



Tree Genetics and Climate Change Adaptation

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***Climate Change Adaptation & Durango's Community
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for the greatest good

Plants are adapted to local climates



Every species, every population, every individual plant has a range of climates in which it can best survive, grow and reproduce



Because of natural selection at a location, we can assume that plants are adapted to their local climate

But climates are changing, which affects adaptation

Populations are genetically adapted to historic climate

warm

And mismatched with future climate

cool

Temperature gradient

warm



Adaptation of species vs populations

Environmental Niche Modelling:

Modelling to predict the distribution of species in geographic space based on their known distribution in environmental space (their realized ecological niche)

- *Also called climatic niche modelling, species distribution modelling, predictive habitat distribution modelling, and climate envelope modelling.*
- *A correlative process*
- *Criticism that it does not always reflect actual species distribution.*
- *Actual distribution may depend on a number of other factors including dispersal ability, evolutionary history, biotic interactions.*

Error rates:

Predict absent, but present 0.5%

Predict present, but absent 5.4%

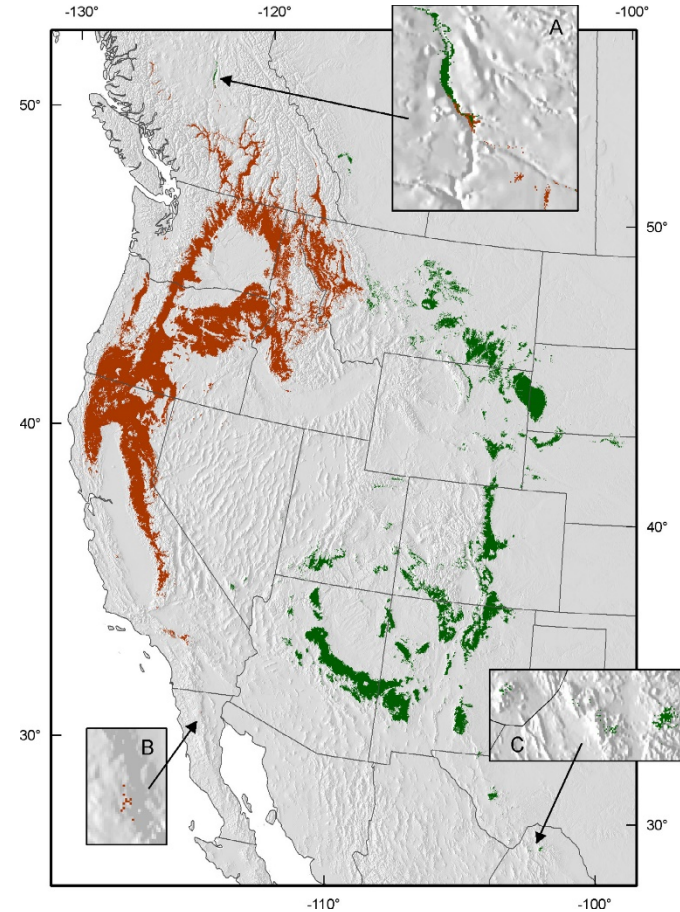
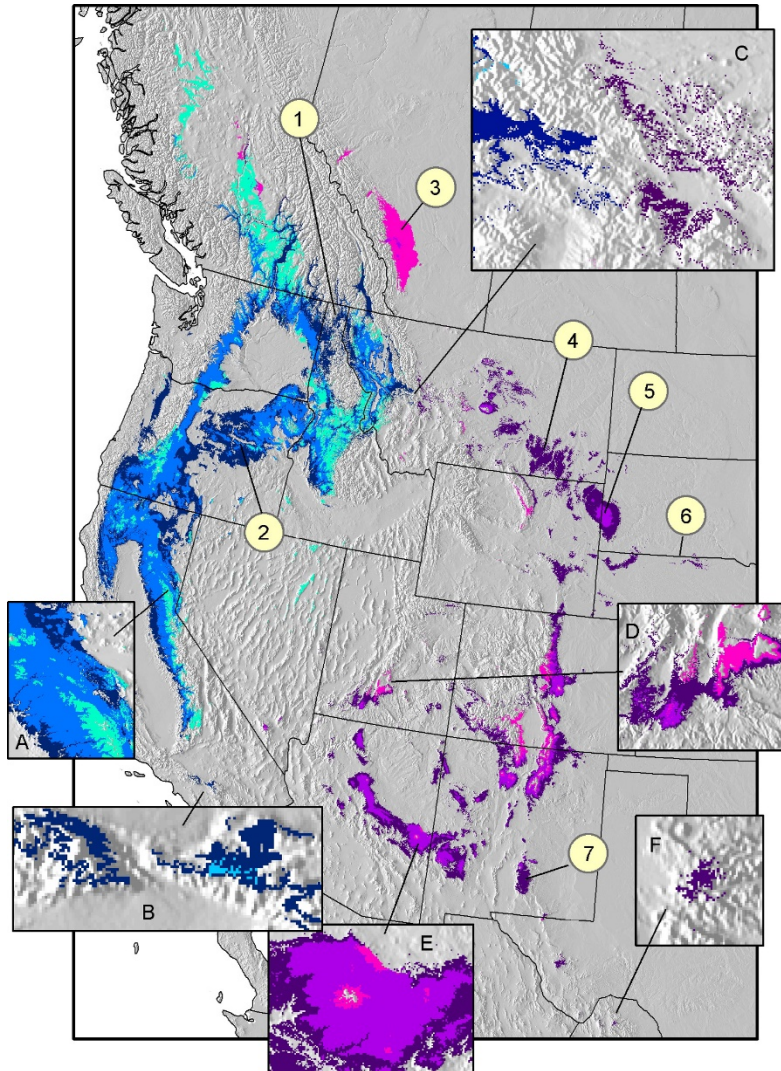


Fig. 3: Mapped prediction for climate niche for *Pinus ponderosa* var. *ponderosa* (brown) and var. *scopulorum* (green)

Rehfeldt et al. 2014. Comparative genetic responses to climate for varieties of *Pinus ponderosa* and *Pseudotsuga menziesii*: Realized climate niches. *Forest Ecology and Management* 324: 126-137

Predicted climatic niches by 2060 for *Pinus ponderosa* varieties



	Habitat lost (dark color)	Remains suitable (middle color)	Habitat gained (light color)
var. ponderosa (blues)	45%	55%	36%
var. scopulorum (purples)	77%	23%	53%

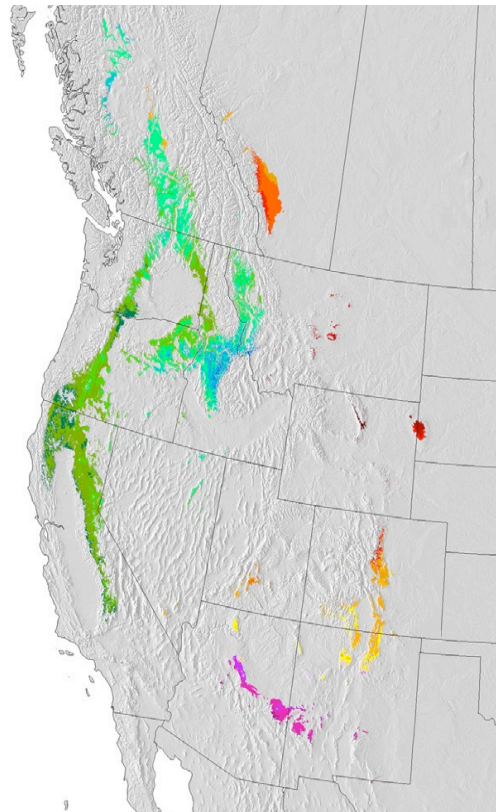
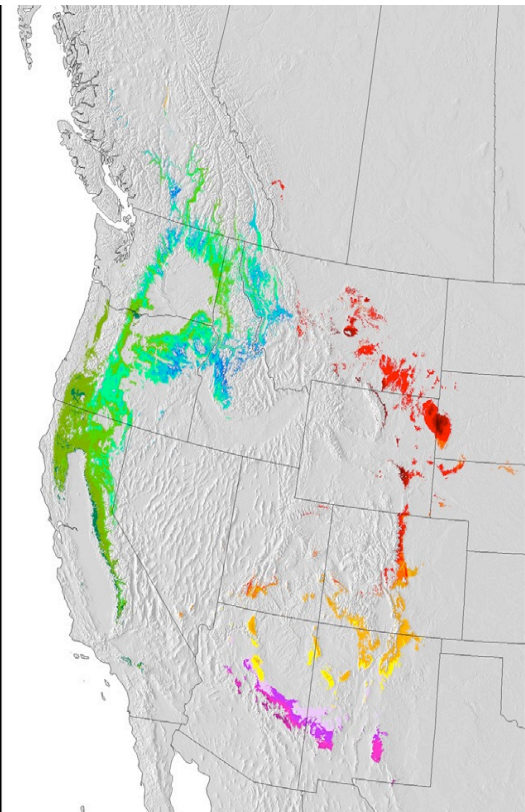
- *Habitat is lost at the trailing edge (lower elevations and further south)*
- *Gained at the leading edge (higher elevations and further north)*

Rehfeldt et al. 2014. Comparative genetic responses to climate for varieties of *Pinus ponderosa* and *Pseudotsuga menziesii*: Realized climate niches. *Forest Ecology and Management* 324: 126-137

Populations variation: Clines in growth potential within current and future (2060) climatic niches

Year 2000

Year 2060



	Remaining suitable from today	Current climatype suitable through 2060
var. ponderosa (dark green = high growth, Dark blue = low	64%	25%
var. scopulorum Magenta = high growth, Dark red = low	47%	8%

Rehfeldt et al. 2014. Comparative genetic responses to climate for varieties of *Pinus ponderosa* and *Pseudotsuga menziesii*: Clines in growth potential. *Forest Ecology and Management* 324: 138-146.

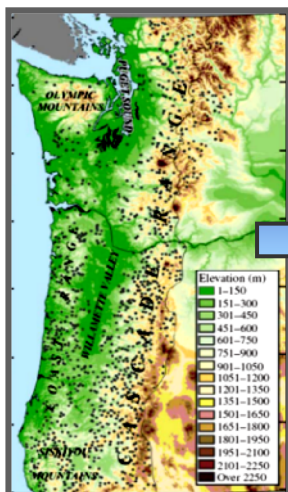


Seed Source Considerations

1. Genetic variation across the landscape tracks climatic gradients = evidence for adaptation

Douglas-Fir Genecology Study

Collect seed from many trees



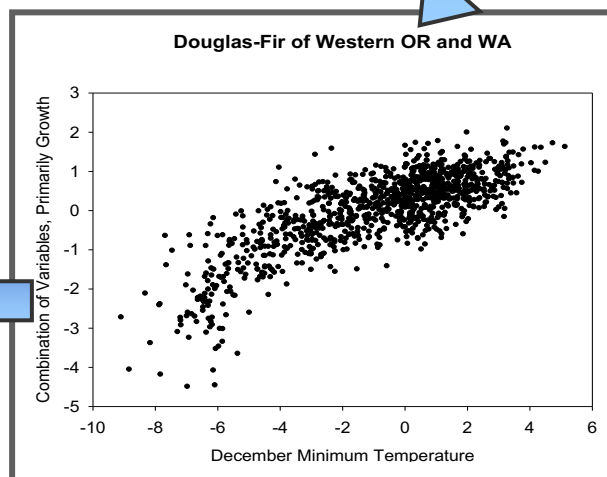
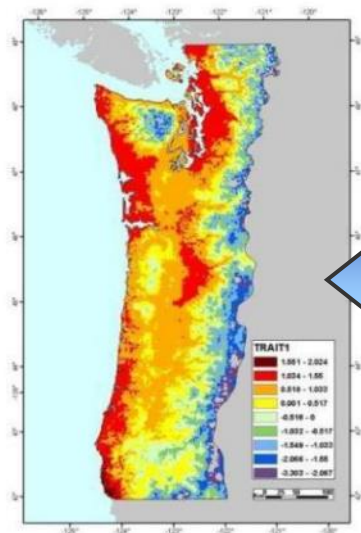
Grow families in a common environment



Measure many adaptive traits



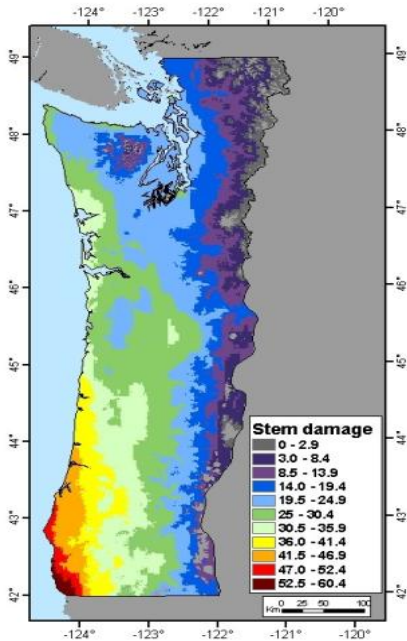
GIS



Traits vs source environment

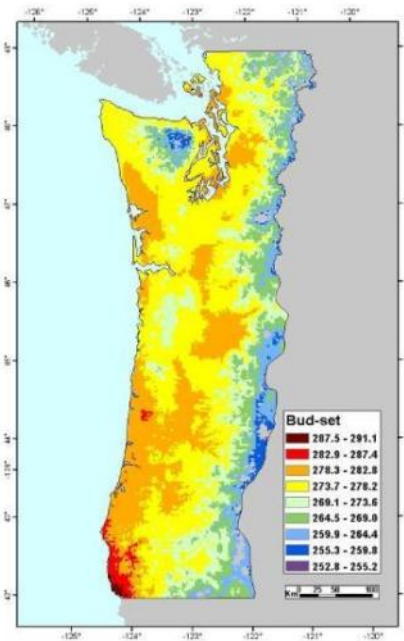
St.Clair et al. 2005. Genecology of Douglas-fir in western Oregon and Washington. *Annals of Botany* 96: 1199-1214.

Fall cold damage



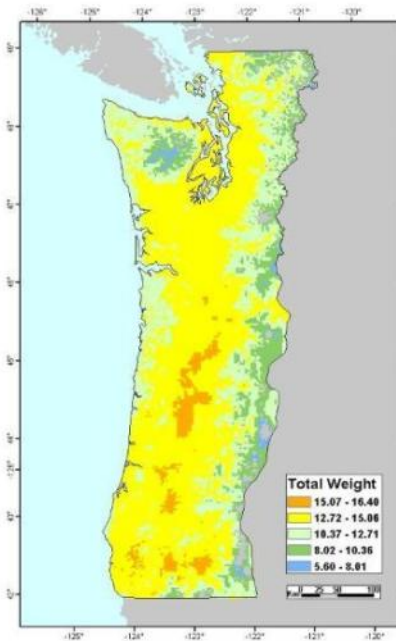
Qst = 0.68
r = 0.79

Bud-set



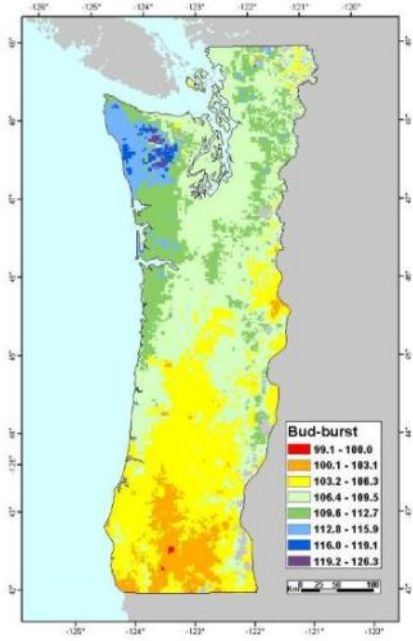
Qst = 0.29
r = 0.76

Biomass



Qst = 0.13
r = 0.52

Bud-burst



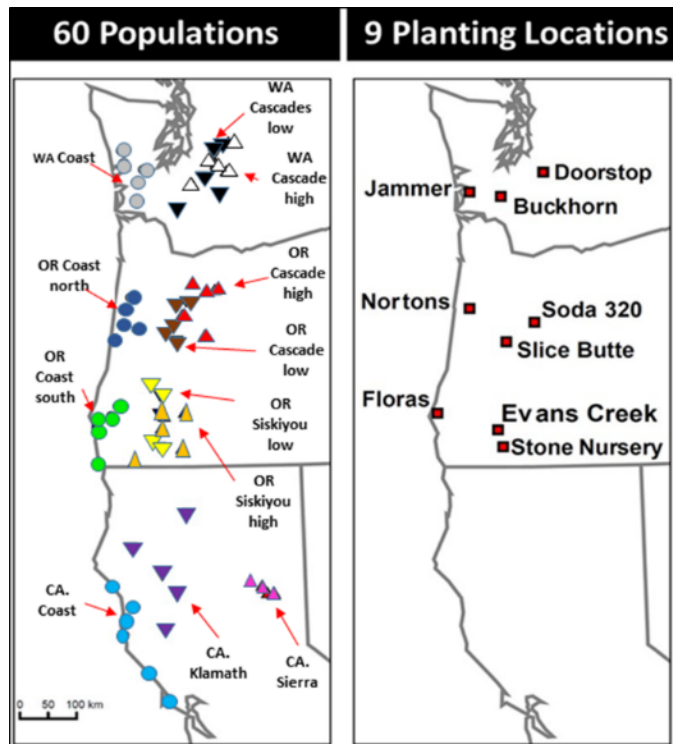
Qst = 0.21
r = 0.60

1. Populations differ
2. Traits are correlated with source environments
3. Relationships make sense

Different traits show different patterns and scales of adaptation

2. Field tests indicate that forest trees are often adapted to local climates

Douglas-Fir Seed Source Movement Trial



Doorstop (WA high elevation):
Coldest, wettest site
Mean cold temp = 34° F
Mean warm temp = 59° F
Annual precip = 72 in



Buckhorn (WA low elevation):
Intermediate site
Mean cold temp = 39° F
Mean warm temp = 64° F
Annual precip = 59 in



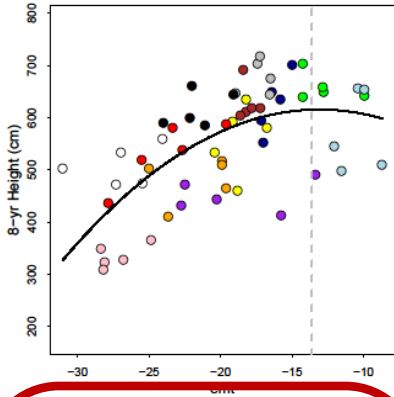
Stone (OR low elevation):
Warmest, driest site
Mean cold temp = 39° F
Mean warm temp = 72° F
Annual precip = 20 in

Can address:

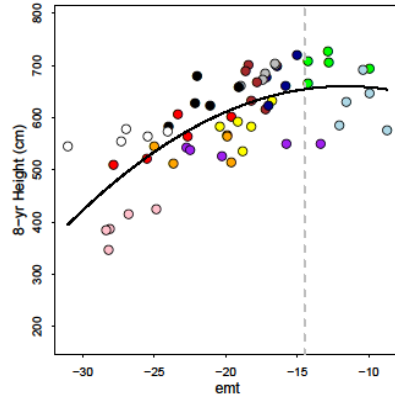
1. *Are local populations best?*
2. *How local is local? = transfer limits*
3. *Which climate variables are driving adaptation.*

emt shared y axis

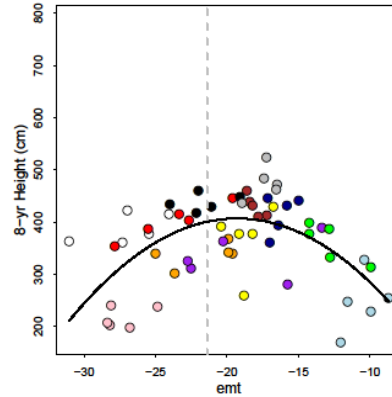
Jammer 3



Buckhorn 2

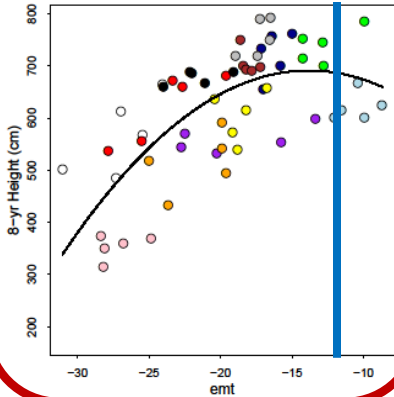


Doorstop

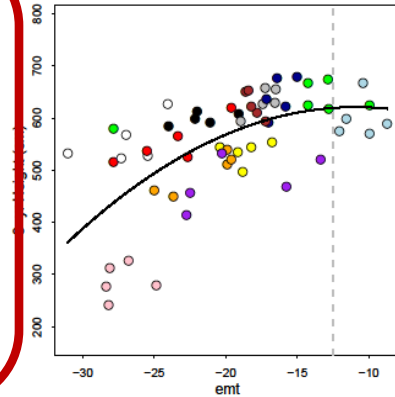


8-year Height (cm)

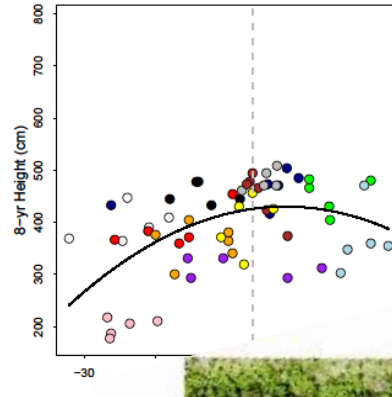
Nortons



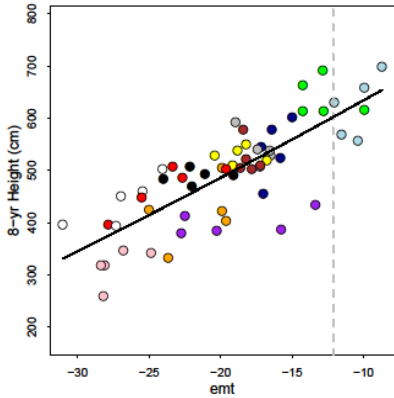
Slice Butte



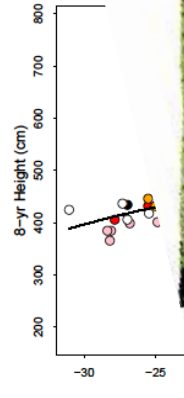
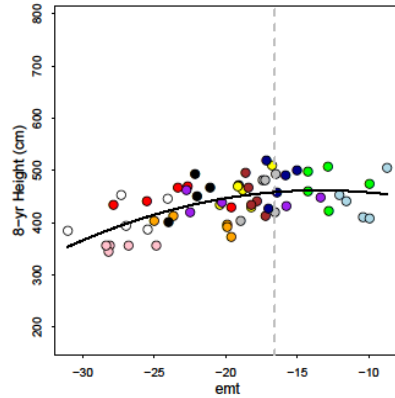
Soda 320



Floras



Stone Nursery



Populations are locally adapted:
 at all sites, sources from climates similar to the test site are among the tallest

Nortons Test Site:
 Warm, coastal site
 EMT = -11.5 °C



Extreme Minimum Temperature (°C)

3. *Species show different patterns and degrees of adaptation*

Distance needed to detect genetic differences in Northern Rockies (Rehfeldt 1994)

Species	Elev. (m)	Frost-free days	Evolutionary mode
Douglas-fir	200	18	Specialist
Lodgepole pine	220	20	Specialist
Engelmann spruce	370	33	Intermediate
Ponderosa pine	420	38	Intermediate
Western larch	450	40	Intermediate
Western redcedar	600	54	Generalist
Western white pine	none	90	Generalist

4. Climates are changing and local populations may no longer be adapted.

Three questions:

1. Are native populations adapted to current and future climates?
2. If not, how far do we have to go to find populations adapted to a planting site (assisted migration)?
3. How far should we move a population to ensure that it continues to exist?



Depends on:

1. Which climate factors are most important for adaptation?
2. How far climatically one can move populations before growth and survival are unacceptable?

Seedlot Selection Tool

Planting Healthy Forests

The seedlot selection tool (SST) is a GIS mapping program designed to help forest managers match seedlots with planting sites based on climatic information. The climates of the planting sites can be chosen to represent current climates, or future climates based on selected climate change scenarios.

- 1. Select Objective**
You can find seedlots for your planting site or planting sites for your seedlot
- 2. Select Location**
You can click on the map or enter coordinates to locate your seedlot or planting site
- 3. Select Climate Scenarios**
You can select historical, current, or future climates for your seedlots of planting sites
- 4. Select Transfer Limit Method**
You can use an existing zone to calculate a transfer limit or enter your own custom limit
- 5. Select Species**
You can use species-specific or generic zones and transfer limits
- 6. Select Zone**
If you use the zone method, you can select among the available zones for your location
- 7. Select Climate Variables**
You can use a variety of climate variables to match your seedlot and planting site
- 8. Map your Results**
The map shows where to find appropriate seedlots of planting sites

<https://seedlotselectiontool.org/sst/>

Three questions:

- 1. Are native populations adapted to current and future climates?***
- 2. If not, how far do we have to go to find populations adapted to a planting site (assisted migration)?***
- 3. How far should we move a population to ensure that it continues to exist?***

Can address two objectives:

Given a planting site

Which seedlot is well adapted today...or in the future?



Find



Given a seedlot

Where is it well adapted today...or in the future?



Find



Seedlot Selection Tool is a powerful tool for:

- Matching seedlots to planting sites
- Characterizing past, current, and future climates at a site
- Illustrating the potential concerns about climate change
- Seed planning given climate change concerns

Seedlot Selection Tool Example

About Tool Layers Saved Runs

1 Select objective

Find seedlots Find planting sites

2 Select planting site location

Locate your planting site
Use the map or enter coordinates

Lat: 37.2411 Lon: -107.8642

Elevation: 6562 ft (2000 m)

3 Select region

Automatic Custom

Region: Western US

4 Select climate scenarios

Which climate are the seedlots adapted to?

1961 - 1990

When should trees be best adapted to the planting site?

1961 - 1990

5 Select transfer limit method

Custom Zone

6 Select climate variables

Units: Metric Imperial

Add a variable...

7 Apply constraints

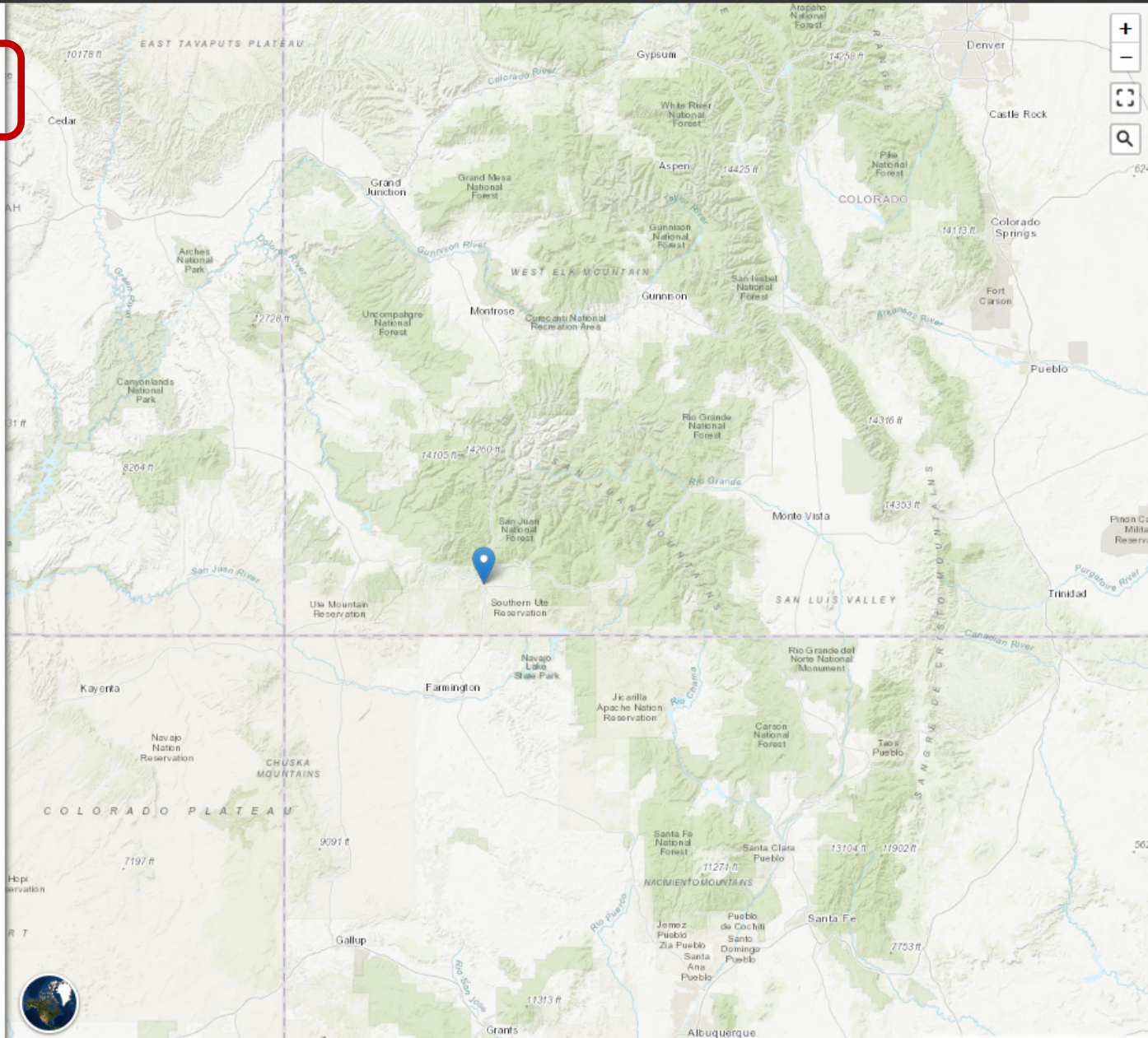
Select...

8 Map your Results

Run Tool

Save Last Run

Export As...



Select location of planting site

About Tool Layers Saved Runs

1 Select objective

Find seedlots Find planting sites

2 Select planting site location

Locate your planting site
Use the map or enter coordinates

Lat: Lon:

3 Select region

Automatic Custom

Region: N/A

4 Select climate scenarios

Which climate are the seedlots adapted to?

1961 - 1990

When should trees be best adapted to the planting site?

1961 - 1990

5 Select transfer limit method

Custom Zone

6 Select climate variables

Units: Metric Imperial

Add a variable...

7 Apply constraints

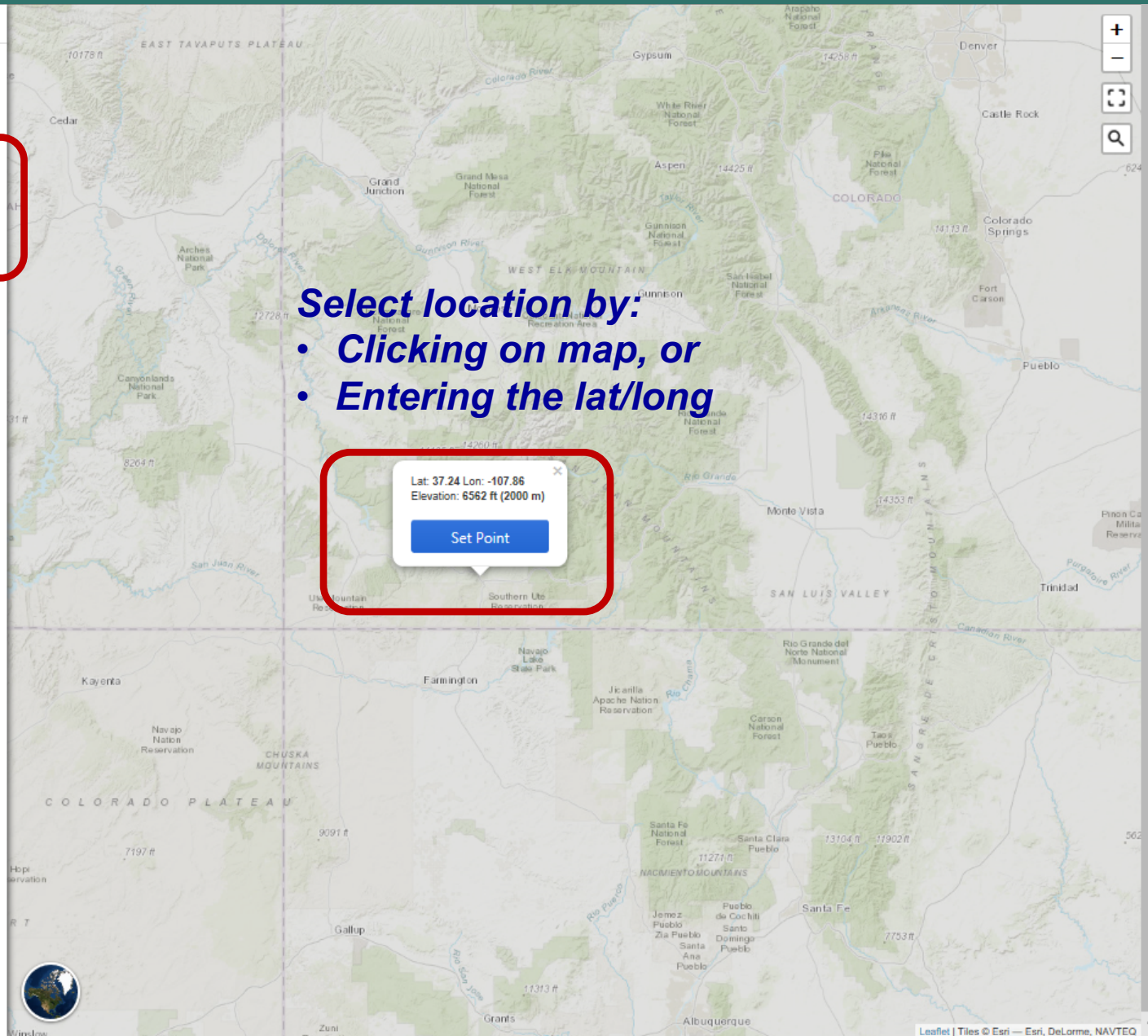
Select...

8 Map your Results

Run Tool

Save Last Run

Export As...



Select location by:

- Clicking on map, or
- Entering the lat/long

Lat: 37.24 Lon: -107.86
Elevation: 6562 ft (2000 m)

Set Point

Select region (use automatic)

About Tool Layers Saved Runs

1 Select objective

Find seedlots Find planting sites

2 Select planting site location

Locate your planting site
Use the map or enter coordinates

Lat: 37.2411 Lon: -107.8642

Elevation: 6562 ft (2000 m)

3 Select region

Automatic Custom

Region: Western US

4 Select climate scenarios

Which climate are the seedlots adapted to?

1961 - 1990

When should trees be best adapted to the planting site?

1961 - 1990

5 Select transfer limit method

Custom Zone

6 Select climate variables

Units: Metric Imperial

Add a variable...

7 Apply constraints

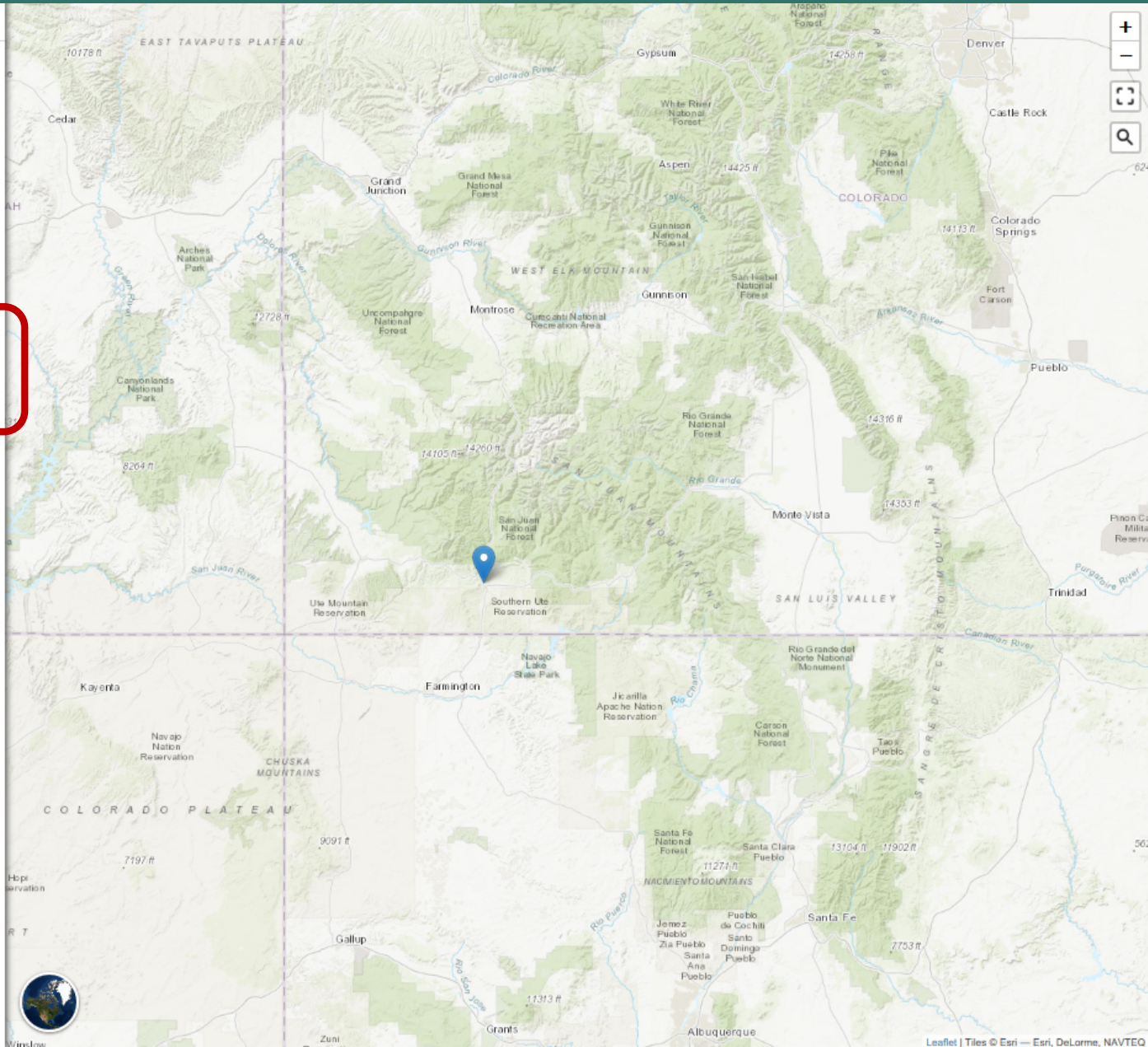
Select...

8 Map your Results

Run Tool

Save Last Run

Export As...



Select climate scenarios

About Tool Layers Saved Runs

1 Select objective

Find seedlots Find planting sites

2 Select planting site location

Locate your planting site
Use the map or enter coordinates

Lat: 37.2411 Lon: -107.8642

Elevation: 6562 ft (2000 m)

3 Select region

Automatic Custom

Region: Western US

4 Select climate scenarios

Which climate are the seedlots adapted to?

1961 - 1990

When should trees be best adapted to the planting site?

1961 - 1990

5 Select transfer limit method

Custom Zone

6 Select climate variables

Units: Metric Imperial

Add a variable...

7 Apply constraints

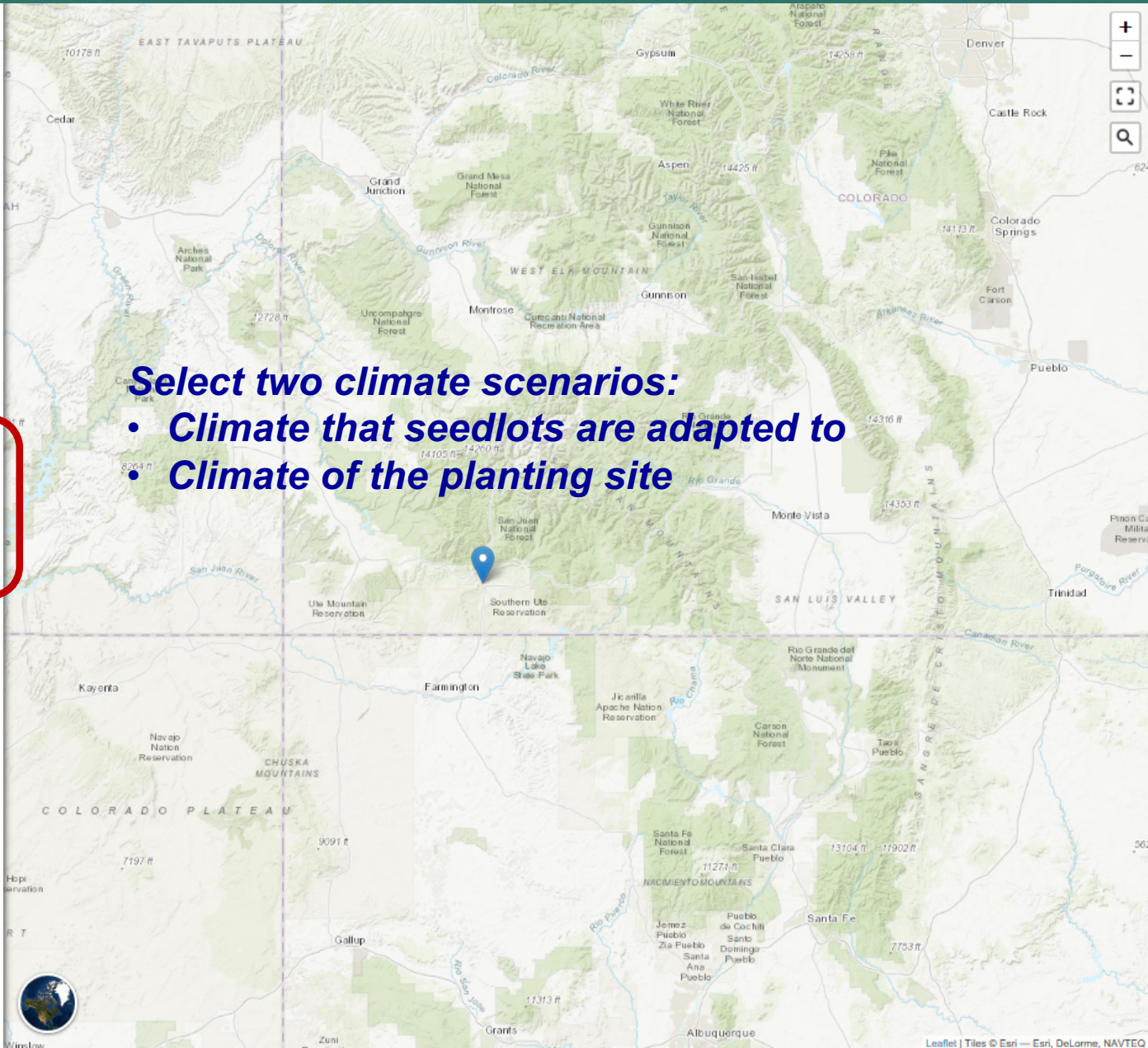
Select...

8 Map your Results

Run Tool

Save Last Run

Export As...



Select two climate scenarios:

- Climate that seedlots are adapted to
- Climate of the planting site

Select transfer limit method

About Tool Layers Saved Runs

1 Select objective

Find seedlots Find planting sites

2 Select planting site location

Locate your planting site
Use the map or enter coordinates

Lat: 37.2411 Lon: -107.8642

Elevation: 6562 ft (2000 m)

3 Select region

Automatic Custom

Region: Western US

4 Select climate scenarios

Which climate are the seedlots adapted to?

1961 - 1990

When should trees be best adapted to the planting site?

1961 - 1990

5 Select transfer limit method

Custom Zone

6 Select climate variables

Units: Metric Imperial

Add a variable...

7 Apply constraints

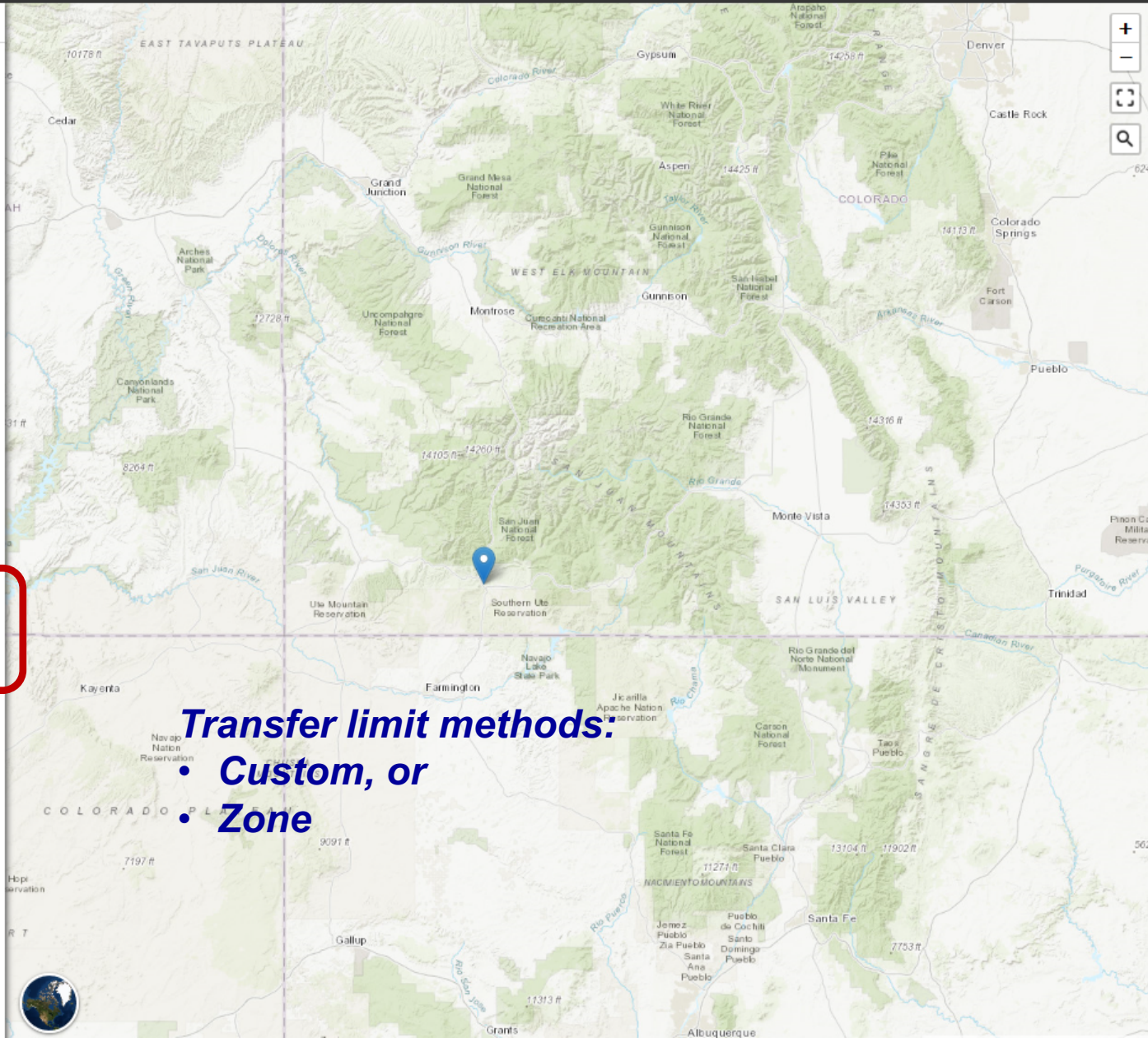
Select...

8 Map your Results

Run Tool

Save Last Run

Export As...



Transfer limit methods:

- Custom, or
- Zone

Using the seed zone method

About Tool Layers Saved Runs

1 Select objective

Find seedlots Find planting sites

2 Select planting site location

Locate your planting site
Use the map or enter coordinates

Lat: 46.8827 Lon: -123.1100

Elevation: 705 ft (215 m)

3 Select region

Automatic Custom

Region: Western US

4 Select climate scenarios

Which climate are the seedlots adapted to?

1961 - 1990

When should trees be best adapted to the planting site?

1961 - 1990

5 Select transfer limit method

Custom **Zone**

Select a species

Generic

Select zone

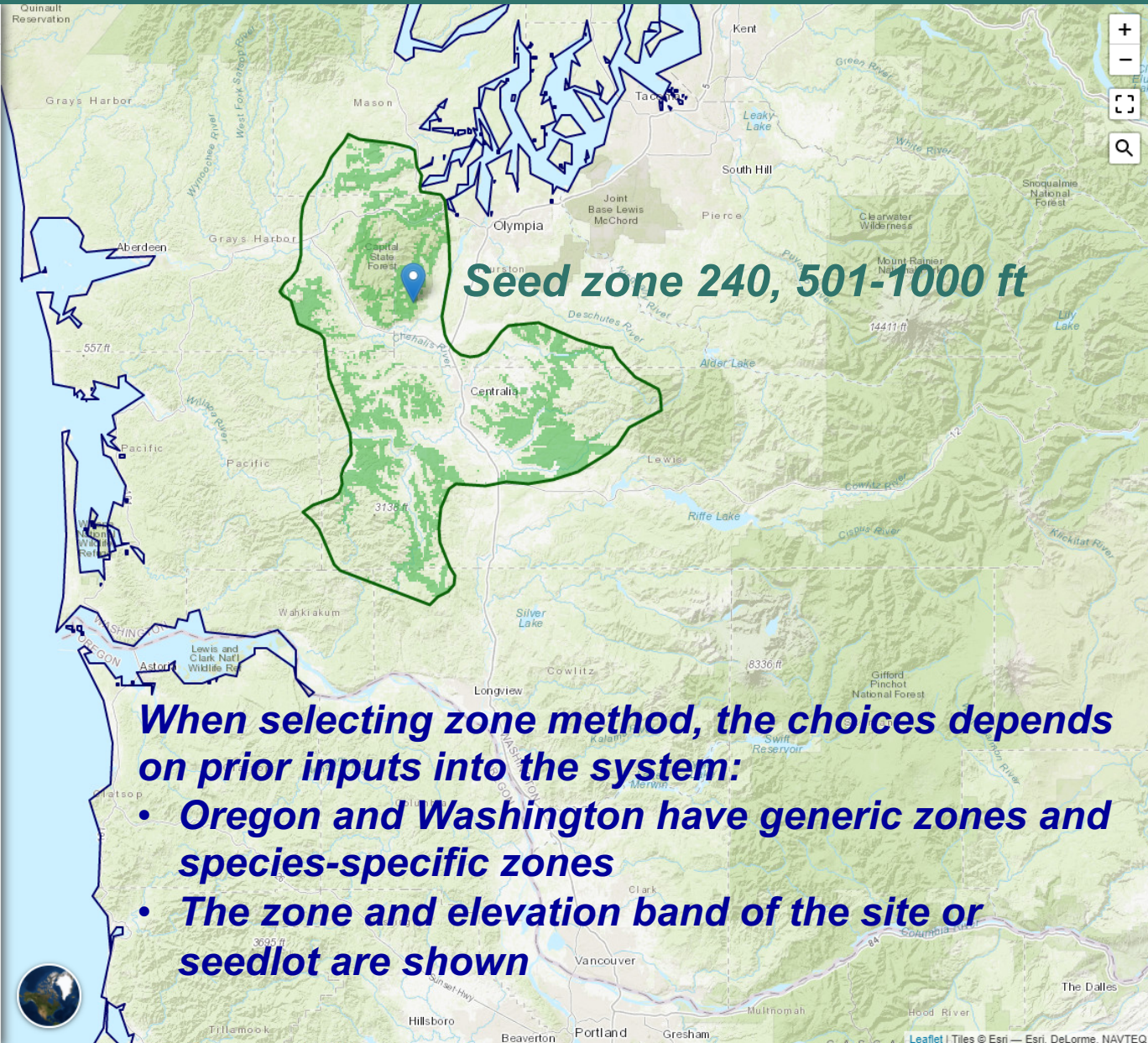
Washington (1966/1973) Zone 240, 501' - 1000'

6 Select climate variables

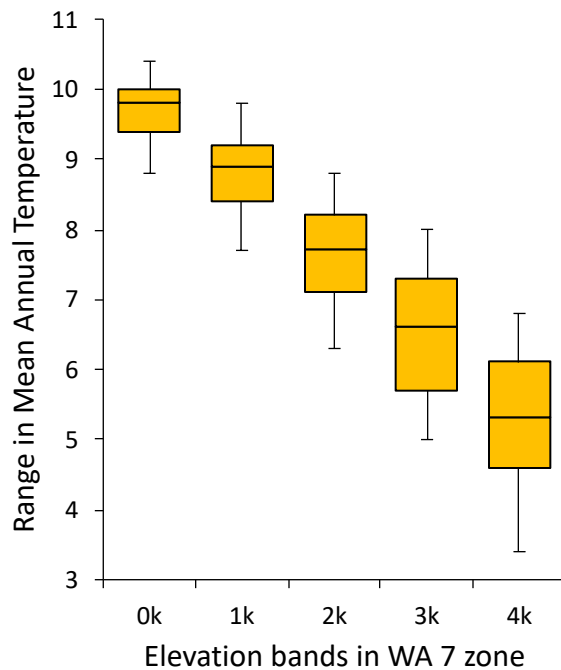
Units: **Metric** Imperial

Add a variable...

7 Apply constraints



Transfer distances based on seed zones



Douglas-fir Seed Zones



Transfer distances in °C mean annual temperature

	25 th – 75 th	5 th – 95 th	Maximum
Zone WA 7 3000-4000'	1.5	3.4	4.2
Average all zones	1.0	2.2	3.2
Greatest all zones (WA 10)	3.6	6.3	8.2

Adjust transfer limits

About Tool Layers Saved Runs

Locate your planting site
Use the map or enter coordinates

Lat: 37.2764 Lon: -107.8822

Elevation: 6529 ft (1990 m)

3 Select region

Automatic Custom

Region: Western US

4 Select climate scenarios

Which climate are the seedlots adapted to?

1961 - 1990

When should trees be best adapted to the planting site?

1961 - 1990

5 Select transfer limit method

Automatic Custom

6 Select climate variables

Units: Metric Imperial

Name	Center	Transfer limit (+/-)
MCMT	-4.6 °C	2.00 °C
MAP	495 mm	100 mm

Add a variable...

7 Apply constraints

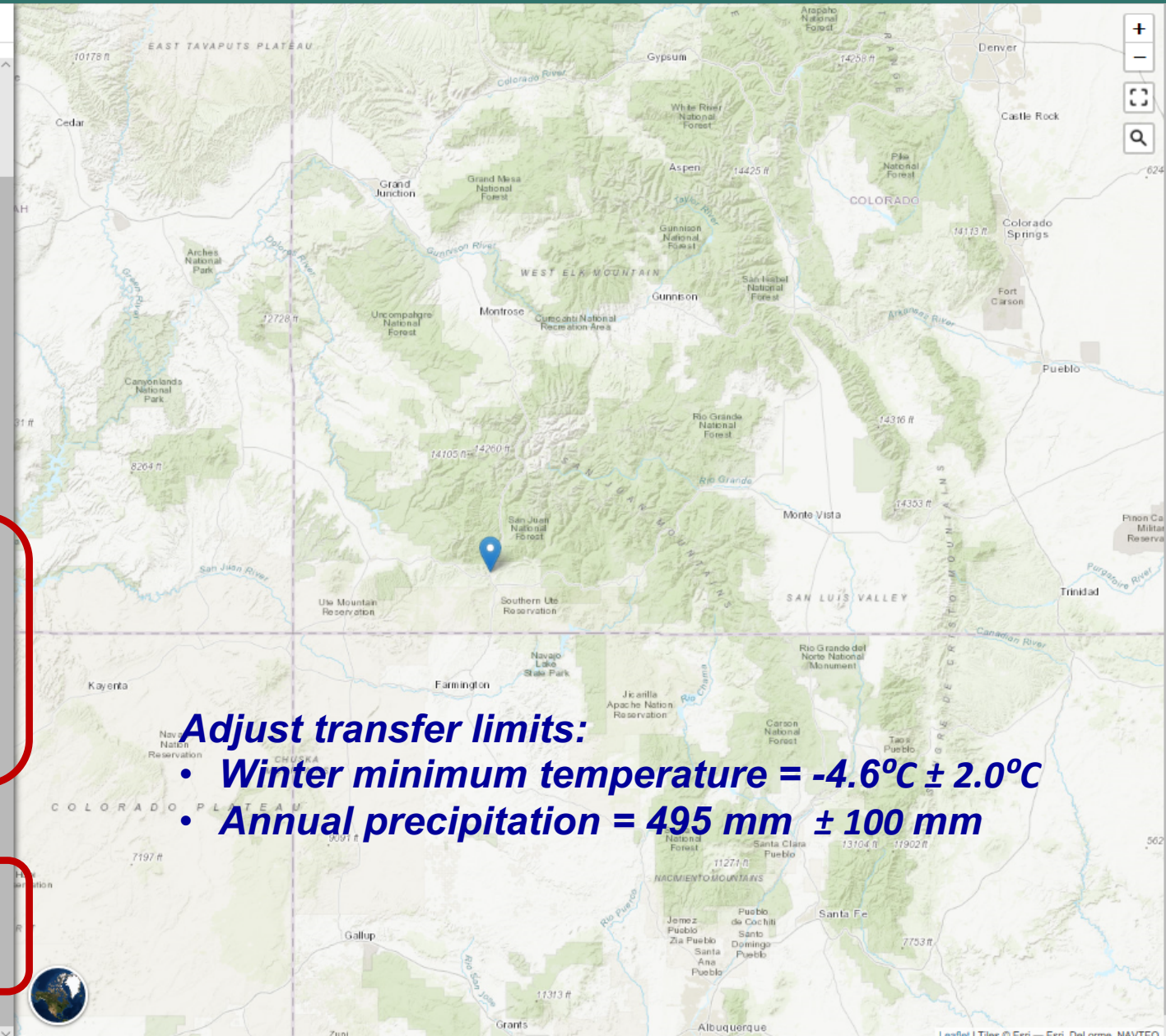
Select...

8 Map your Results

Run Tool

Save Last Run

Export As...



Adjust transfer limits:

- Winter minimum temperature = $-4.6^{\circ}\text{C} \pm 2.0^{\circ}\text{C}$
- Annual precipitation = $495 \text{ mm} \pm 100 \text{ mm}$

Seedlots for planting site - Ignoring climate change

About Tool Layers Saved Runs

Locate your planting site
Use the map or enter coordinates

Lat: Lon:

Elevation: 6529 ft (1990 m)

3 Select region

Region: Western US

4 Select climate scenarios

Which climate are the seedlots adapted to?

When should trees be best adapted to the planting site?

5 Select transfer limit method

6 Select climate variables

Units:

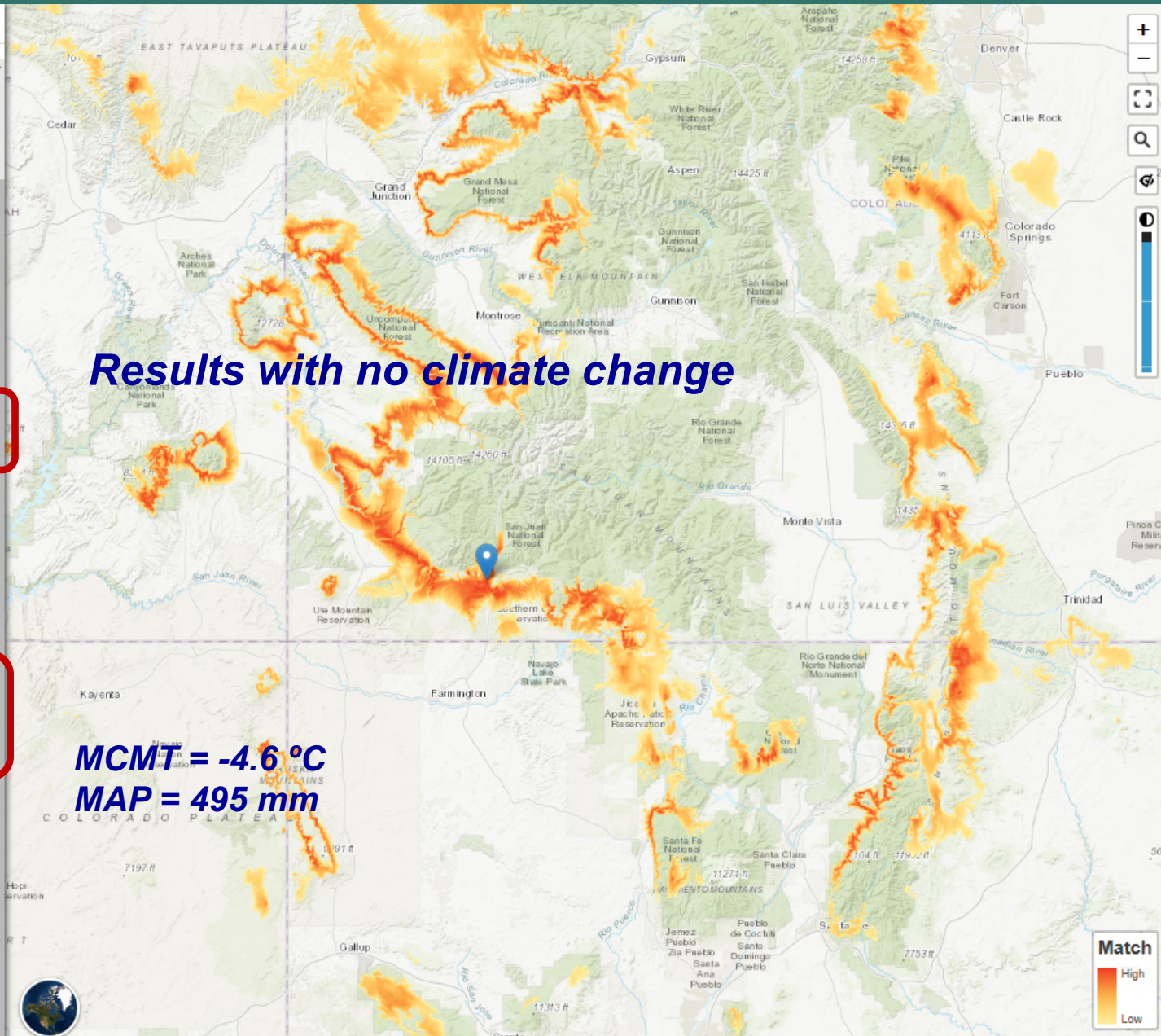
Name	Center	Transfer limit (+/-)
<input type="checkbox"/> MCMT	-4.6 °C	<u>2.00 °C</u>
<input type="checkbox"/> MAP	495 mm	<u>100 mm</u>

Add a variable...

7 Apply constraints

Select...

8 Map your Results



Seedlots for planting site – Recent climate

About Tool Layers Saved Runs

Locate your planting site
Use the map or enter coordinates

Lat: 37.2764 Lon: -107.8822

Elevation: 6529 ft (1990 m)

3 Select region

Automatic Custom

Region: Western US

4 Select climate scenarios

Which climate are the seedlots adapted to?

1961 - 1990

When should trees be best adapted to the planting site?

1981 - 2010

5 Select transfer limit method

Custom Zone

6 Select climate variables

Units: Metric Imperial

Name	Center	Transfer limit (+/-)
MCMT	-3.3 °C	2.00 °C
MAP	495 mm	100 mm

Add a variable...

7 Apply constraints

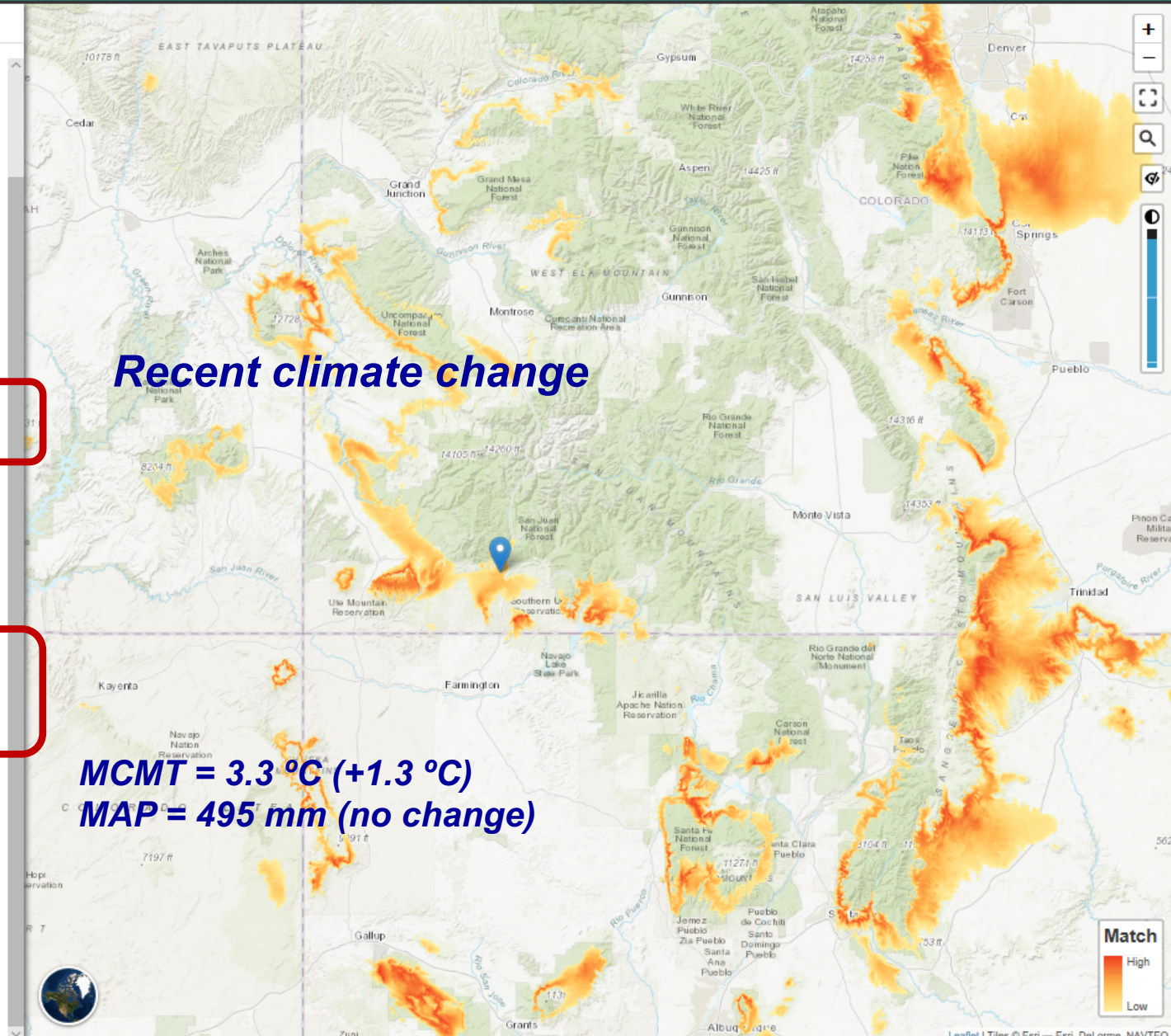
Select...

8 Map your Results

Run Tool

Save Last Run

Export As...



Seedlots for planting site – 2020s climate

About Tool Layers Saved Runs

Locate your planting site
Use the map or enter coordinates

Lat: 37.2764 Lon: -107.8822

Elevation: 6529 ft (1990 m)

3 Select region

Automatic Custom

Region: Western US

4 Select climate scenarios

Which climate are the seedlots adapted to?

1961 - 1990

When should trees be best adapted to the planting site?

2011 - 2040

RCP8.5

5 Select transfer limit method

Custom Zone

6 Select climate variables

Units: Metric Imperial

Name	Center	Transfer limit (+/-)
MCMT	-2.7 °C	2.00 °C
MAP	504 mm	100 mm

Add a variable...

7 Apply constraints

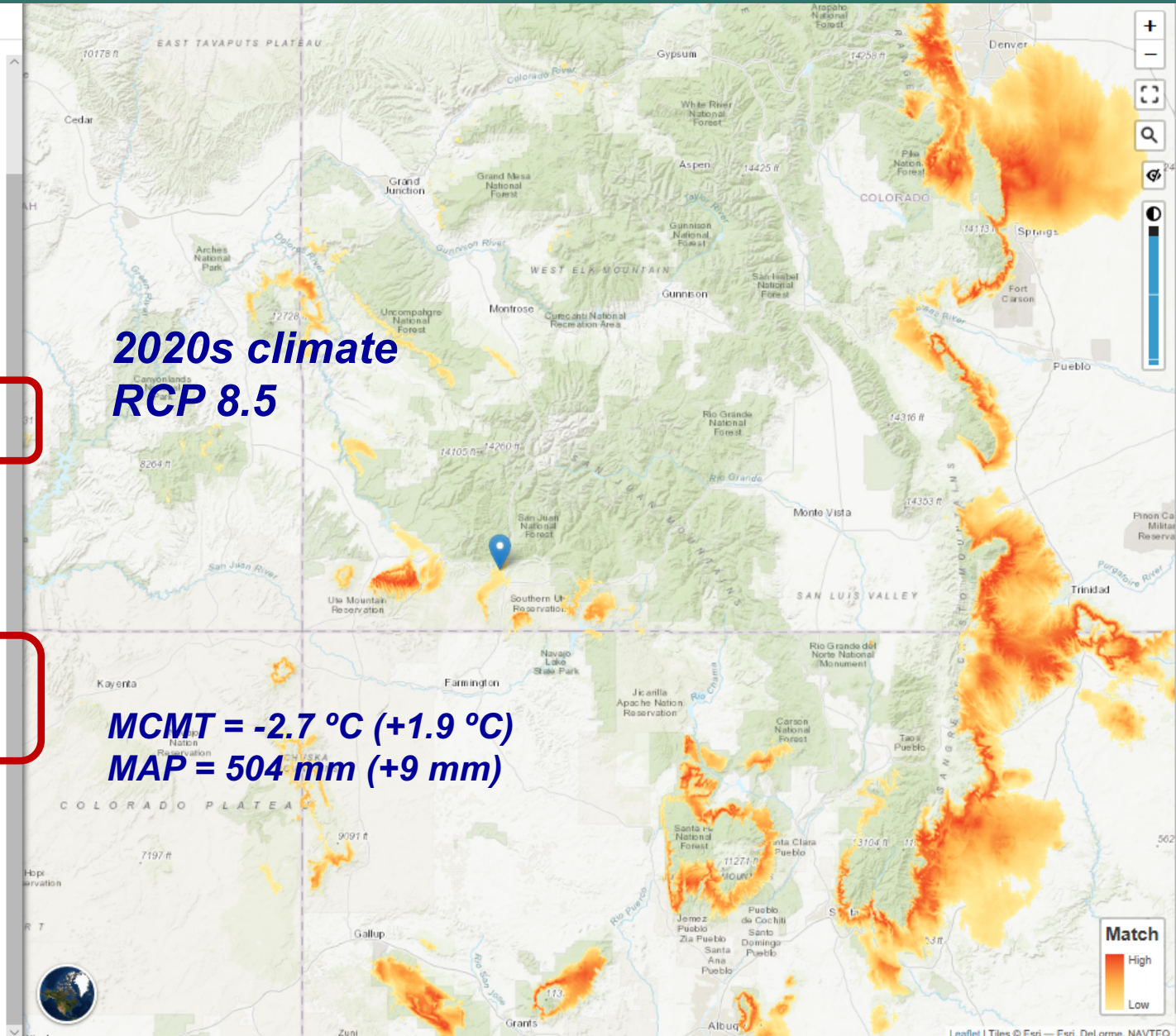
Select...

8 Map your Results

Run Tool

Save Last Run

Export As...



Seedlots for planting site – 2050s climate

About Tool Layers Saved Runs

Locate your planting site
Use the map or enter coordinates

Lat: 37.2764 Lon: -107.8822

Elevation: 6529 ft (1990 m)

3 Select region

Automatic Custom

Region: Western US

4 Select climate scenarios

Which climate are the seedlots adapted to?

1961 - 1990

When should trees be best adapted to the planting site?

2041 - 2070

RCP8.5

5 Select transfer limit method

Custom Zone

6 Select climate variables

Units: Metric Imperial

Name	Center	Transfer limit (+/-)
MCMT	-1.0 °C	2.00 °C
MAP	501 mm	100 mm

Add a variable...

7 Apply constraints

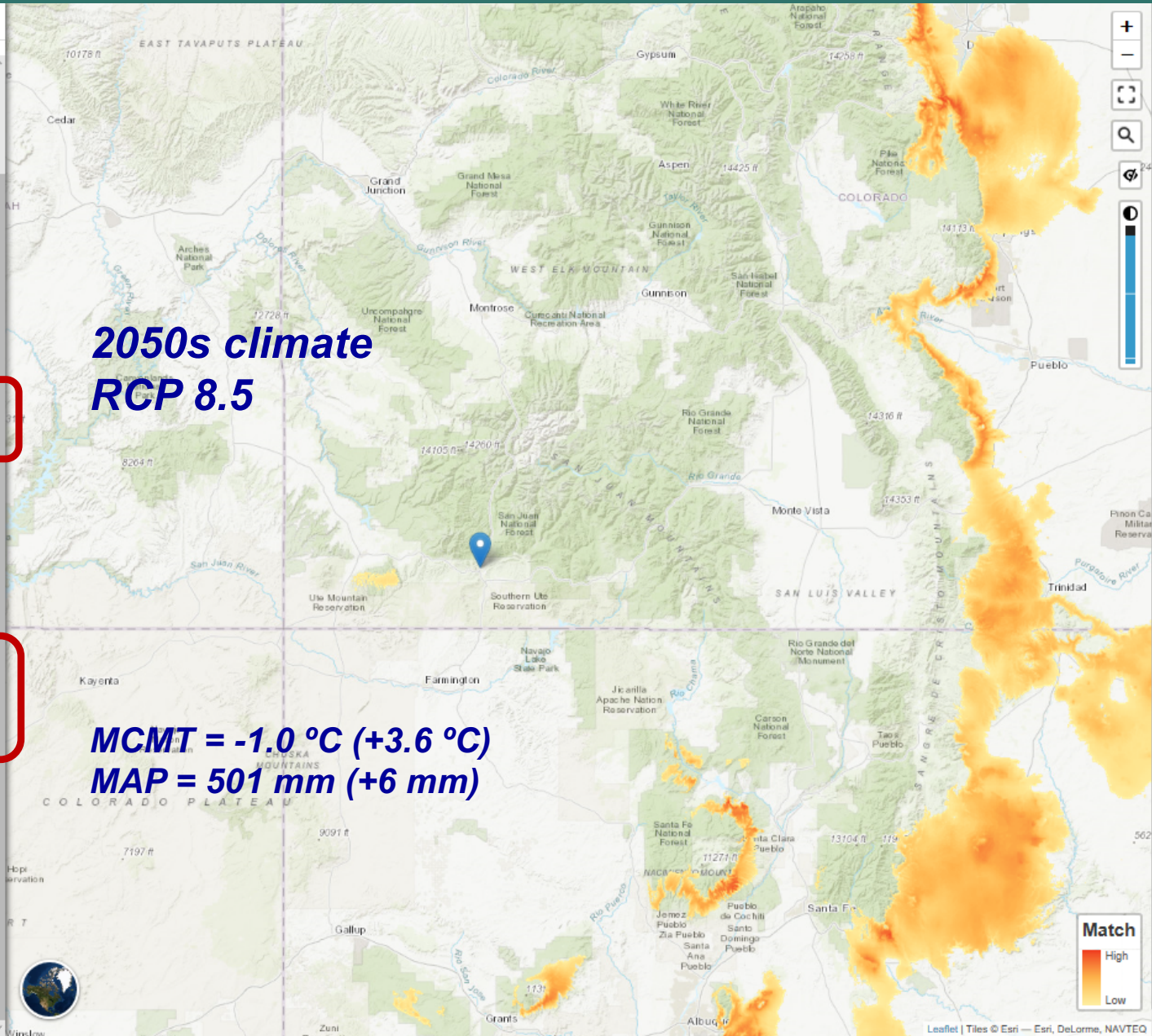
Select...

8 Map your Results

Run Tool

Save Last Run

Export As...



Seedlots for planting site – 2080s climate

About Tool Layers Saved Runs

Locate your planting site
Use the map or enter coordinates

Lat: 37.2764 Lon: -107.8822

Elevation: 6529 ft (1990 m)

3 Select region

Automatic Custom

Region: Western US

4 Select climate scenarios

Which climate are the seedlots adapted to?

1961 - 1990

When should trees be best adapted to the planting site?

2071 - 2100 RCP8.5

5 Select transfer limit method

Custom Zone

6 Select climate variables

Units: Metric Imperial

Name	Center	Transfer limit (+/-)
MCMT	1.0 °C	2.00 °C
MAP	503 mm	100 mm

Add a variable...

7 Apply constraints

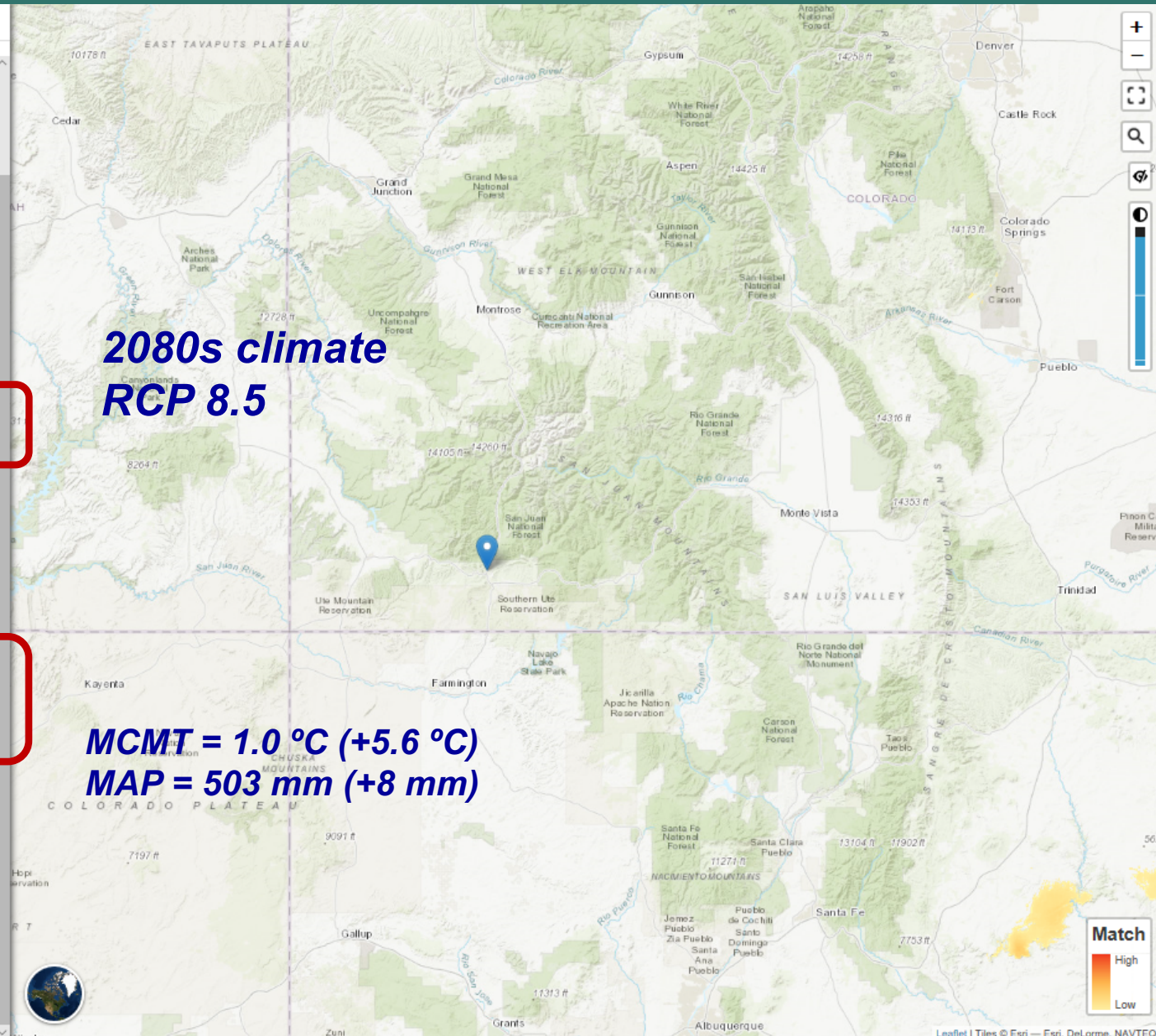
Select...

8 Map your Results

Run Tool

Save Last Run

Export As...



2080s climate
RCP 8.5

MCMT = 1.0 °C (+5.6 °C)
MAP = 503 mm (+8 mm)

Match
High
Low

Seedlots for planting site – 2080s climate

About Tool Layers Saved Runs

Locate your planting site
Use the map or enter coordinates

Lat: Lon:

Elevation: 6529 ft (1990 m)

3 Select region

Automatic Custom

Region: Western US

4 Select climate scenarios

Which climate are the seedlots adapted to?

When should trees be best adapted to the planting site?

5 Select transfer limit method

Custom Zone

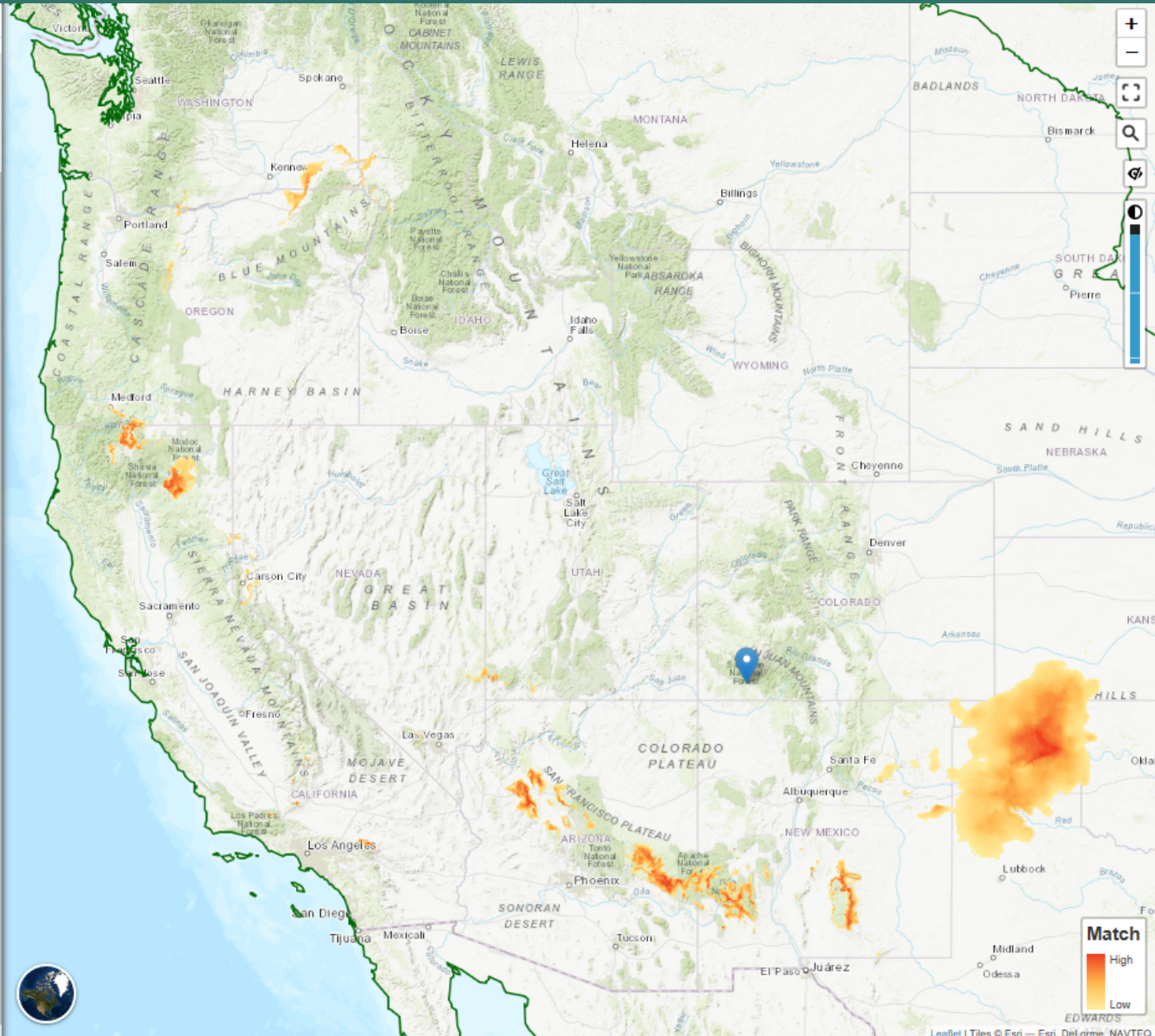
6 Select climate variables

Units: Metric Imperial

Name	Center	Transfer limit (+/-)
<input type="checkbox"/> MCMT	1.0 °C	<u>2.00 °C</u>
<input type="checkbox"/> MAP	503 mm	<u>100 mm</u>

7 Apply constraints

8 Map your Results



Seedlots for planting site – 2020s climate

About Tool Layers Saved Runs

Locate your planting site
Use the map or enter coordinates

Lat: 37.2764 Lon: -107.8822

Elevation: 6529 ft (1990 m)

3 Select region

Automatic Custom

Region: Western US

4 Select climate scenarios

Which climate are the seedlots adapted to?

1961 - 1990

When should trees be best adapted to the planting site?

2011 - 2040

RCP8.5

5 Select transfer limit method

Custom Zone

6 Select climate variables

Units: Metric Imperial

Name	Center	Transfer limit (+/-)
✕ MCMT	-2.7 °C	<u>2.00 °C</u>
✕ MAP	504 mm	<u>100 mm</u>

Add a variable...

7 Apply constraints

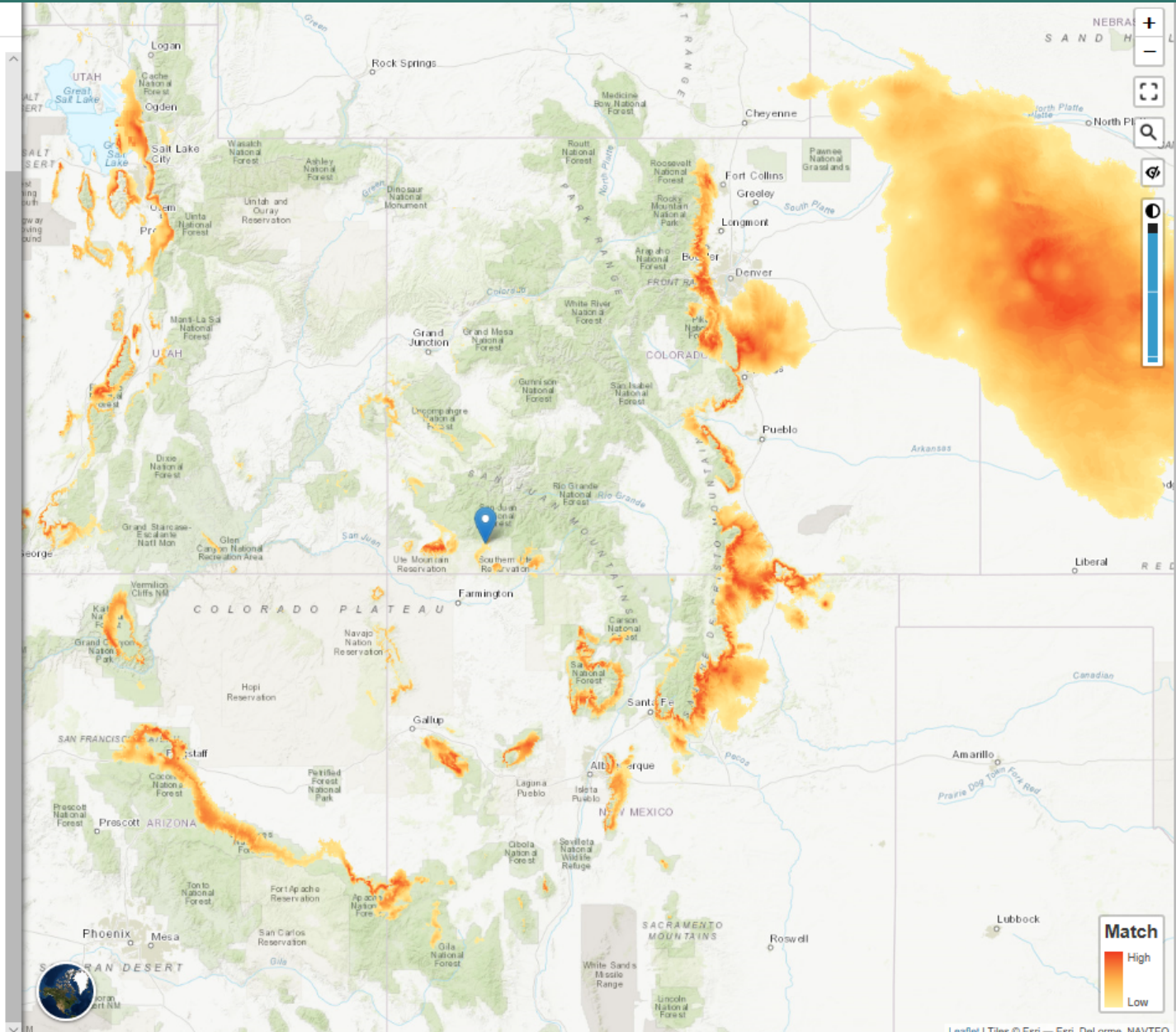
Select...

8 Map your Results

Run Tool

Save Last Run

Export As... ^



Seedlots for planting site – 2050s climate

About Tool Layers Saved Runs

Locate your planting site
Use the map or enter coordinates

Lat: 37.2764 Lon: -107.8822

Elevation: 6529 ft (1990 m)

3 Select region

Automatic Custom

Region: Western US

4 Select climate scenarios

Which climate are the seedlots adapted to?

1961 - 1990

When should trees be best adapted to the planting site?

2041 - 2070

RCP8.5

5 Select transfer limit method

Custom Zone

6 Select climate variables

Units: Metric Imperial

Name	Center	Transfer limit (+/-)
MCMT	-1.0 °C	2.00 °C
MAP	501 mm	100 mm

Add a variable...

7 Apply constraints

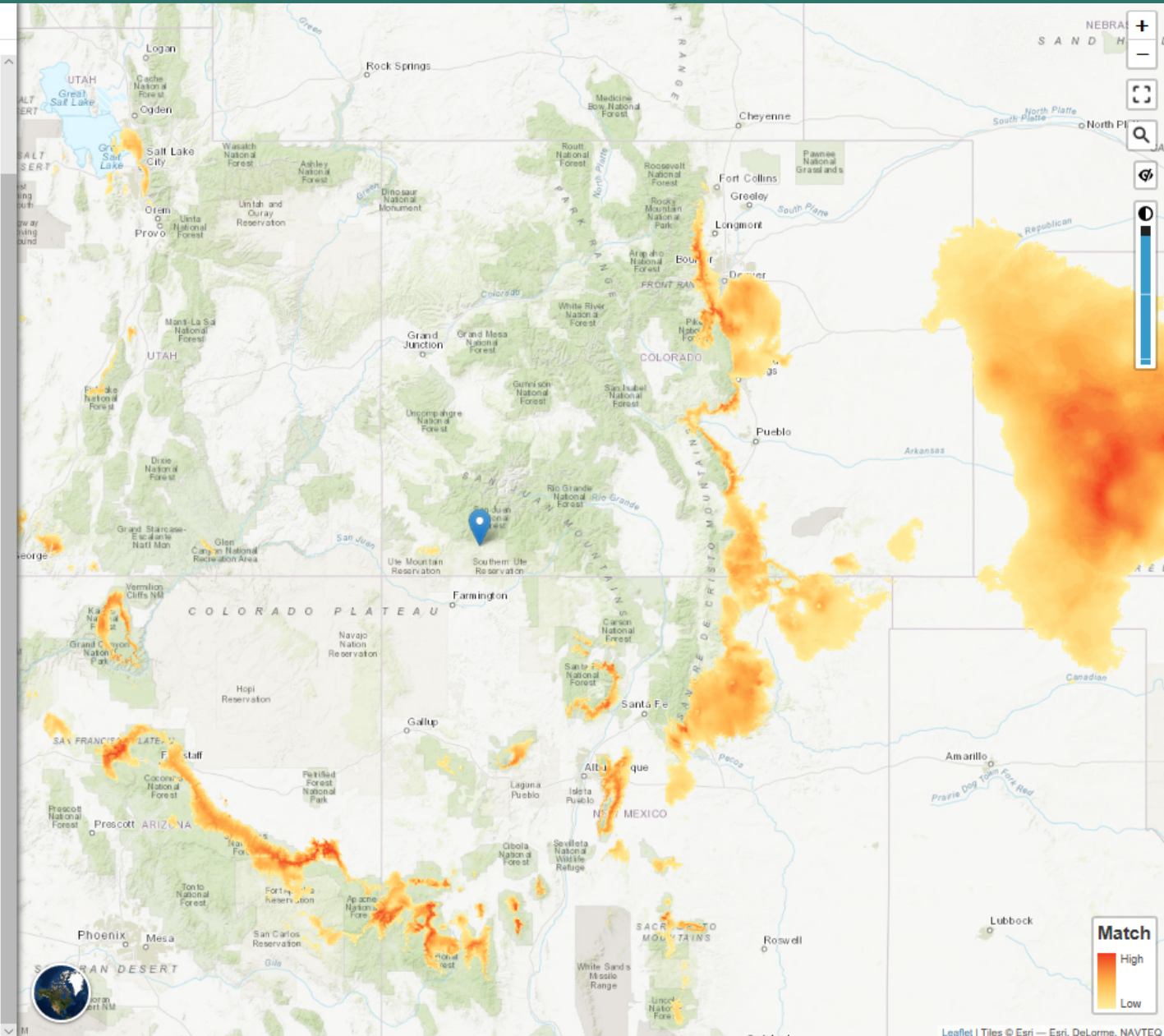
Select...

8 Map your Results

Run Tool

Save Last Run

Export As...



Seedlots for planting site – 2080s climate

About Tool Layers Saved Runs

Locate your planting site
Use the map or enter coordinates

Lat: 37.2764 Lon: -107.8822

Elevation: 6529 ft (1990 m)

3 Select region

Automatic Custom

Region: Western US

4 Select climate scenarios

Which climate are the seedlots adapted to?

1961 - 1990

When should trees be best adapted to the planting site?

2071 - 2100

RCP8.5

5 Select transfer limit method

Custom Zone

6 Select climate variables

Units: Metric Imperial

Name	Center	Transfer limit (+/-)
MCMT	1.0 °C	2.00 °C
MAP	503 mm	100 mm

Add a variable...

7 Apply constraints

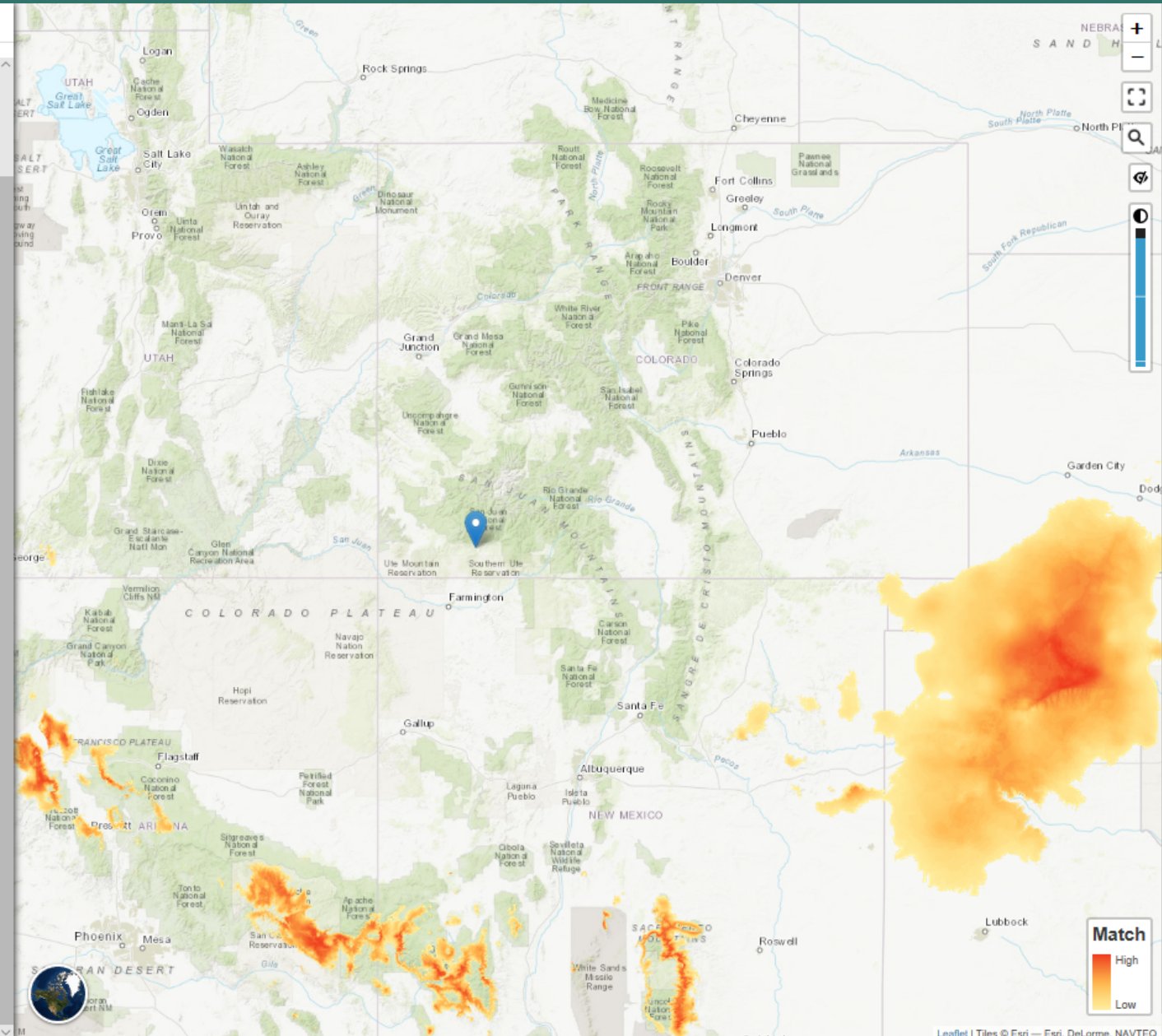
Select...

8 Map your Results

Run Tool

Save Last Run

Export As...



Potential loss of species habitat niche

<https://specieshabitattool.org/spht/>

Species Potential Habitat Tool People Source Code

About **Tool** Advanced

- Select Species**
Ponderosa pine
- Select Species Distribution Record**
1981 - 2010
- Select Modeling Conditions**
Select a future time range and a model

	RCP 4.5	RCP 8.5
2011 - 2040	<input type="checkbox"/>	<input type="checkbox"/>
2041 - 2070	<input type="checkbox"/>	<input type="checkbox"/>
2071 - 2100	<input type="checkbox"/>	<input type="checkbox"/>
- Download**
Download results to a pdf

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10:49 AM
11/27/2019

Potential loss of species habitat niche

Species Potential Habitat Tool

People Source Code

About Tool Advanced

2 Select Species Distribution Record

1981 - 2010

3 Select Modeling Conditions

Select a future time range and a model

	RCP 4.5	RCP 8.5
2011 - 2040	<input type="checkbox"/>	<input type="checkbox"/>
2041 - 2070	<input type="checkbox"/>	<input checked="" type="checkbox"/>
2071 - 2100	<input type="checkbox"/>	<input type="checkbox"/>

4 Download

Download results to a pdf

<http://leafletjs.com/>
Download

Ponderosa Pine

- Habitat lost
- Habitat kept (1 scenario)
- Habitat gained (1 scenario)

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10:53 AM
11/27/2019

Conclusions: Addressing climate change risk

- Climates are warming and are expected to continue to warm, more so in the north than in the south.
- In the short-term (currently, next decade or so), local populations are adapted to the local climate (within range of current transfer guidelines).
- In the long-term (by mid- to late-century), local populations are at a high risk of maladaptation to projected climates (and species at the warm edge of range).
- Adapted populations (i.e., from similar climates as present) may be found at lower elevations or further south.
- Need to balance adaptation to the present conditions with adaptation to future conditions – a moving target.
 - Match to the climate of the next decade or two.
 - Stand establishment is highly critical phase
 - Aim too far out and likely to see frost damage in the near term
- Use mixtures to account for uncertainty and climate change over the life of a stand.
- Start planning for future seed needs for warming climates.

People and Funding

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The screenshot shows the website for the Conservation Biology Institute (CBI). The header includes the CBI logo and name, with the tagline "Bridging conservation science and practice". A navigation menu contains links for ABOUT, PEOPLE, PRODUCTS & PUBLICATIONS, PROJECTS, and NEWS & EVENTS. The main content area features a large banner for the "Seedlot Selection Tool" with a background image of a forest at sunset. Below the banner, there is a breadcrumb trail: "Home > Products & Publications > Projects > Seedlot Selection Tool". Social media sharing buttons for Twitter, LinkedIn, Facebook, and YouTube are visible. The text describes the tool as a GIS mapping program for matching seedlots with planting sites based on climatic information. A date range "September 2015 – September 2020" is shown. Below the text, there are tabs for "About" and "People". The "About" tab is active, showing a map of the Pacific Northwest and a paragraph describing the collaborative development of the tool by the U.S. Forest Service, Oregon State University, and the Conservation Biology Institute.

consbio.org/products/webinars/climate-smart-seedlot-selection-tool





“The vast possibilities of our great future will become realities only if we make ourselves responsible for that future”

- Gifford Pinchot

A dense forest of tall, green evergreen trees is shrouded in a thick, white mist. The trees are of varying heights and are scattered throughout the frame. The mist is most prominent in the background, creating a sense of depth and atmosphere. The overall color palette is dominated by the greens of the trees and the whites and greys of the mist.

Questions?