Tree Genetics and Climate Change Adaptation

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USDA Forest Service, Pacific Northwest Region and PNWRS

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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

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%

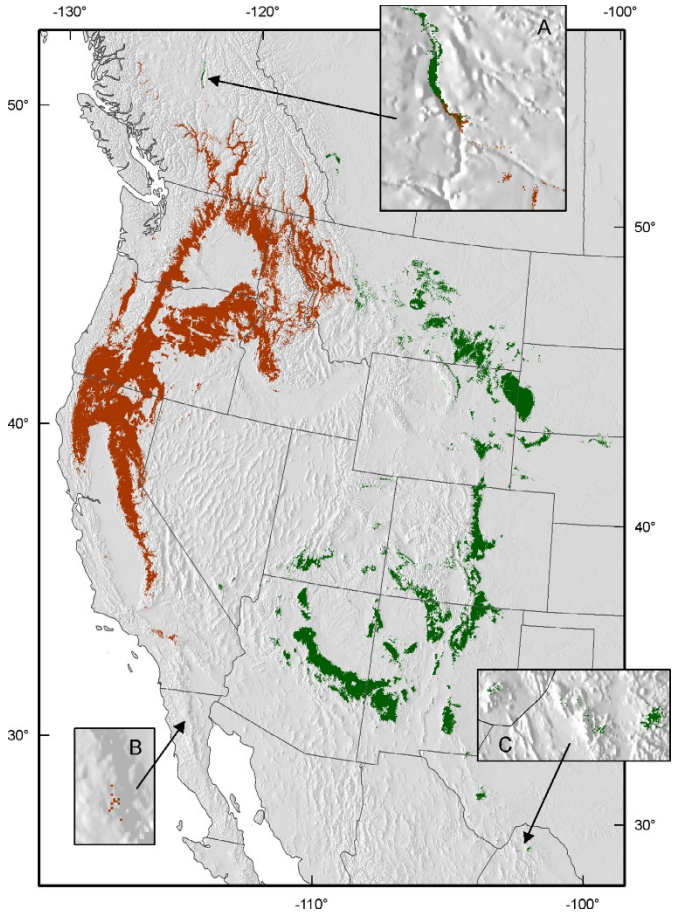
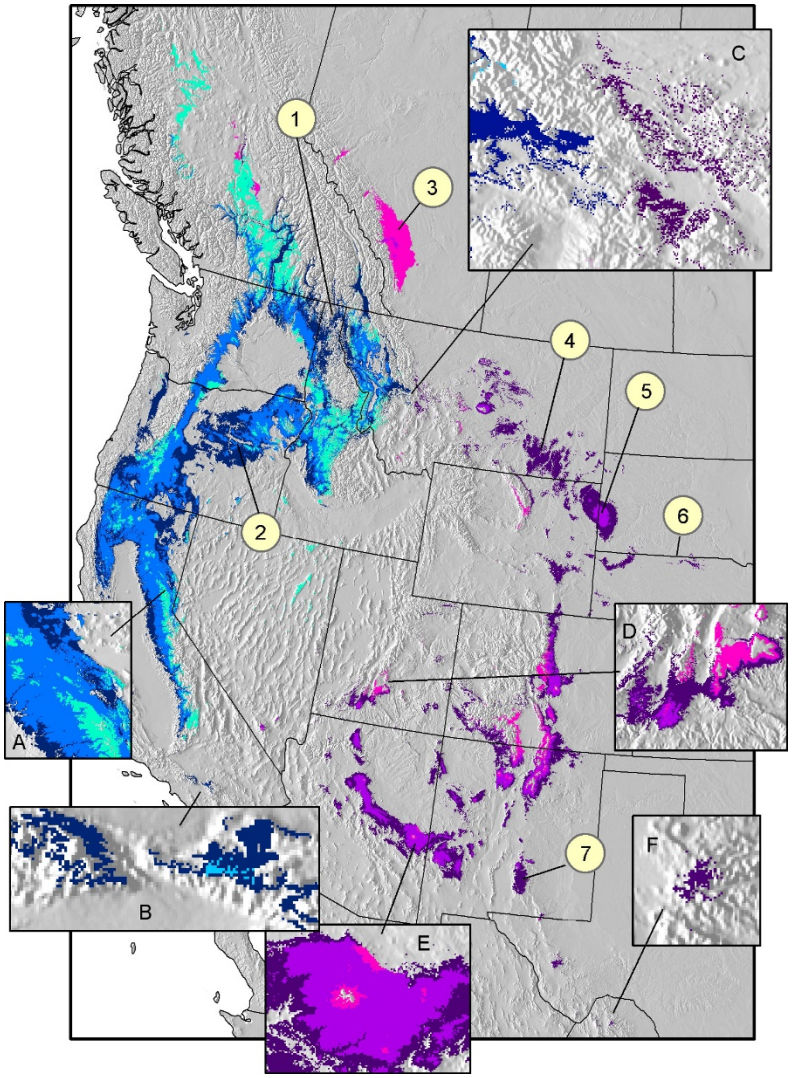


Fig. 3: Mapped prediction for climate niche for Pinus ponderosa var ponderosa (brown) and var. scopulorum (green)

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



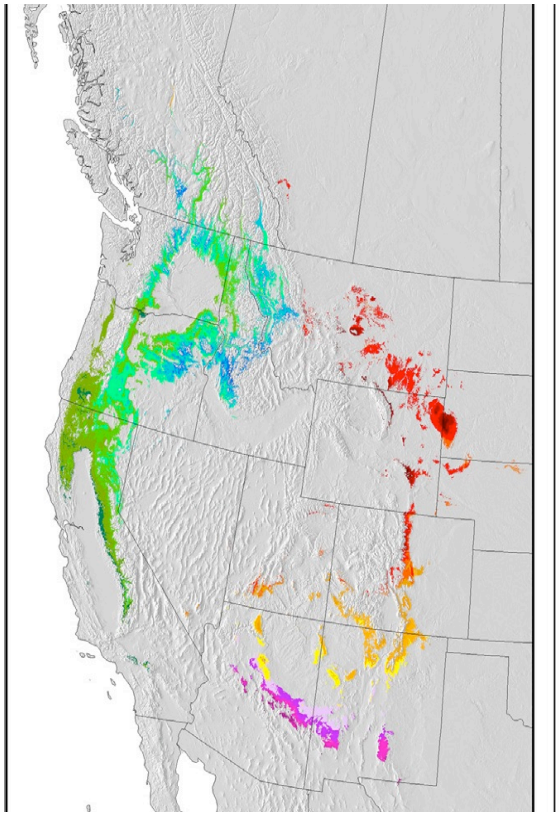
	Habitat lost (dark color)	Remains suitable (middle color)	Habitat gained (light color)
var. ponderosa (blues)	45%	55%	36%
var. scopulorum (purples)	77%	23%	53%

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

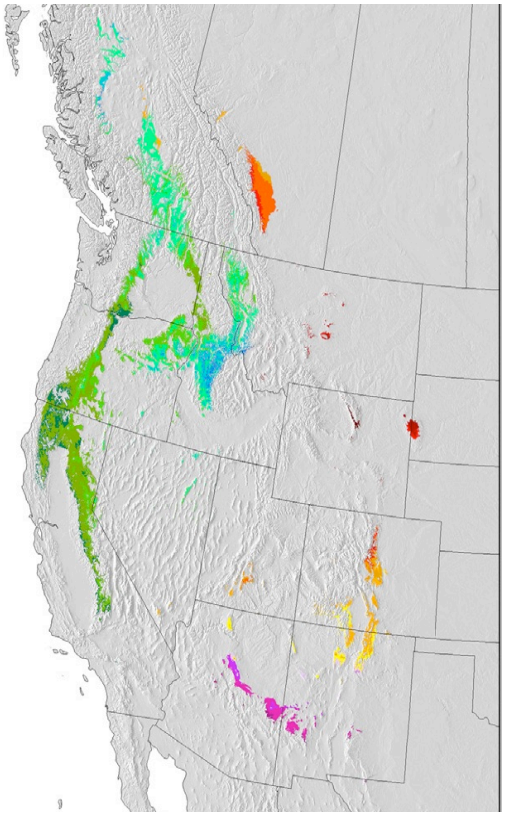
Rehfeldt et al. 2014. Comparative genetic responses to climate for varieties of Pinus ponderosa and Pseudotsuga menziesii: Realized climate niches. Forest Ecology and Management 324: 126-137

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%

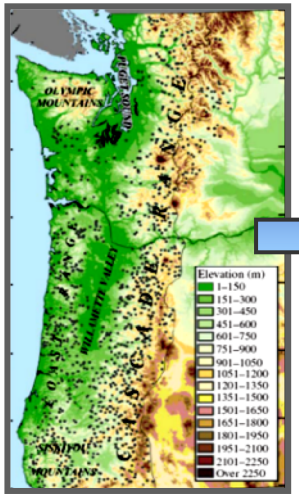
Rehfeldt et al. 2014. Comparative genetic responses to climate for varieties of Pinus ponderosa and Pseudotsuga menziesii: Clines in growth potential. Forest Ecology and Management 324: 138-146.


Seed Source
Considerations

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

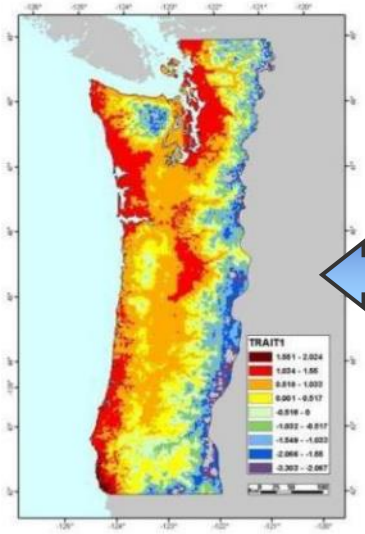
Douglas-Fir Genecology Study

Collect seed from many trees

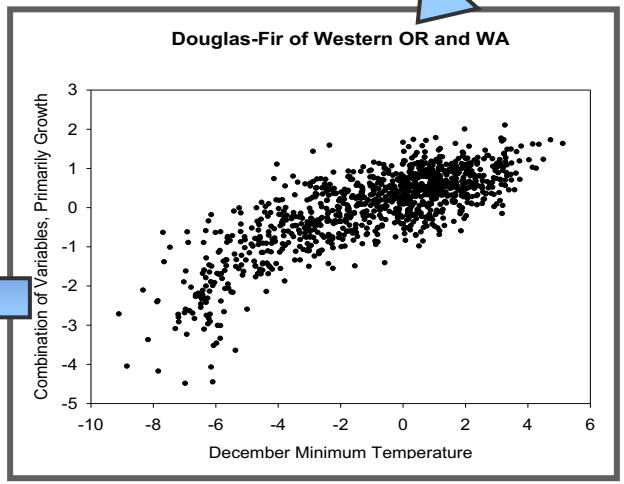


Grow families in a common environment

Measure many adaptive traits



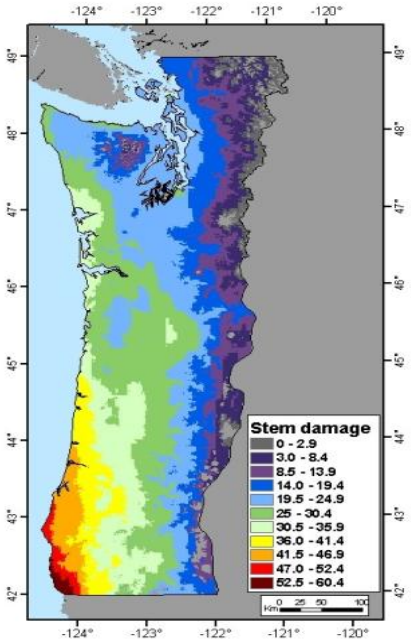
GIS



Traits vs source environment

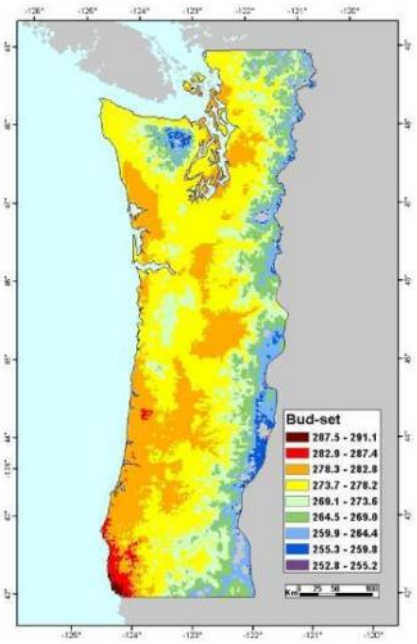
St.Clair et al. 2005. Genecology of Douglas-fir in western Oregon and Washington. Annals of Botany 96: 1199-1214.

Fall cold damage



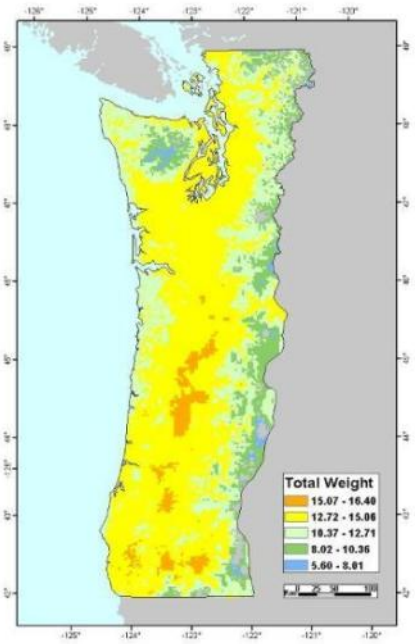
Qst = 0.68
r = 0.79

Bud-set



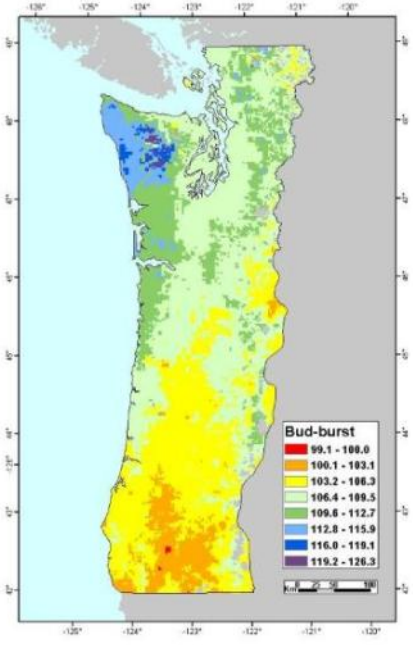
Qst = 0.29
r = 0.76

Biomass



Qst = 0.13
r = 0.52

Bud-burst



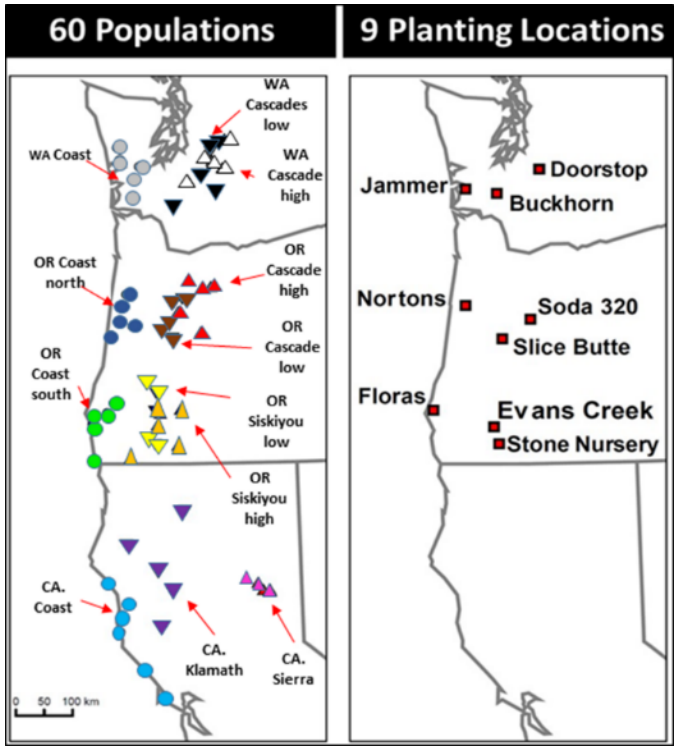
Qst = 0.21
r = 0.60

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

Nortons | Slice Butte | Soda 320

Floras | Stone Nursery

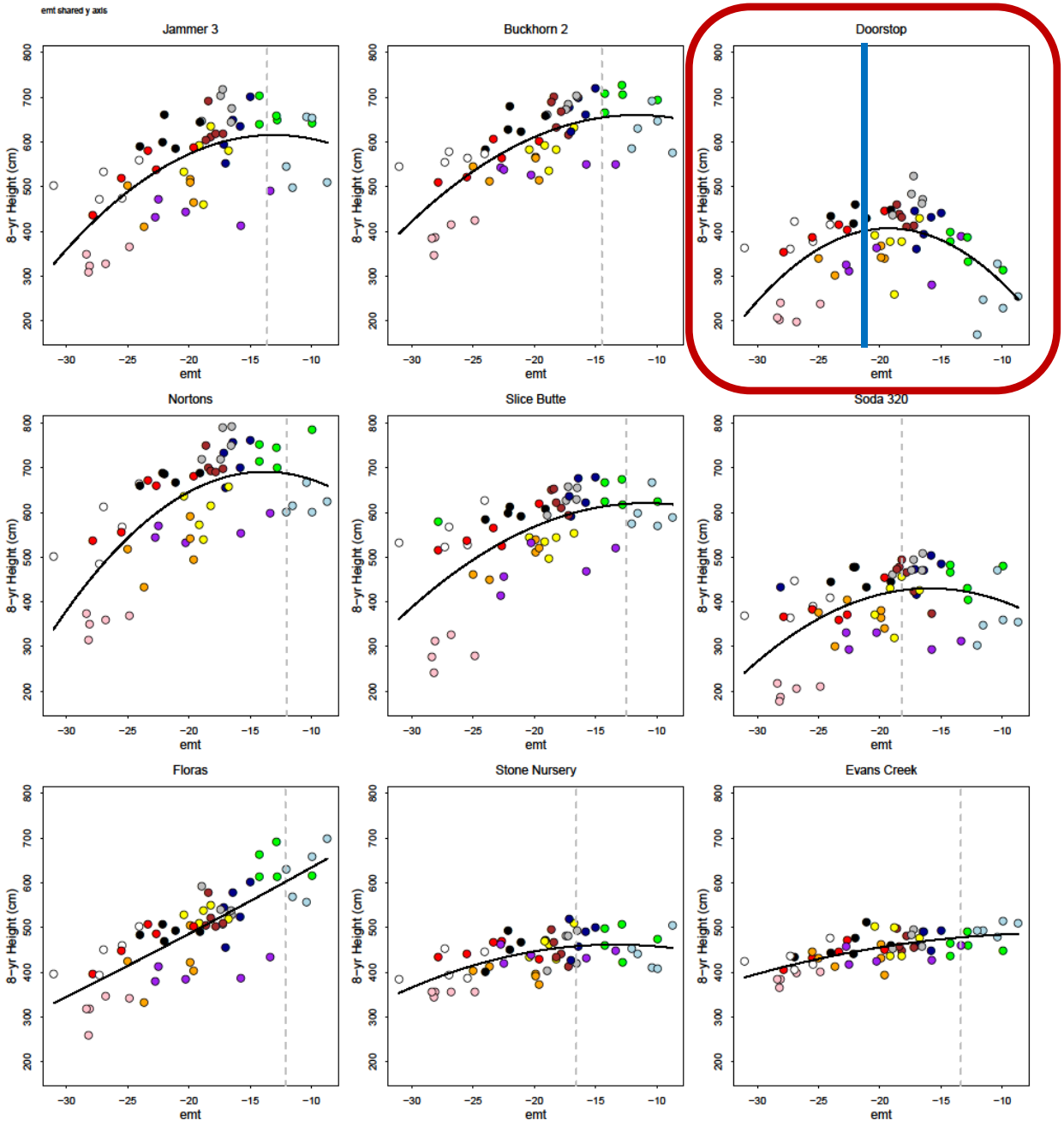
8-yr Height (cm)

emt

Extreme Minimum Temperature (°C)

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 = -12 °C



8-year Height (cm)

Extreme Minimum Temperature (°C)

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

Doorstop Test Site:
Cold, montane site
EMT = -21 °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?

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 <u>planting site</u>

<u>Which seedlot</u> is well adapted today…or in the future?

Find

Given a <u>seedlot</u>

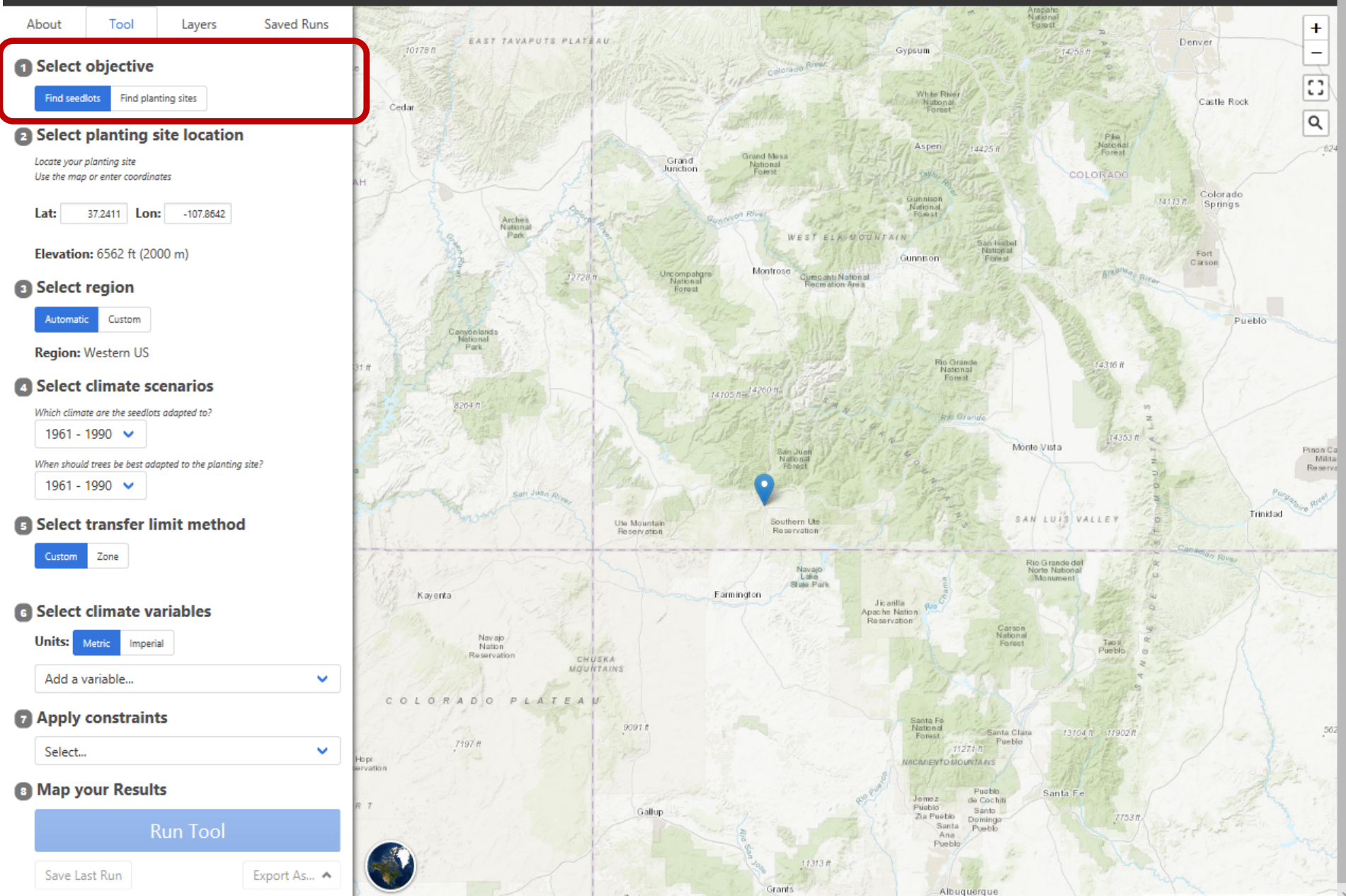
<u>Where</u> is it well adapted today…or in the future?

Find

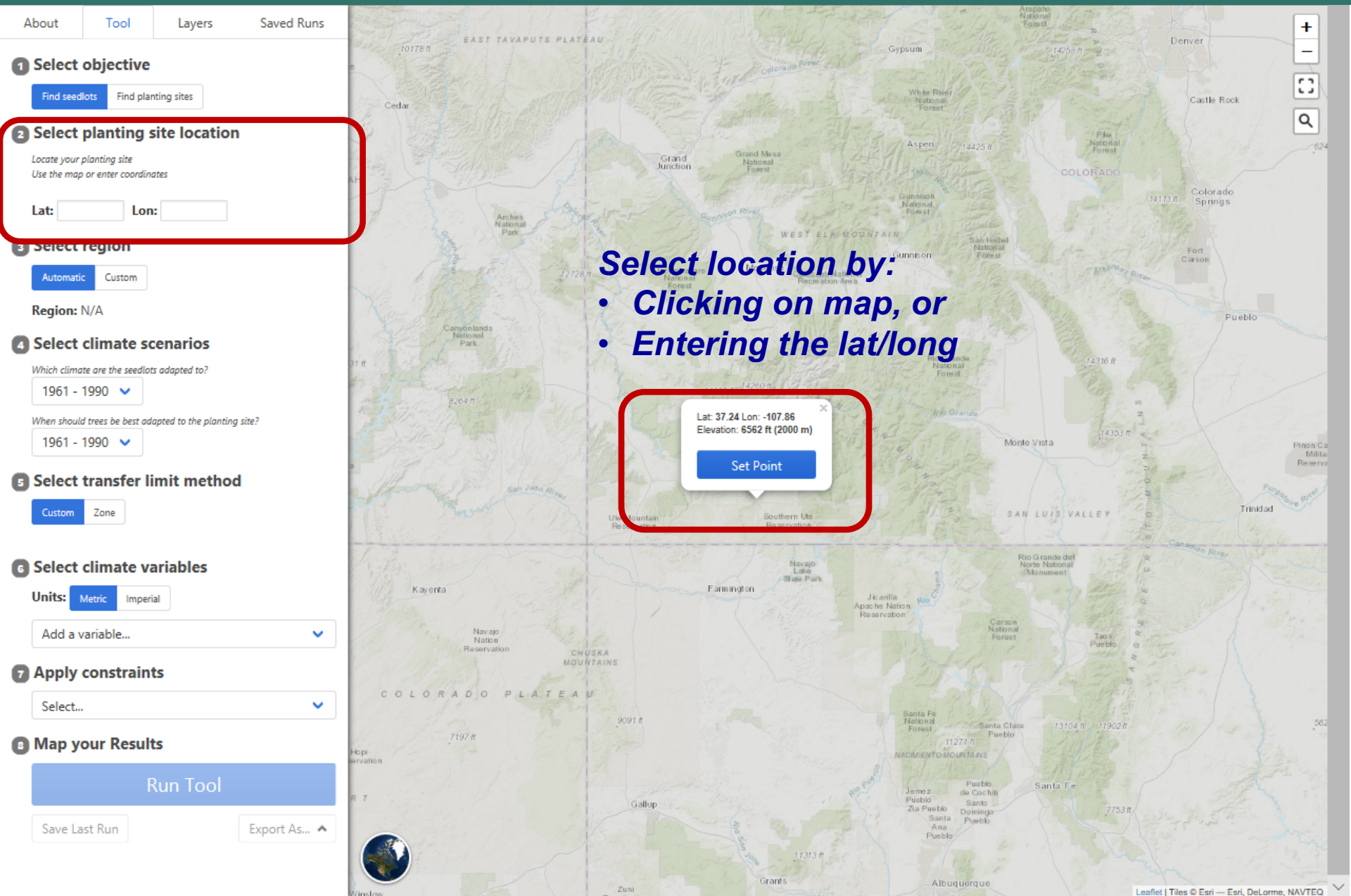
Seedlot Selection Tool is a powerful tool for:

- 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

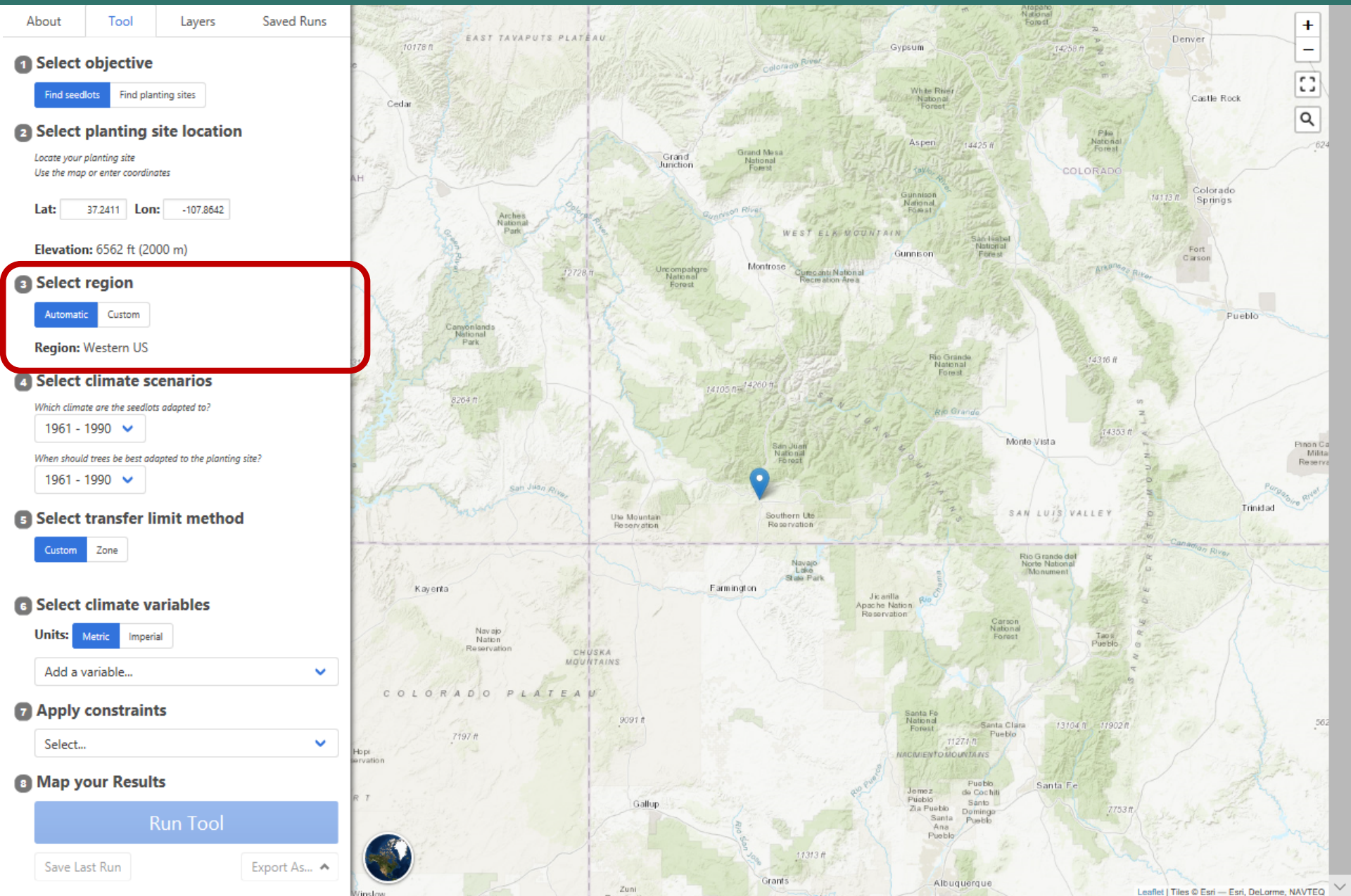
Seedlot Selection Tool Example



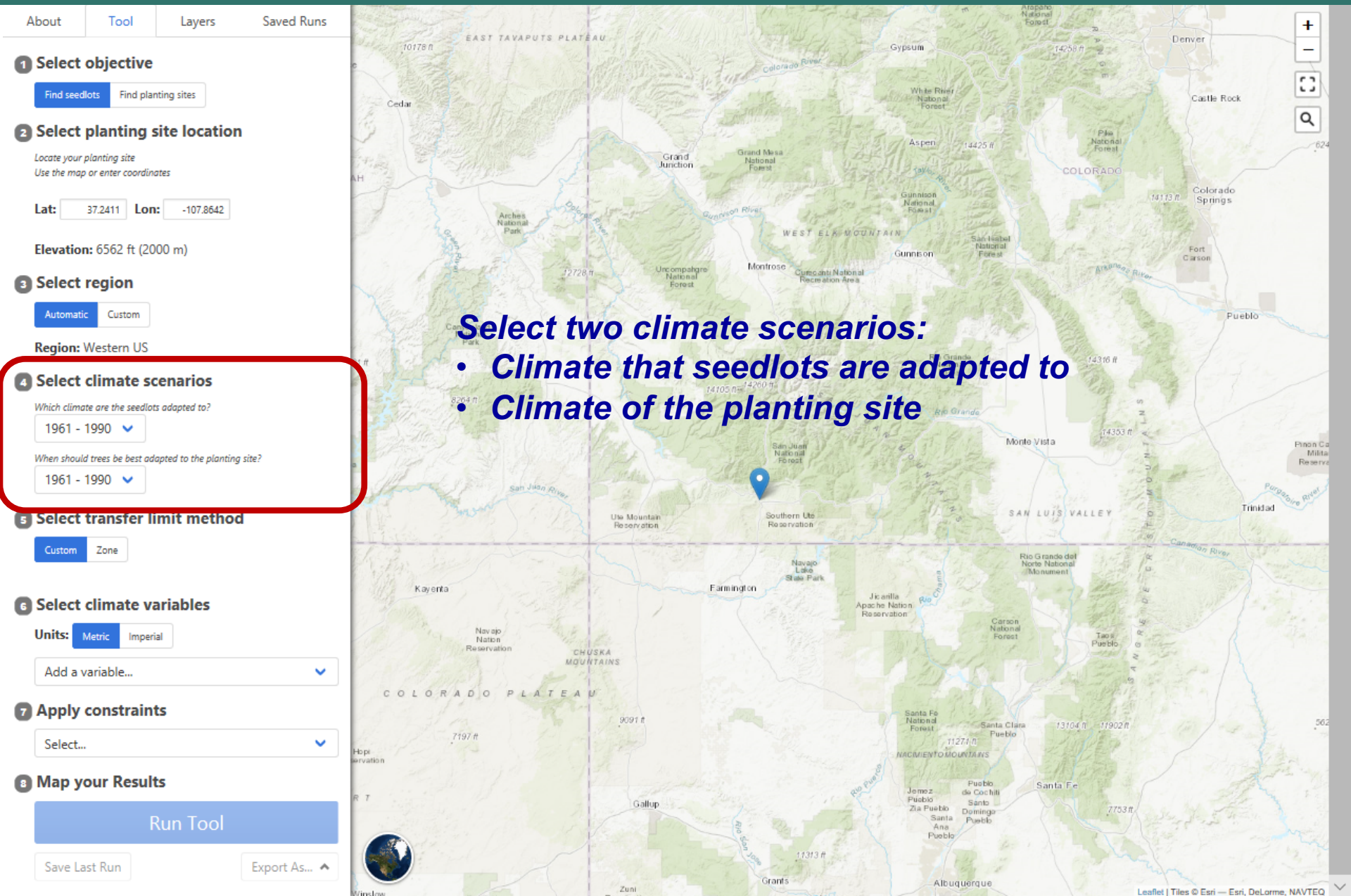
Select location of planting site



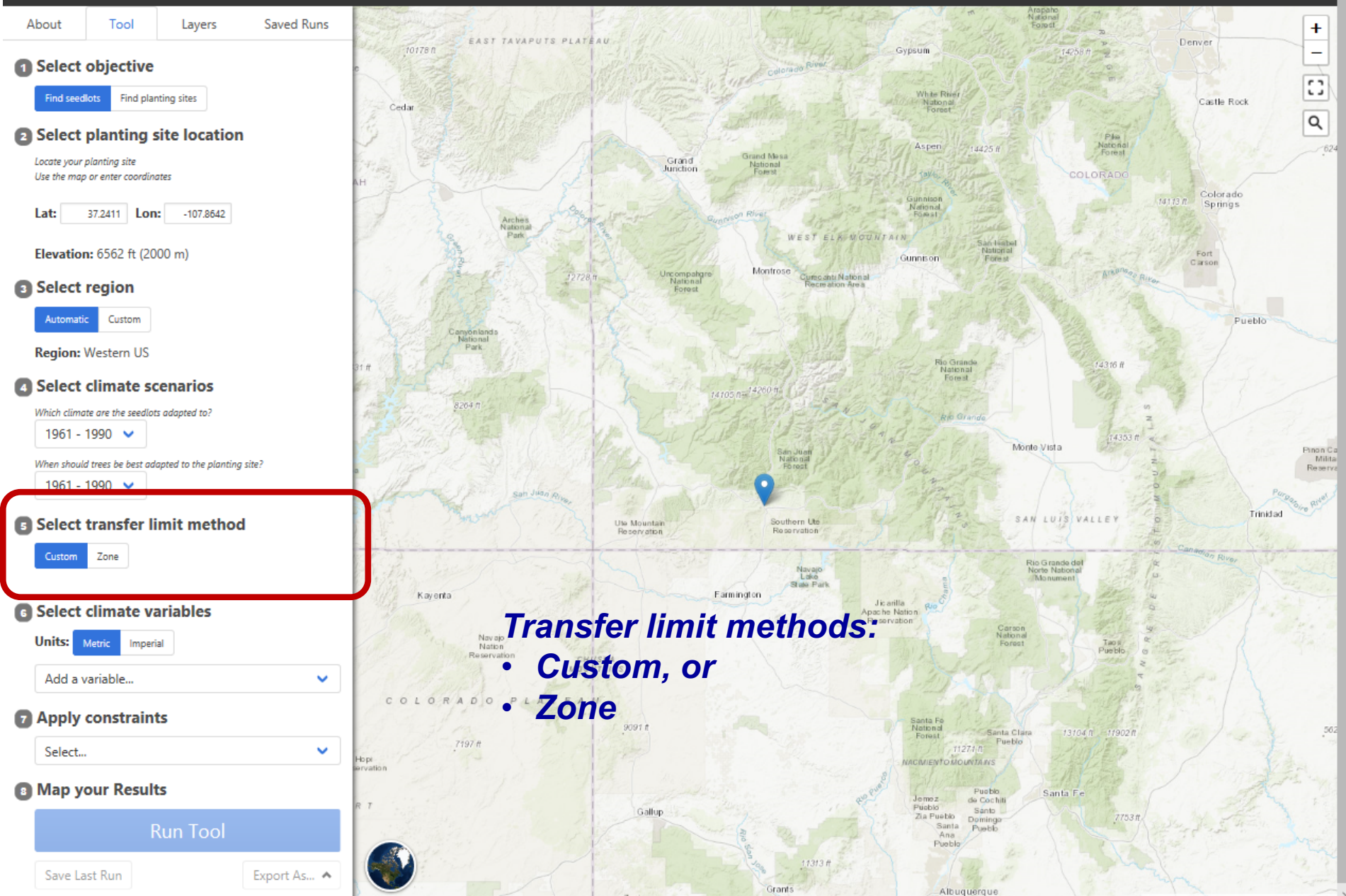
Select region (use automatic)



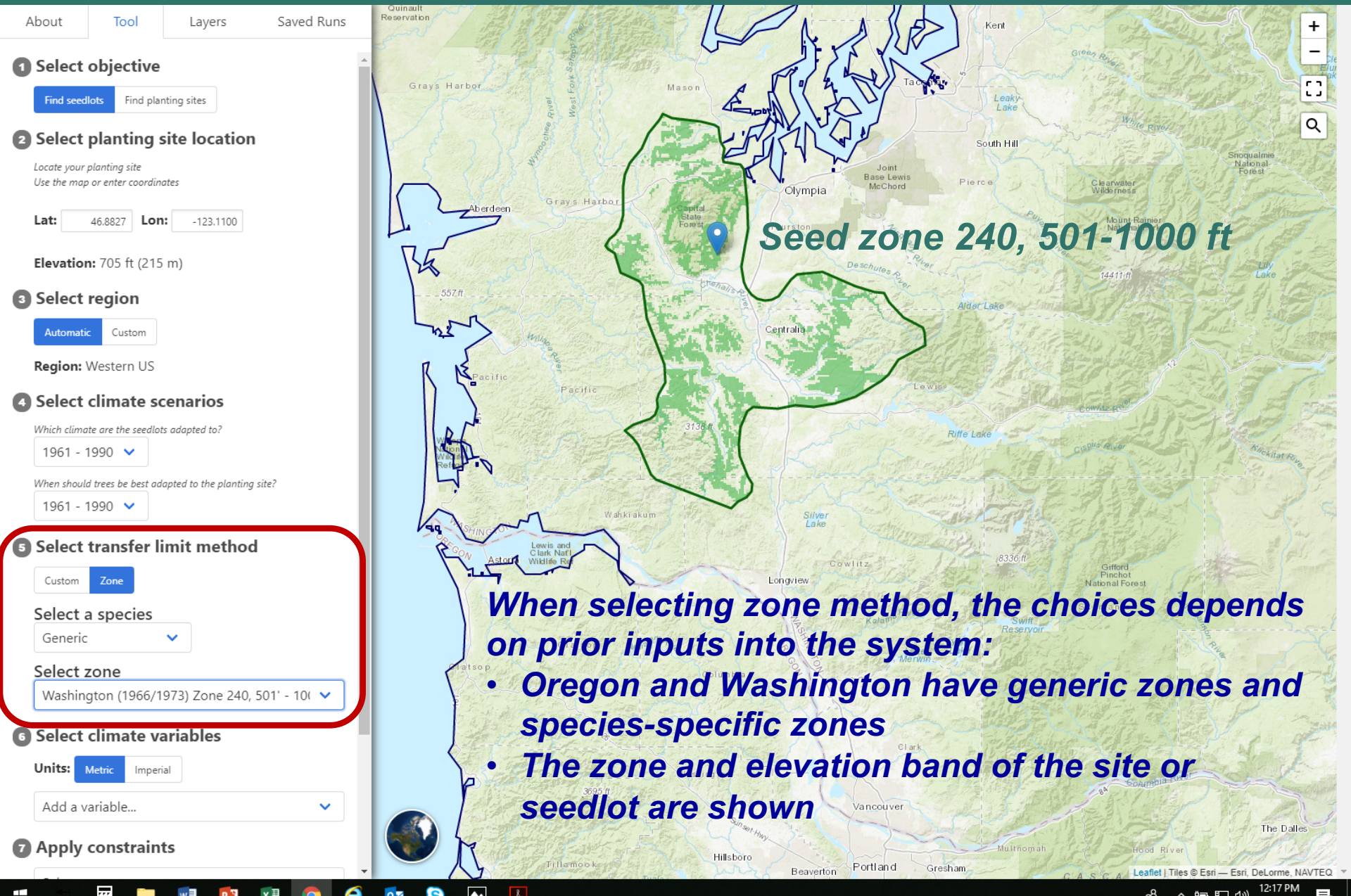
Select climate scenarios



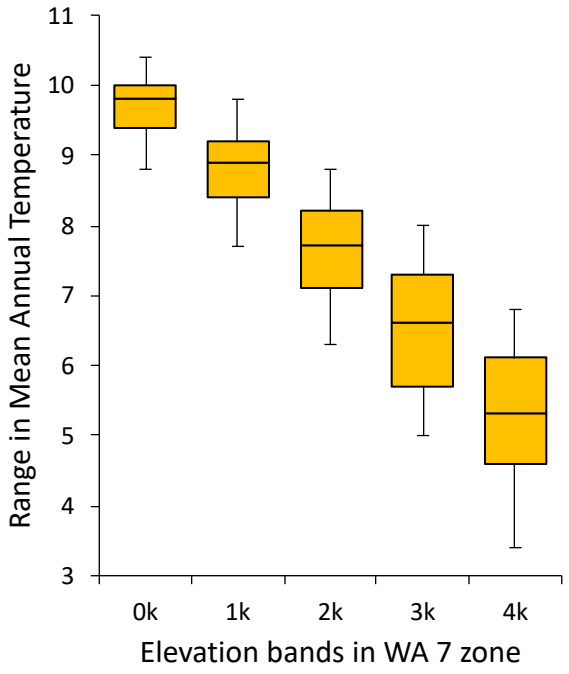
Select transfer limit method



Using the seed zone method



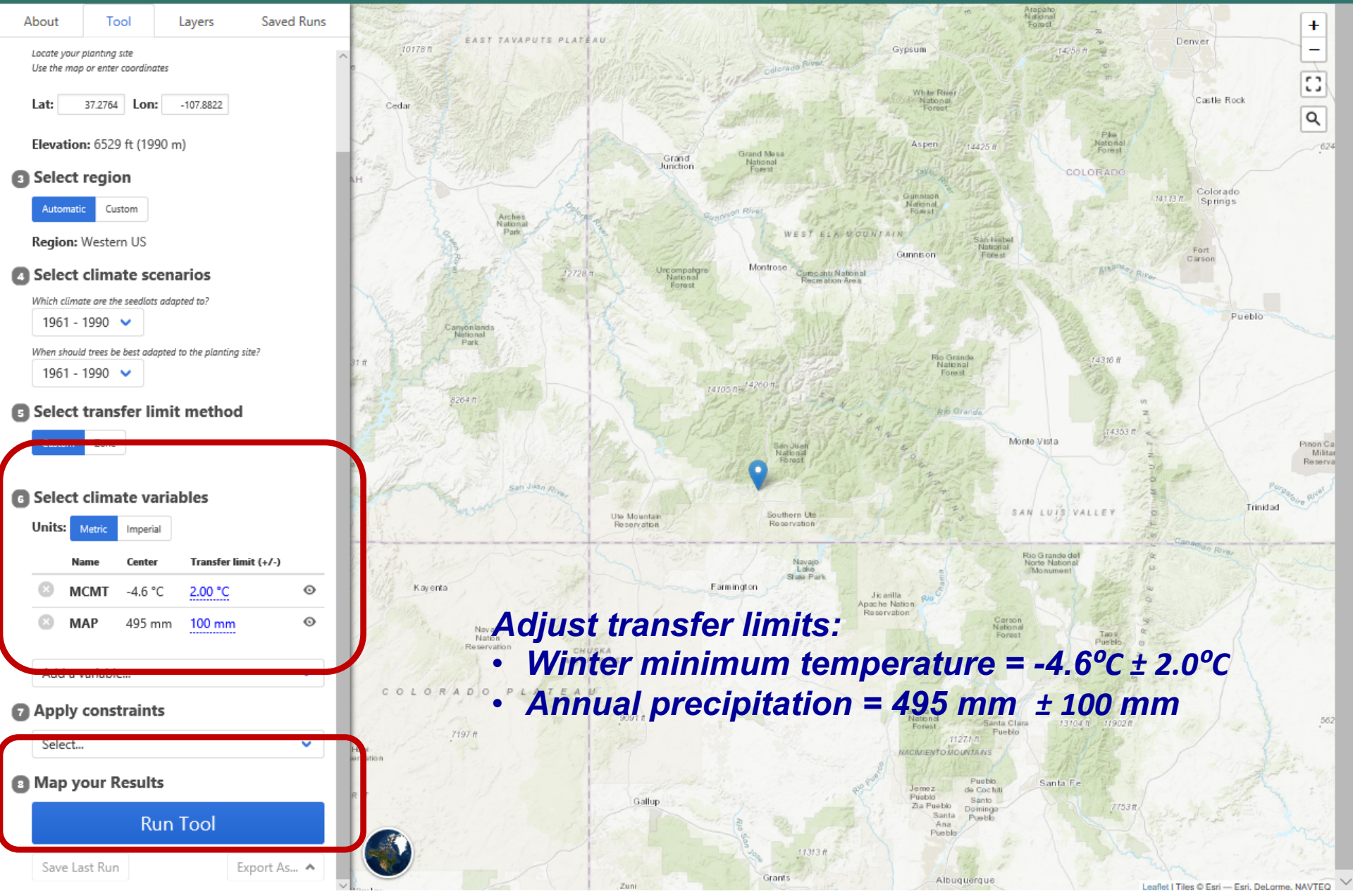
Transfer distances based on seed zones



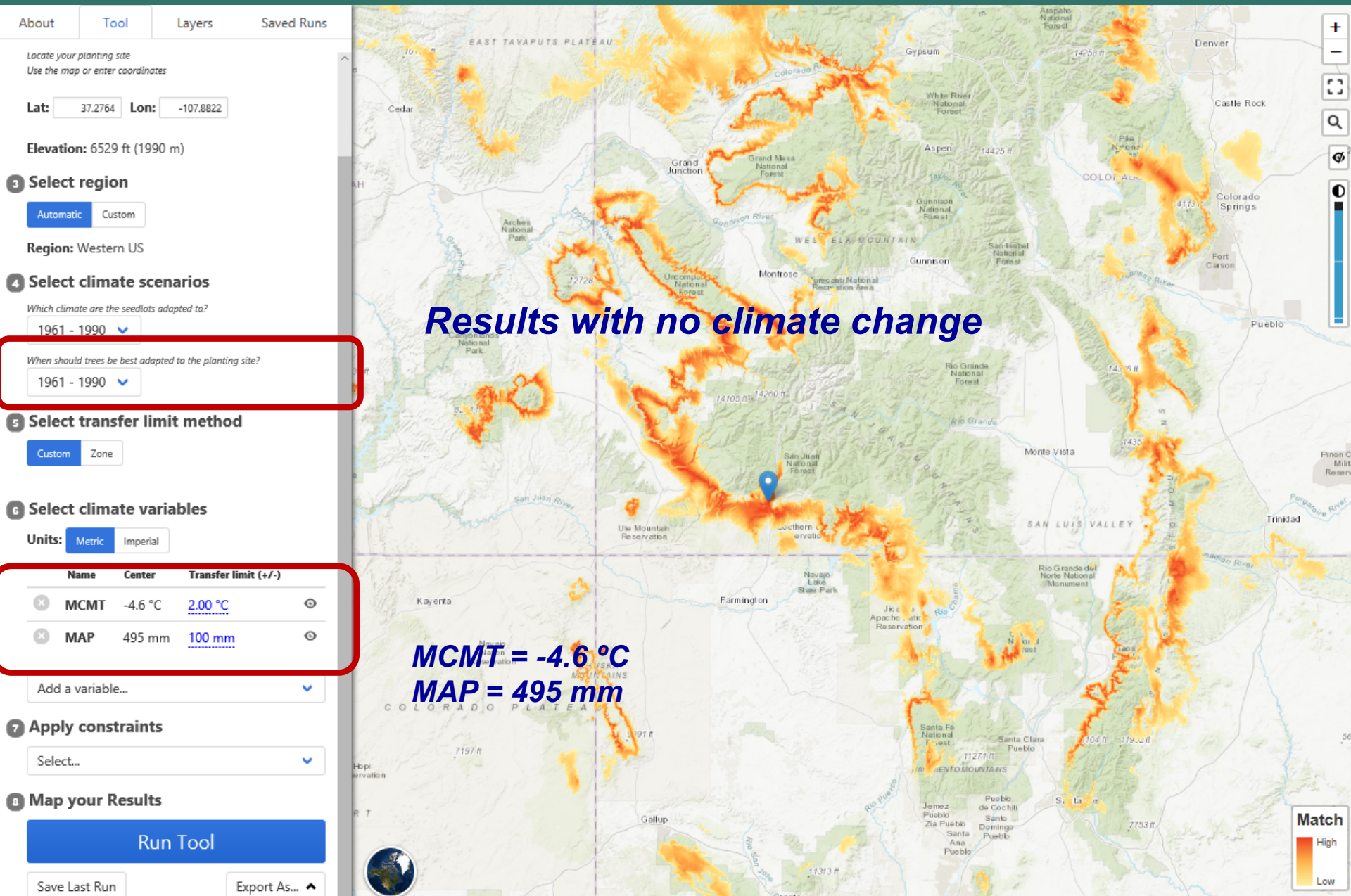
Transfer distances in °C mean annual temperature

	25th – 75th	5th – 95th	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

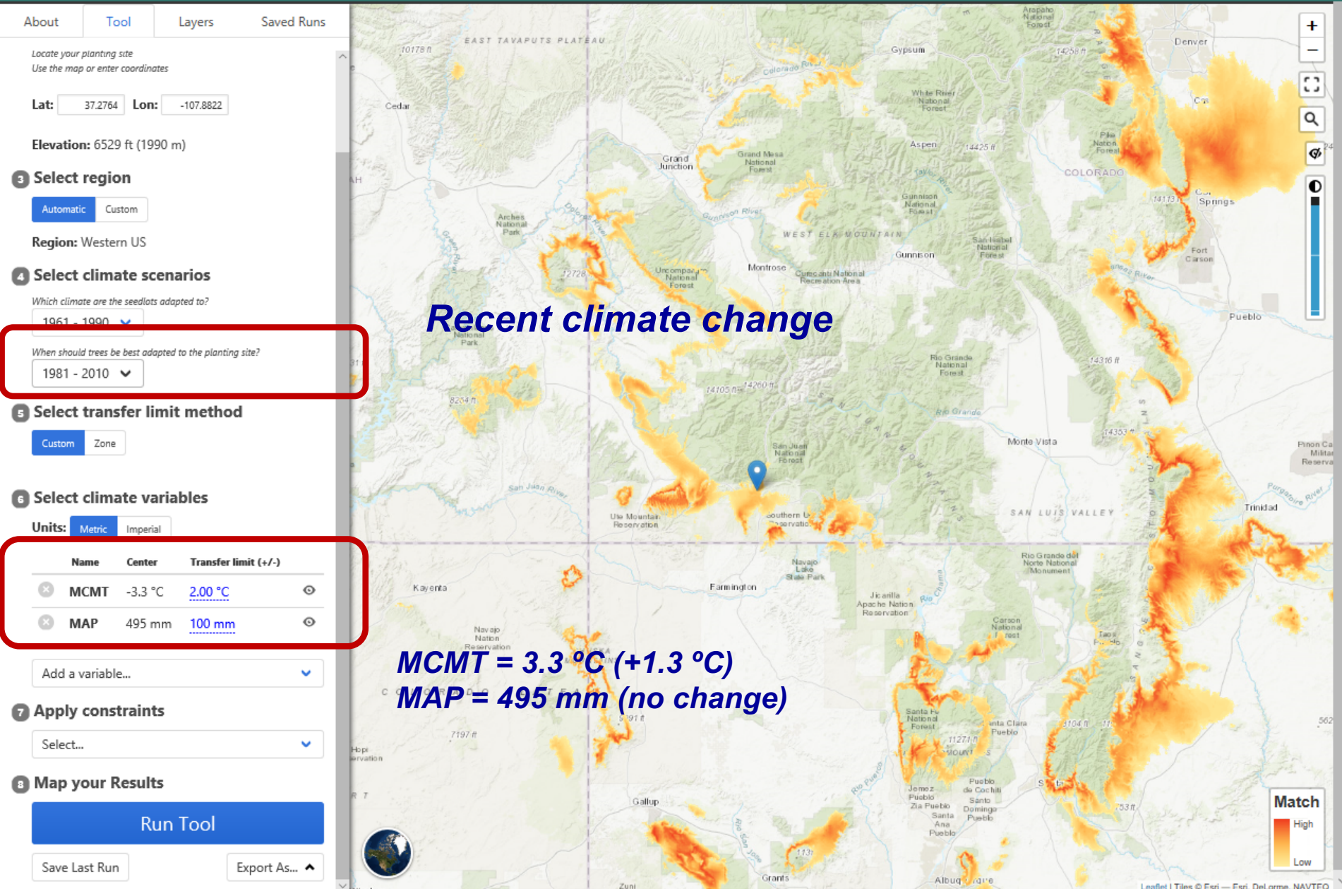
Adjust transfer limits



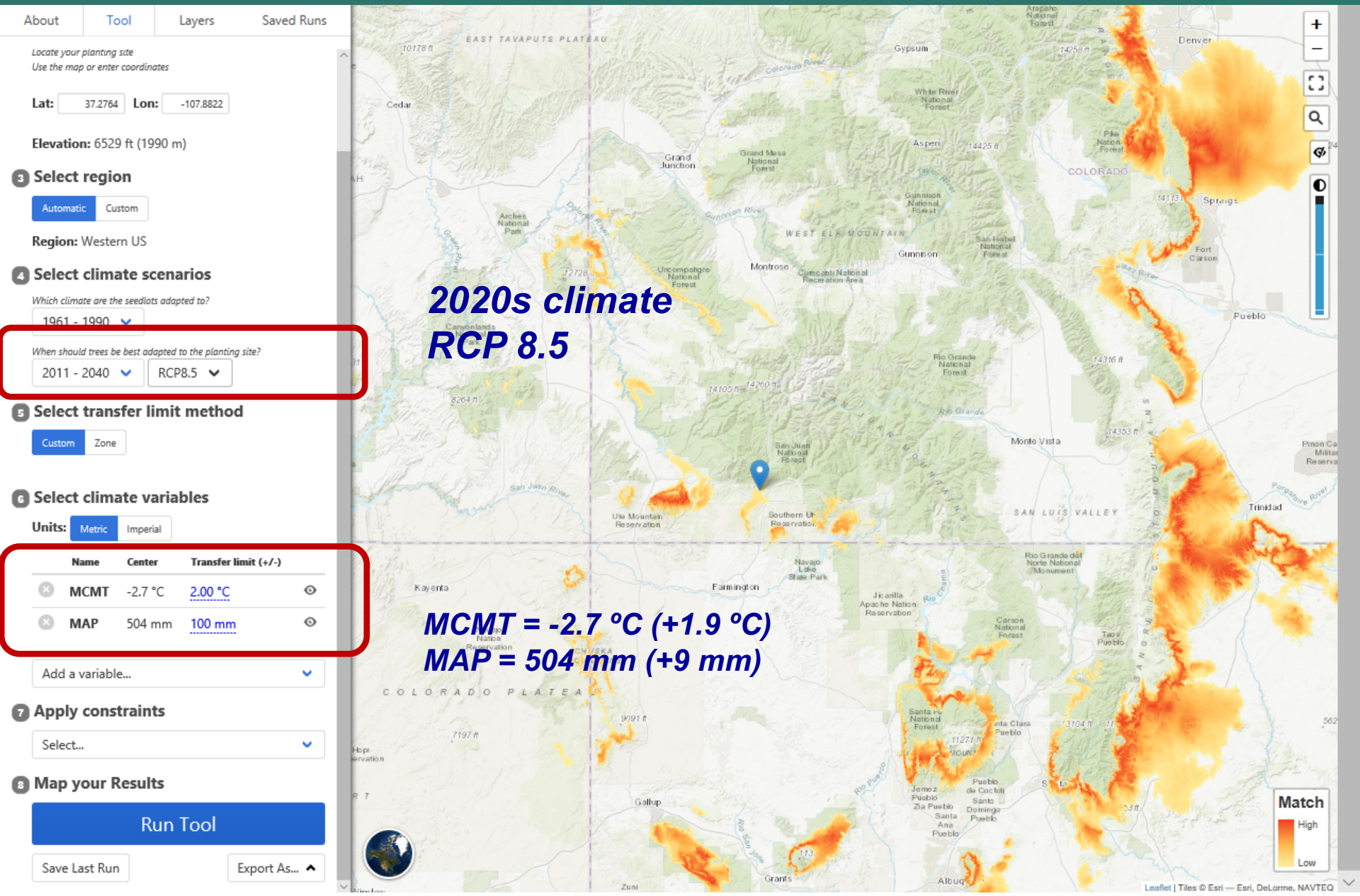
Seedlots for planting site - Ignoring climate change



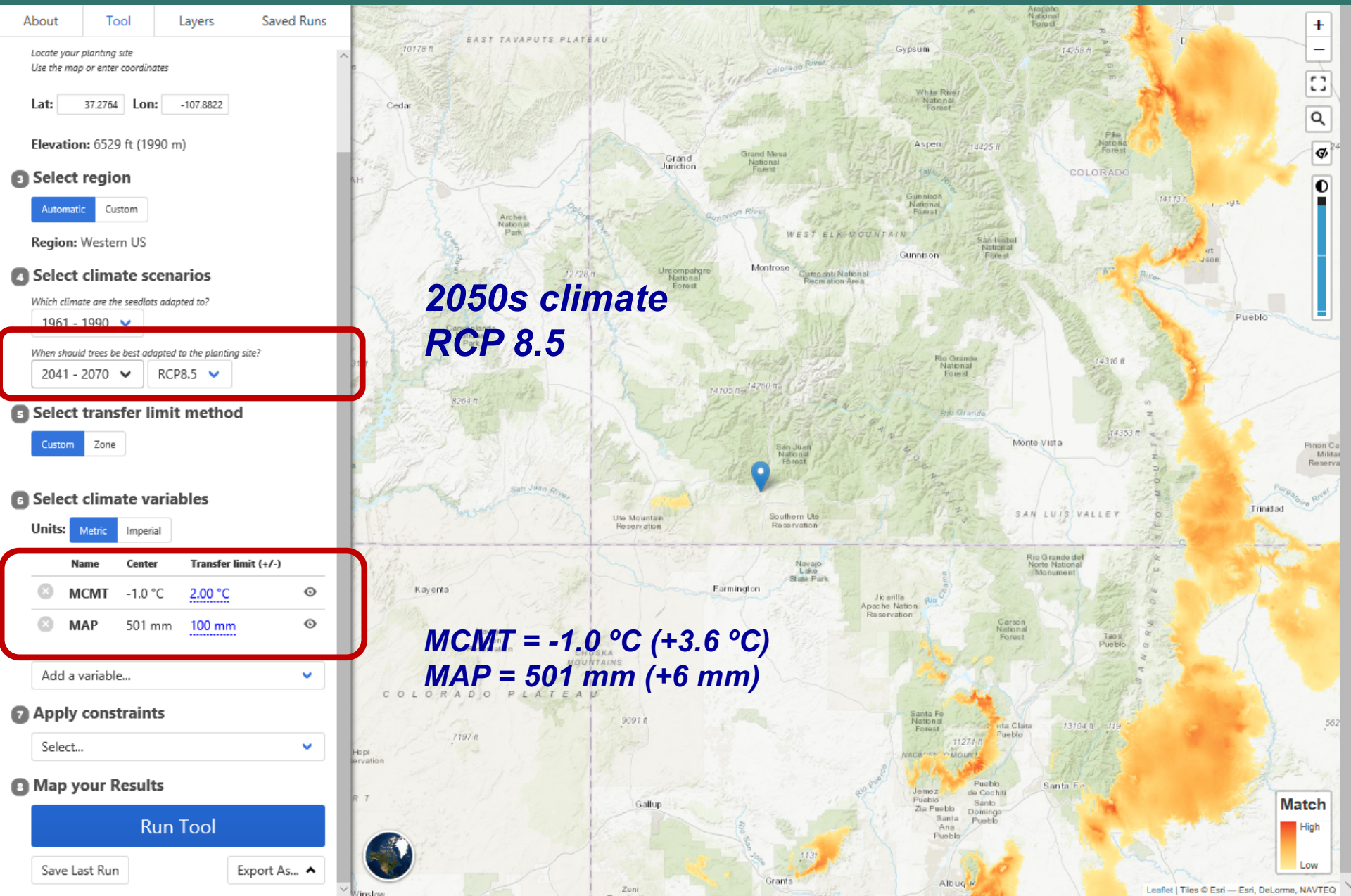
Seedlots for planting site – Recent climate



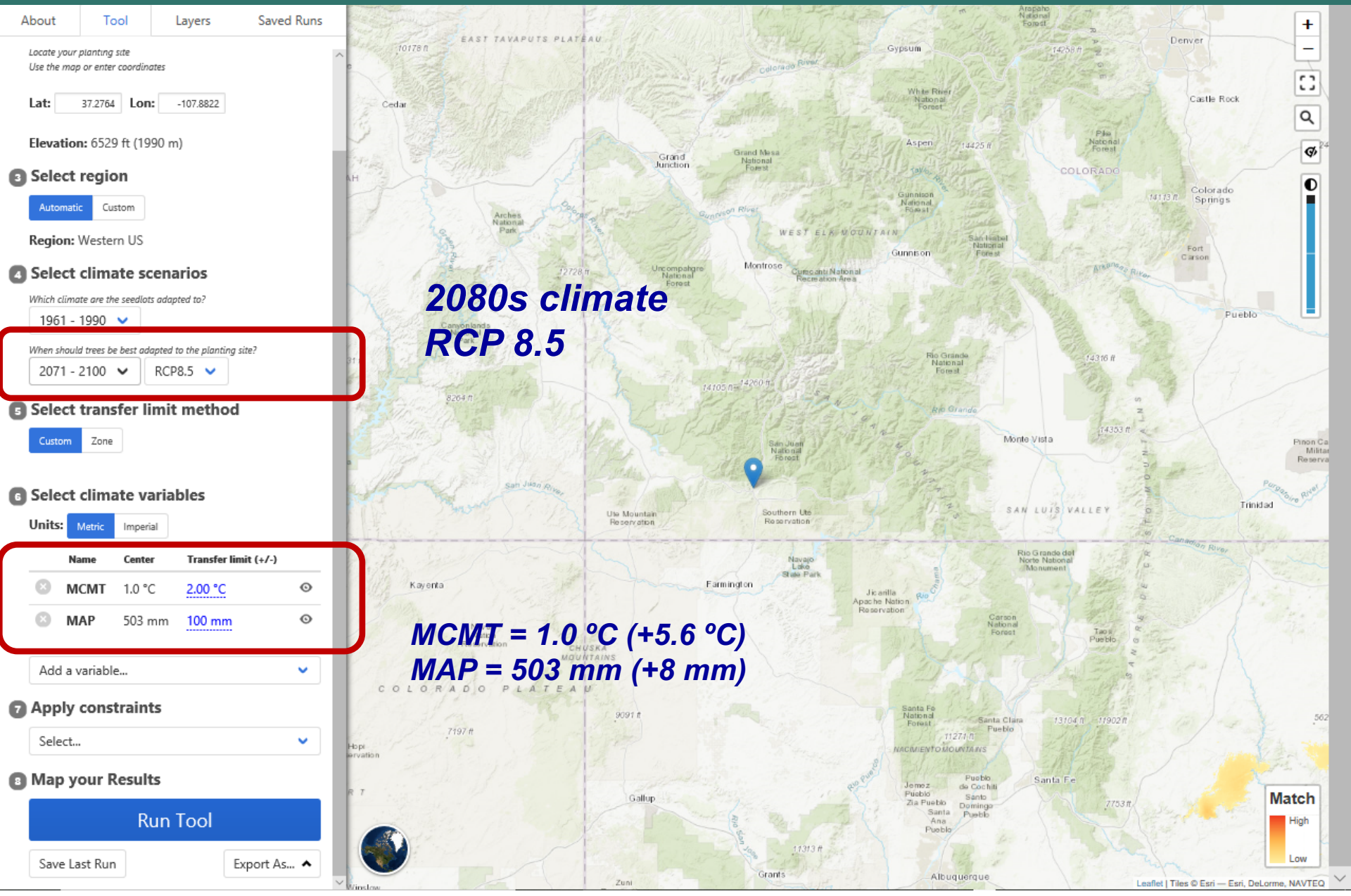
Seedlots for planting site – 2020s climate



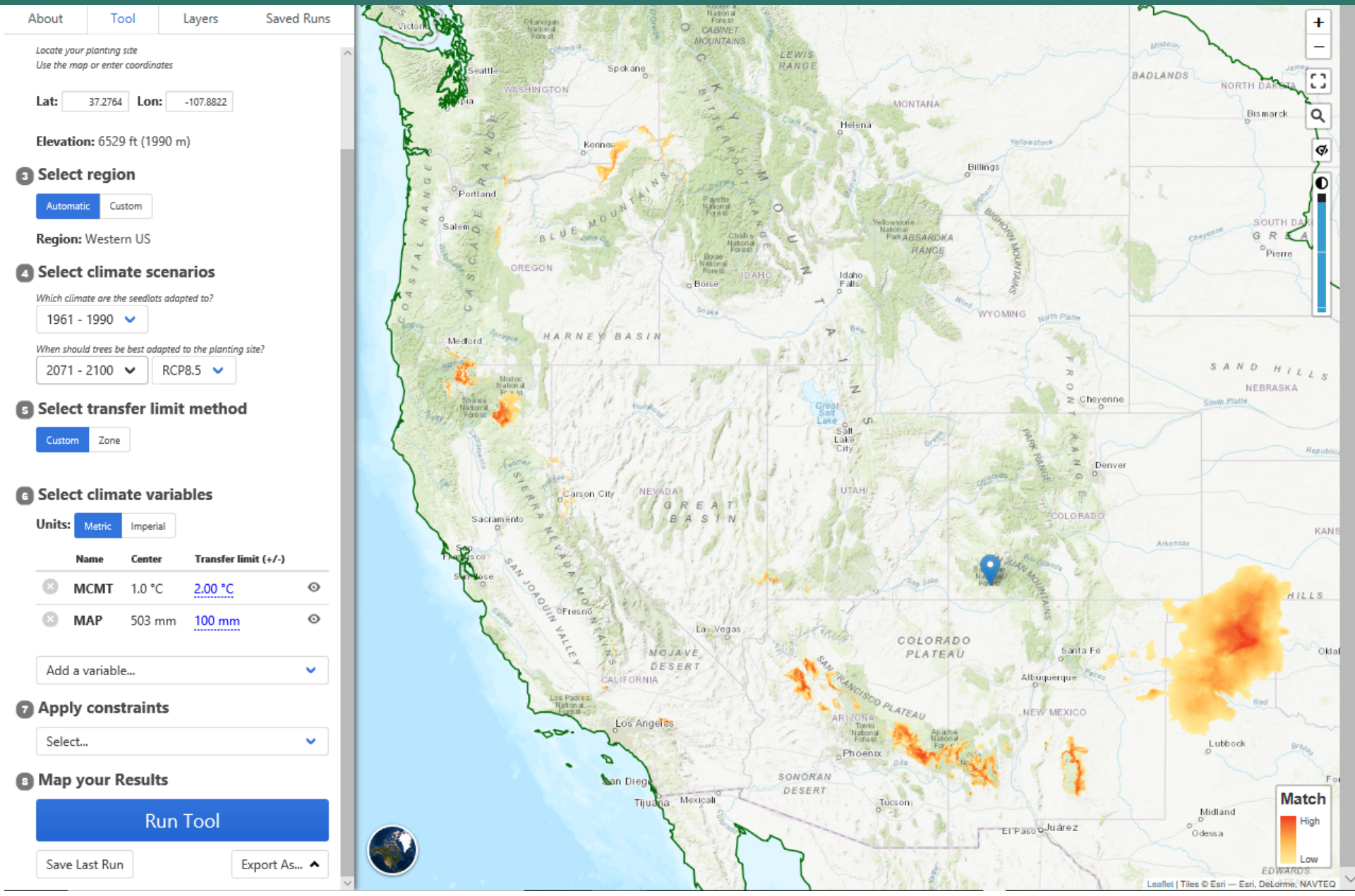
Seedlots for planting site – 2050s climate



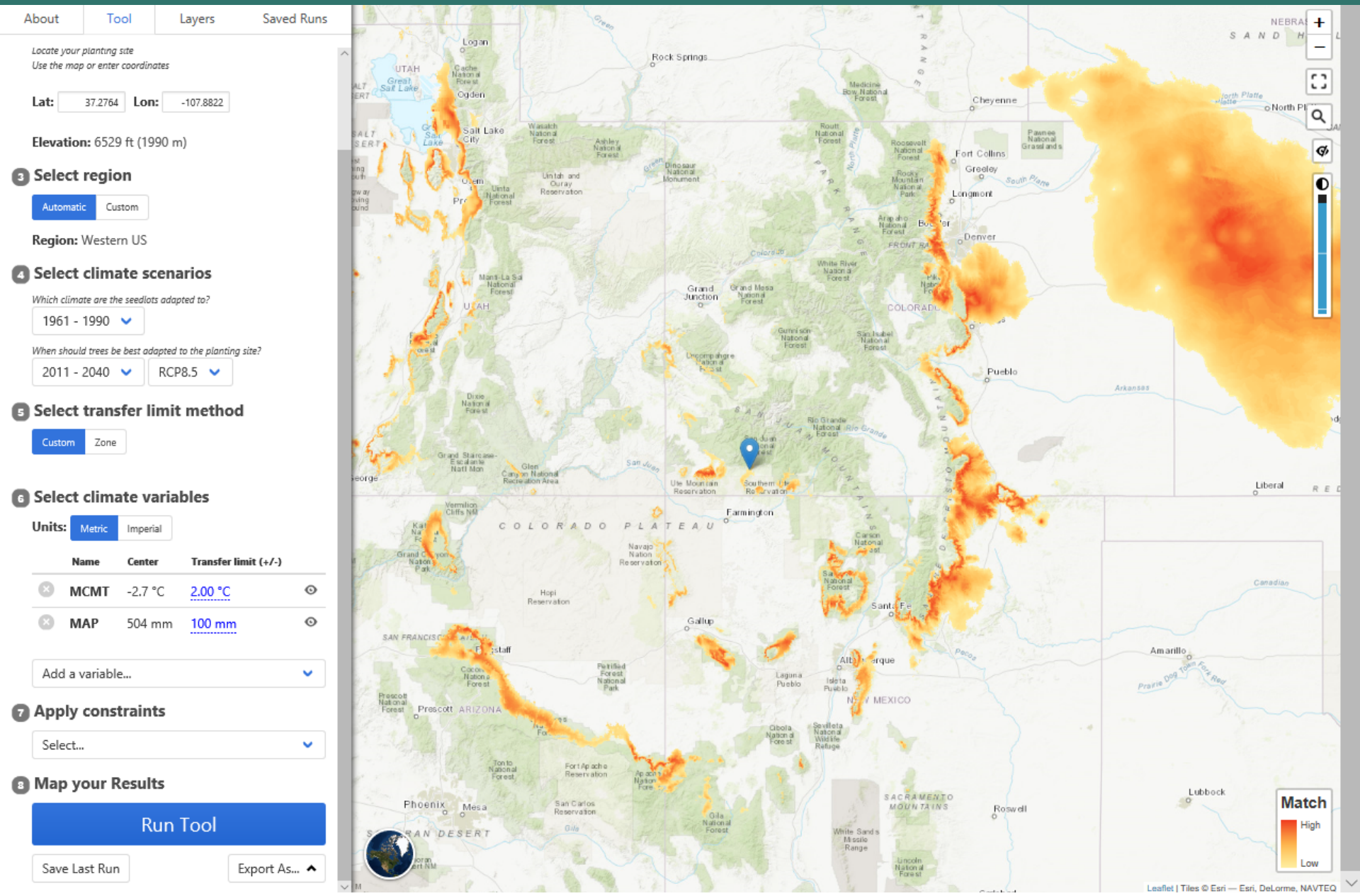
Seedlots for planting site – 2080s climate



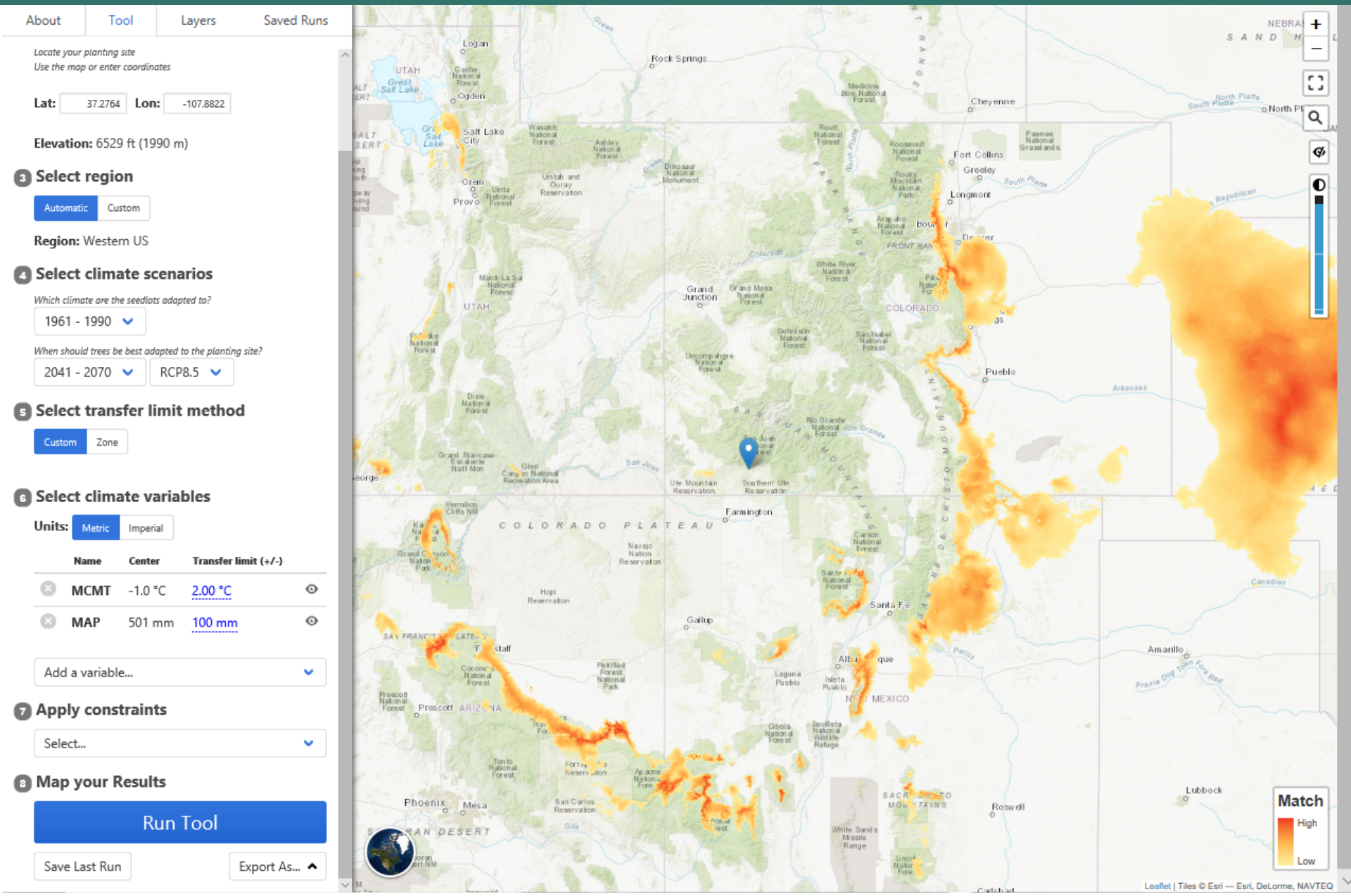
Seedlots for planting site – 2080s climate



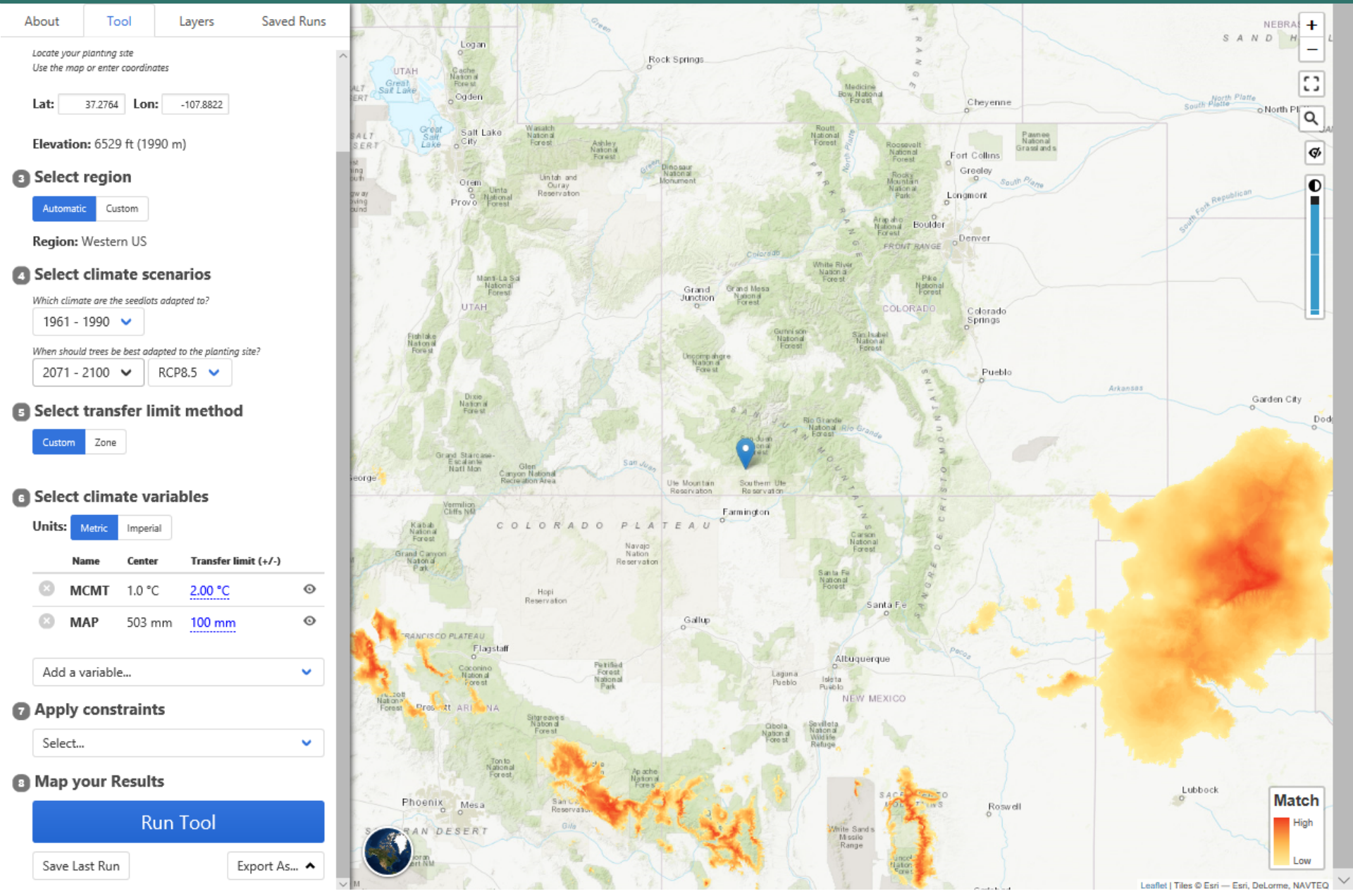
Seedlots for planting site – 2020s climate



Seedlots for planting site – 2050s climate

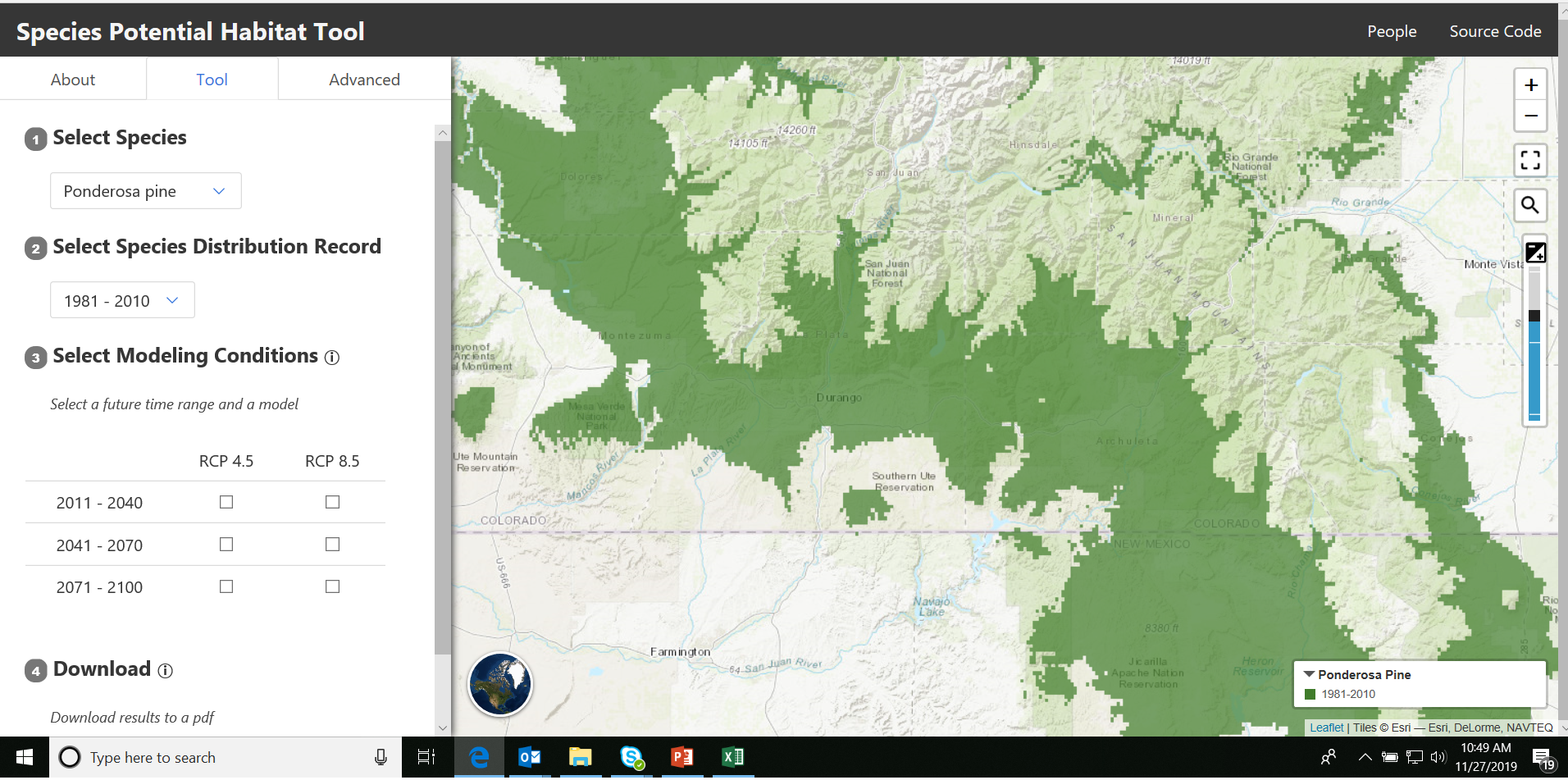


Seedlots for planting site – 2080s climate

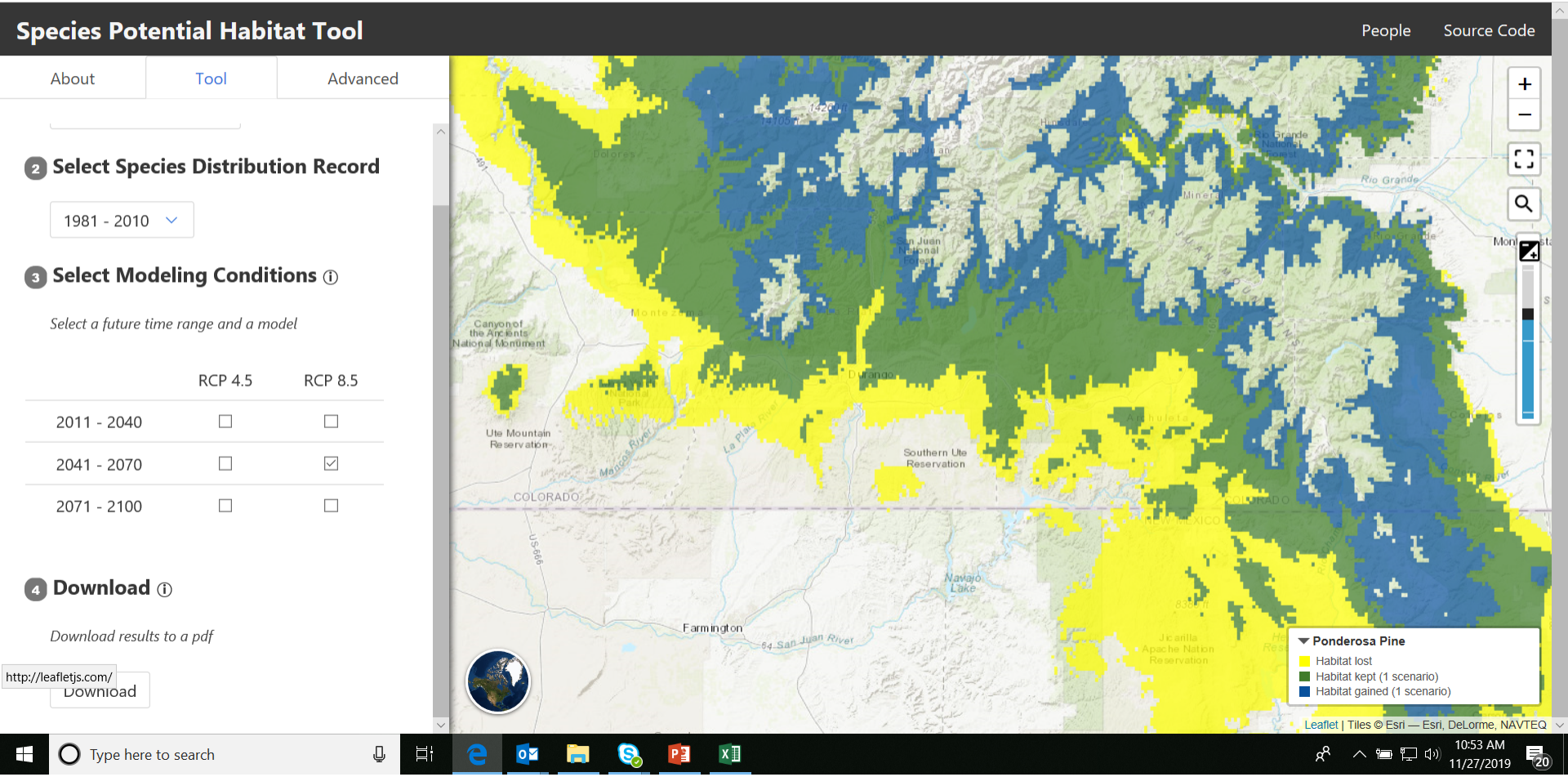


Potential loss of species habitat niche

https://specieshabitattool.org/spht/



Potential loss of species habitat niche



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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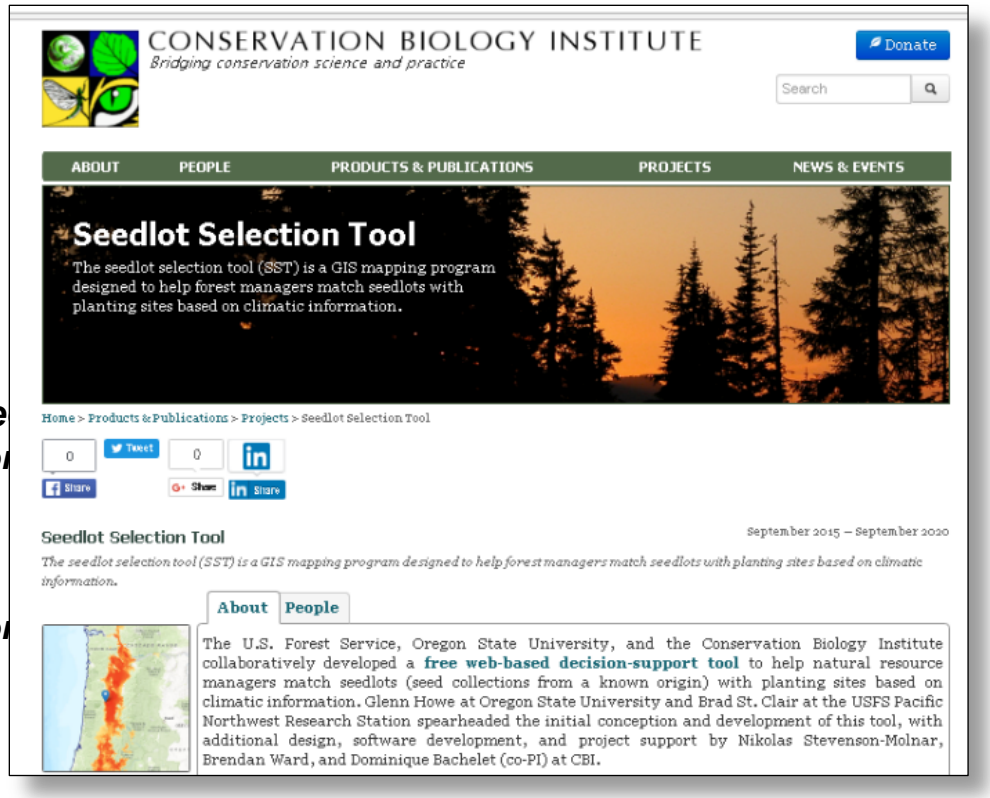

consbio.org/products/webinars/climate-smart-seedlot-selection-tool

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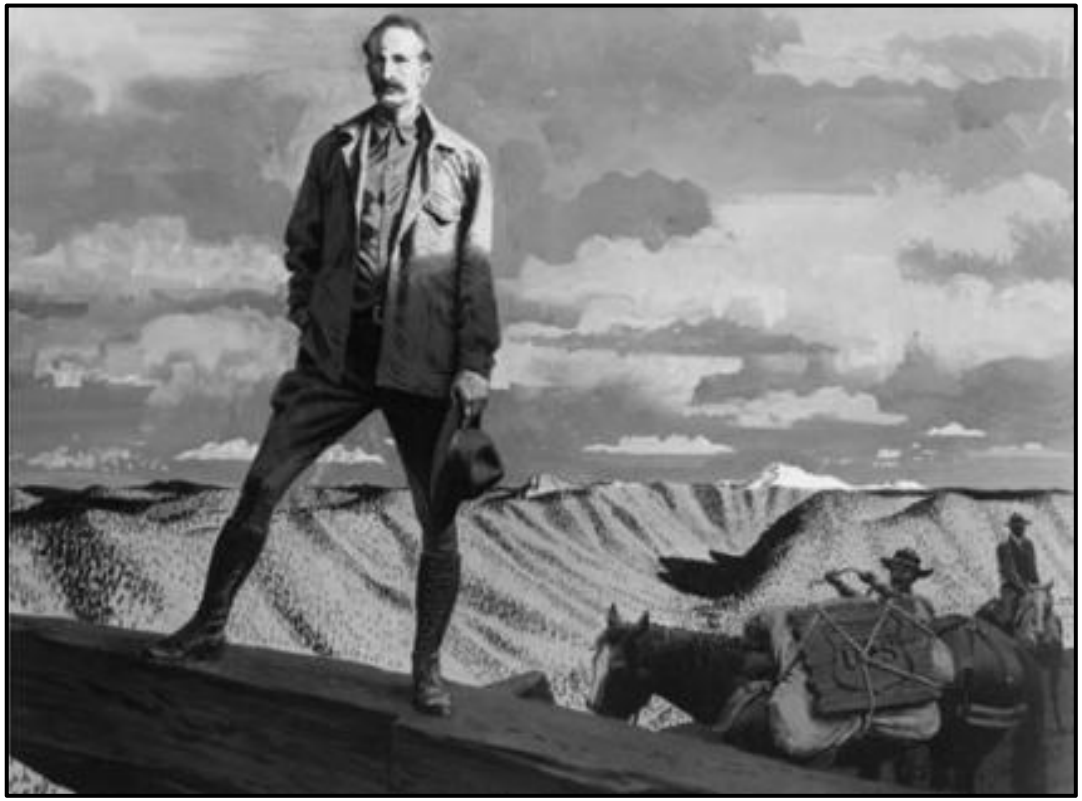

"The vast possibilities of our great future will become realities only if we make ourselves responsible for that future"

- Gifford Pinchot


Questions?