorporates past & future climate, 16 climate variables, two IPCC climate scenarios
- Three types of transfer limit options
- Includes Wyoming Big Sagebrush empirical data! Mountain Big Sage coming soon.

Seed Selector & Climpart Tools:

- Global extent; downloadable open-source code
- Helps guide seed collection & find locations where specific sources of seed may do well
- Helps prioritize project seed choice from all available
- Can partition areas by climate similarity for other purposes
- Current climate only; Uses 7 orthogonal weightable climate variables
- 12 species-specific PSTZS available for greater Colorado Plateau (not online)
- Empirical STZs in development for ~10 species (grass & forbs; many for sage grouse habitat)

Climate Distance Mapper Tool for Southwest:

- Four US Southwest Ecoregions
- Unique Provisional STZs
- Helps guide seed collection & find locations where specific sources of seed may do well
- Incorporates past & future climate, two IPCC climate scenarios
- Empirical STZs for Mojave ecoregion (Ephedra, Globemallow)
- Uses Principle Components Analysis of 12 climate variables, can constrain level of CS
Climate Smart Restoration Tool

**CSRT** – under development:  https://climaterestorationtool.org.

- **Web-based; covers North America**
- **Two Objectives:**
  - Find a project site appropriate for your seedlot, or
  - Find seedlots to supply projects
- **Seedlots can be from, or be directed to, a single geospatial location or within a zone**
- **Must use one or two Time Periods ~Climate:**
  - Current/ Future: 2011 - 2040, 2041 – 2070, 2070 – 2100 - which climate will the seedlot experience?
- **If using future, choose from two possible climate change scenarios:**
  - RCP4.5 or RCP8.5
  - RCP = representative GHG concentration pathway (from IPCC AR5)
- **Options for choosing seed transfer limits: Custom, Zone, or Function**
  - Custom - Enter your own transfer limits for one or more of 16 climate variables climate variables
  - Zone - Use an existing STZ to calculate transfer limits for one or more variables
  - Function - if a species has genecological values & limits are pre-loaded
    - E.g. *Artemisia tridentata var. wyomingensis*  A. tridentata var. vaseyana coming soon.
- **Can apply constraints using SDMs and/or ecoregions e.g. SDM for ARTRW**
- **Maps results; can download and/or save to your account**
Climate Smart Restoration Tool (under development)

Uses the Seedlot Selection Tool framework and offers CSRT differs in its a geocological function.

Workflow: Steps 1
1. Select Objective
   - Seedlots or plantings
   - Planting sites for future climate

2. Select site
3. Select Region
4. Select climate scenario (past, current)
5. Select transfer limit
   - Custom
   - Zone
   - Function

CSRT: function option for sagebrush

6. Select traits
7. Apply constraints (SDM automatically applied)

Apply constraints

<table>
<thead>
<tr>
<th>Name</th>
<th>Value</th>
<th>Range (+/-)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Wyoming big sagebrush</td>
<td>1861 - 2010</td>
<td></td>
</tr>
</tbody>
</table>

Map your Results

Run Tool

B. Richardson slides
Focal point seed transfer: examples of use

Notify seed coordinator or vendors of where seed collection is needed based on specific sites.

Use of change projections

CSRT will also to the climatic seed transfer: precision

Long-term strategies: look for warmer adapted spp? Rescue existing seed for elsewhere?

B. Richardson slides
Seed Selector & Climpart Tools

Seed Selector & Climpart:

- Web-based or use offline; global extent; Open-source R code
- Helps guide seed collection from climatically under-collected areas
  - User can upload data points of inventory sources
- Helps prioritize seed source choice/s for projects
  - E.g. from commercial &/or wildland sources
- Partitions geospatially by climate similarity (gradients) for other purposes
- Uses Provisional and species-specific STZs
  - 12 SDM-constrained Climate Similarity Zones available to date
    - For CP only; not yet online
- Adjustable weighting of climate variables
  - Worldclim Bioclimatic data (Hijmans et al., 2005)
  - Seven uncorrelated variables
- Genecological (Empirical) STZs in development for 12 species:
  - Western wheatgrass, Astragalus longocarpus, Bottlebrush squirreltail, Yellow & Rocky mountain beeplants, Blue grama, Tanseyaster, Sand dropseed, Smallflower globemallow, Galleta grass, Manyflower sunflower, Hairy false goldenaster
  - Mostly for CP Region, but collaborating more broadly for some (western wheatgrass)
- Maps & displays downloadable results
- Future directions –
  - incorporate future climate
  - add more environmental information, e.g. soils
Seed Selector Tutorial – Graphical Layout

Controls

Tabs for addition features

Interactive Map

https://www.worldclim.org/bioclim
Seed Selector Tutorial—Overlay Products
Seed Selector Tutorial – Assessing Similarity

Climate properties

Properties
- Long: -113.80737
- Lat: 41.26955
- MAT: 9.5
- DiurnalRange: 14.6
- TSeasonality: 9234
- TWettestQtr: 13.7
- MAP: 197
- PSeasonality: 29
- PWarmestQtr: 56

Similarity Rankings
1) gamma (96)
2) beta (82)
3) zeta (81)
4) eta (80)
5) alpha (75)
6) epsilon (70)
7) delta (70)

Values = similarity

Ranked list of accessions
# Seed Selector Tutorial – Accession Climate Data

## ID’s Coordinates

<table>
<thead>
<tr>
<th>ID</th>
<th>Longitude</th>
<th>Latitude</th>
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<tbody>
<tr>
<td>alpha</td>
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<tr>
<td>beta</td>
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<tr>
<td>eta</td>
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## Climate Properties

<table>
<thead>
<tr>
<th>MAT</th>
<th>DiurnalRange</th>
<th>TSeasonality</th>
<th>TWettestQtr</th>
<th>MAP</th>
<th>PSeasonality</th>
<th>PWarmestQtr</th>
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</thead>
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<tr>
<td>6.8</td>
<td>16.4</td>
<td>7506</td>
<td>-2.0</td>
<td>299</td>
<td>28</td>
<td>55</td>
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<td>6.9</td>
<td>15.0</td>
<td>8785</td>
<td>10.9</td>
<td>388</td>
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<td>9.9</td>
<td>14.3</td>
<td>9315</td>
<td>14.1</td>
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<td>59</td>
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<td>15.7</td>
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<tr>
<td>10.1</td>
<td>17.8</td>
<td>8114</td>
<td>8.7</td>
<td>204</td>
<td>24</td>
<td>41</td>
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</tbody>
</table>
Click to start analysis
Climpart Tutorial -- Increasing Partition Number

Results from 5 partitions

Results from 15 partitions

Results from 30 partitions
Climpart Tutorial – Assessing Partitions

Switch plotted variables

Center 2 MAT Distribution
Climpart Tutorial – Weighting Variables

**Equal Weights**

- **Mean Annual Temperature**
- **Diurnal Range**
- **Temperature Seasonality**
- **Temperature Wettest Qtr.**
- **Mean Annual Precipitation**
- **Precipitation Seasonality**
- **Precipitation Warmest Qtr.**

**Only MAT and MAP**

- **Mean Annual Temperature**
- **Diurnal Range**
- **Temperature Seasonality**
- **Temperature Wettest Qtr.**
- **Mean Annual Precipitation**
- **Precipitation Seasonality**
- **Precipitation Warmest Qtr.**
Seed Selector Offline Instructions

Step 1: Install Required Software

R Programming Language
R Studio IDE
GDAL(Windows Install, MacOS Install Part 1, MacOS Install Part 2)

Step 2: Install R Packages

After installing the required software, open R Studio and run the following to install the required R package dependencies:

```r
install.packages(
  c("rgdal","rgeos","raster","sp","shiny",
    "gdalUtils","data.table","leaflet",
    "shinyWidgets","htmlWidgets","tidyverse",
    "shinyalert","ClusterR","matrixStats",
    "RLeafShiny")
)
```

Step 3: Download Climate Data

Download the climateMerc.tif.zip from this location, then unzip the contents to your working directory. Run the following to check if the file is in your working directory:

```r
file.exists('climateMerc.tif')
```

Step 4: Execute the Source Code for the App
Climate Distance Mapper Tool:

- Uses **unique** Provisional STZs developed for four US Southwest Ecoregions
  - Southern Great Basin, Colorado Plateau, Mojave, Sonoran Ecoregion
  - 10 separate zones per Ecoregion
  - By default constrains by Ecoregion
- Defines & prioritizes seed planting and collection zones
- Calculates & maps climate similarity distances from one or many points
- Uses Principle Components Analysis of 12 climate variables (Shryock et al 2018 for details)
- Includes current and future climates
- Uses two IPCC RCP climate scenario projections
- Empirical STZs for Mojave ecoregion
  - Ephedra, Globemallow; Plantago soon
- User can constrain level of Climate Similarity (i.e. transfer limits) by percent
- Maps and downloads results
WERC Provisional Seed Transfer Zones

- Includes 12 climate variables

## Comparison of Provisional Seed Transfer Zones

### USGS Provisional Seed Zones
**Shryock et al. 2018**

#### Time period
- Current climate
- 2040-2070 RCP4.5 and RCP8.5

#### Climate Variables
- **Precipitation:**
  - Mean annual ppt.
  - Winter ppt.
  - Summer ppt.
  - Ppt. seasonality
  - Winter / Summer ppt. ratio
  - Long-term ppt. variability

- **Temperature:**
  - Mean annual temp.
  - Summer max temp.
  - Winter min temp.
  - Temp. seasonality
  - Annual temp. range

#### Method:
- Principal components analysis (PCA) followed by hierarchical clustering
- Accounts for covariation, natural breaks in climate

### USFS Provisional Seed Zones
**Bower et al. 2014**

#### Time period
- Current climate

#### Climate Variables
- Aridity index (MAT / MAP)
- Winter minimum temperature

#### Method:
- Combination of ordinal classes
Coverage for four regions:
- Mojave Desert
- Sonoran Desert
- Colorado Plateau
- Southern Great Basin

Climate data includes:
- 12 climate variables (precipitation and temperature)
- Current and future climate
  - 1980-2010
  - 2040-2070
  - RCP4.5 and RCP8.5
  - Coming soon: 2010-2040

https://usgs-werc-shinytools.shinyapps.io/Climate_Distance_Mapper/
Key features:

- View climate distances
- Define seed planting and collection zones
- Guide sample collections
- Future climate projections for all types of output
- Online help pages and tutorial

https://usgs-werc-shinytools.shinyapps.io/Climate_Distance_Mapper/
## Tool Comparison

<table>
<thead>
<tr>
<th>Tool Similarities &amp; Differences</th>
<th>CSRT</th>
<th>SS &amp; C</th>
<th>CDM 4 SW</th>
</tr>
</thead>
<tbody>
<tr>
<td>Online (Web-based)</td>
<td>Y, soon. Individual account</td>
<td>Y</td>
<td>Y</td>
</tr>
<tr>
<td>Offline (code free &amp; downloadable)</td>
<td>N</td>
<td>Y</td>
<td>N</td>
</tr>
<tr>
<td>Geographic extent</td>
<td>N. America</td>
<td>Global</td>
<td>4 US SW Ecoregions</td>
</tr>
<tr>
<td>Finds project site/s for seed source</td>
<td>Y</td>
<td>Y</td>
<td>Y</td>
</tr>
<tr>
<td>Finds seed source/s for project site</td>
<td>Y</td>
<td>Y</td>
<td>Y</td>
</tr>
<tr>
<td>Ranks seed source options</td>
<td>Y</td>
<td>Y</td>
<td>Y</td>
</tr>
<tr>
<td>Transfer limits for one or more location/s</td>
<td>One</td>
<td>&gt;one, upload</td>
<td>&gt;one, upload</td>
</tr>
<tr>
<td>Includes future climate scenarios</td>
<td>Y; plus RCPs</td>
<td>N</td>
<td>Y; plus RCPs</td>
</tr>
<tr>
<td>Climate variable source</td>
<td>PRISM; Climate WNA</td>
<td>Worldclim</td>
<td>PRISM; ClimateNA</td>
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<tr>
<td>Climate variables used</td>
<td>16</td>
<td>7; selected via PCA</td>
<td>12</td>
</tr>
<tr>
<td>Climate variables processed</td>
<td>N</td>
<td>N</td>
<td>Y, PCA</td>
</tr>
<tr>
<td>Transfer limit options</td>
<td>Y</td>
<td>Y</td>
<td>Y</td>
</tr>
<tr>
<td>Constraint by SMD or Ecoregion</td>
<td>Y</td>
<td>Y</td>
<td>Y</td>
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<tr>
<td>Species-specific PSTZs</td>
<td>ARTRW SDM</td>
<td>Y, 12 avail. For CP; N</td>
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<tr>
<td>Empirical (genecological) STZs</td>
<td>Y ARTRW, ARTRV soon in development</td>
<td>2 for Mojave ecoregion</td>
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<td>Trait selection</td>
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<td>N</td>
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<tr>
<td>Climate similarity Weighting</td>
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<td>Geospatial climate partitioning</td>
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<tr>
<td>Online Instructions</td>
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<td>Y (Tutorial videos)</td>
<td>Y</td>
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<tr>
<td>Ease of use</td>
<td>?</td>
<td>?</td>
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<tr>
<td>Speed</td>
<td>?</td>
<td>?</td>
<td>?</td>
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<tr>
<td>Long-term support (funding, staff)</td>
<td>?</td>
<td>?</td>
<td>?</td>
</tr>
<tr>
<td>Cost to build</td>
<td>?</td>
<td>less</td>
<td>?</td>
</tr>
</tbody>
</table>

*Not radical differences in climate similarity results*
Needs, Wants, Future Actions?

- Publish a **comparative review** of these three with examples (there are more!), perhaps dichotomous key (which one do I use?)
  - Proposed Seed Sourcing Tool session / workshop at NAU’s Biennial Conference of Science & Management, September 9-12, 2019

- Do Beta **testing with variety of users** & Power users (e.g. BLM, WRI)

- **Inter-application collaboration** – species, workshops, user needs compilations, funding, tech support, code, bug fixes, improvements, etc.
  - Interdisciplinary Seed-Sourcing Tools Committee/s with agency/entity support. Different consumers have different needs.

- Host **hands-on workshops** for collectors, producers, buyers, practitioners

Questions? Adrienne Pilmanis 801-539-4076, apilman@blm.gov
Online Resources

- Climate Smart Restoration Tool: https://climaterestorationtool.org
  - Seedlot Selection Tool: https://seedlotselectiontool.org/sst/

  - Seed Selector: https://seedmapper.shinyapps.io/seed_selector/
  - Climpart: https://seedmapper.shinyapps.io/climpart/

- Climate Distance Mapper Tool for Southwest: https://www.usgs.gov/media/images/climate-distance-mapper-0
Primary Citations:


Thanks to Tool authors for content!

- **Bryce Richardson**, USFS Rocky Mountain Research Station, Grassland Shrubland and Desert Ecosystems (brichardson02@fs.fed.us)
  - Sagebrush Genetics Team (Nancy Shaw et al)
  - CSRT Team (Brad St. Clair et al)

- **Kyle Doherty**, Northern Arizona University (kd498@nau.edu)
  - Brad Butterfield, NAU & Troy Wood
  - USGS Southwest Biological Sciences Center

- **Dan Shryock**, USGS Western Ecological Research Center (dshryock@usgs.gov)
  - WERC Team

*Tool Authors did not have opportunity to review this presentation due to condensed preparation time after federal government shutdown. Any errors are my own*
What is climate similarity?

Doherty et al. 2017

Climate conditions

Point of interest
Applications of Climate Similarity—Assignment Process

Hijmans et al. 2005
Doherty et al. 2017
CRST zones for ARTRW vs. PSTZs

Provisional Seed Transfer Zone
Bower et al 2014, etc.

Empirical STZ using CRST with ARTRW SDM
Richardson and Chaney 2018, etc.

Scientific rationale to use fewer zoned seed sources than expect based on climate alone - assumptions and other scientific jargon applies, read fine print, take-home message useful as guidance

B. Richardson slides
Using Species-specific PSTZs

2016 CPNPP Seed Collection Guidance

Select Species

Cleome lutea
Submit

Map
Collection Needs

- Light Basemap
- Terrain
- Fancy
- Zone Maps
- Field Offices
- Occurrence Records

CLLU2 Climate Zone

Climate Similarity

-0.55
-0.70
-0.75
-0.80
-0.85
-0.90
-0.95