Quantifying GDE vegetation use of and dependence on groundwater*

Christine Albano, Desert Research Institute
Laurel Saito, The Nature Conservancy
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DRI
Desert Research Institute

The Nature Conservancy
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Welcome!

We are recording this workshop

*Support provided by the Bureau of Reclamation through WaterSmart Grant #R19AP00278. Any opinions, findings, and conclusions or recommendations expressed in this material are those of the authors and do not necessarily reflect the views of the Bureau of Reclamation.

Agenda

Welcome and Meeting Overview

Introduction to Project

Updates on Modeling

BREAK

Framework Discussion

Wrap-Up and Next Steps

Project Introduction

Soldier Meadows (D. Page / DRI)

What are groundwater dependent ecosystems (GDEs)?

- GDEs rely on groundwater to maintain ecological structure and function
  - Ecosystem types (Eamus et al. 2006)

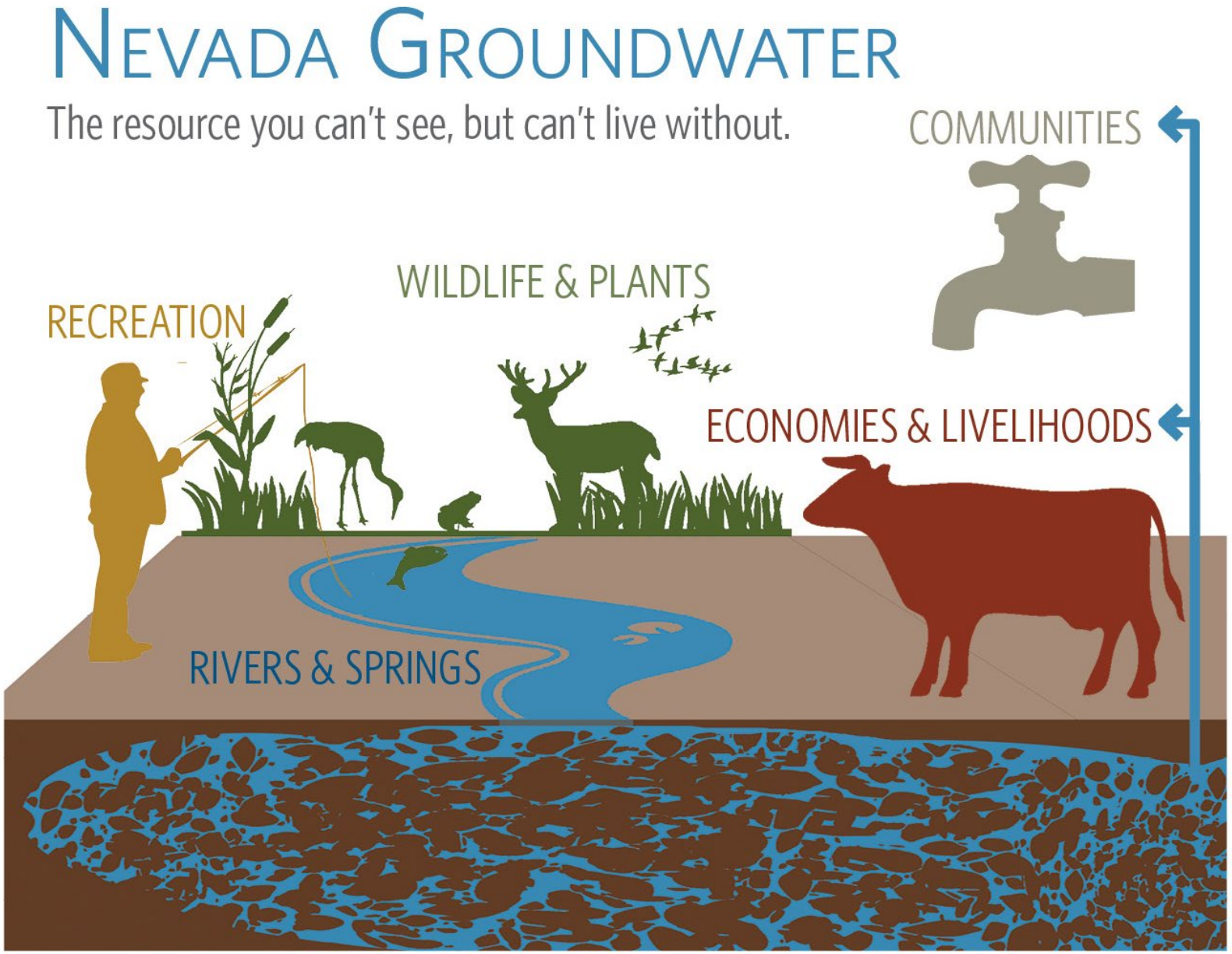
Springs	Lakes
Subterranean	Rivers
Phreatophytes	Wetlands

  - GDEs benefit people and nature

water storage/purification	recreation
soil preservation	economic value
carbon storage	cultural value
flood reduction	water supply

Eamus D, Froend R, Loomes R, Hose G, Murray B. 2006. *Australian Journal of Botany* 54:97-114.

Bog Hot Springs (H. Maude)

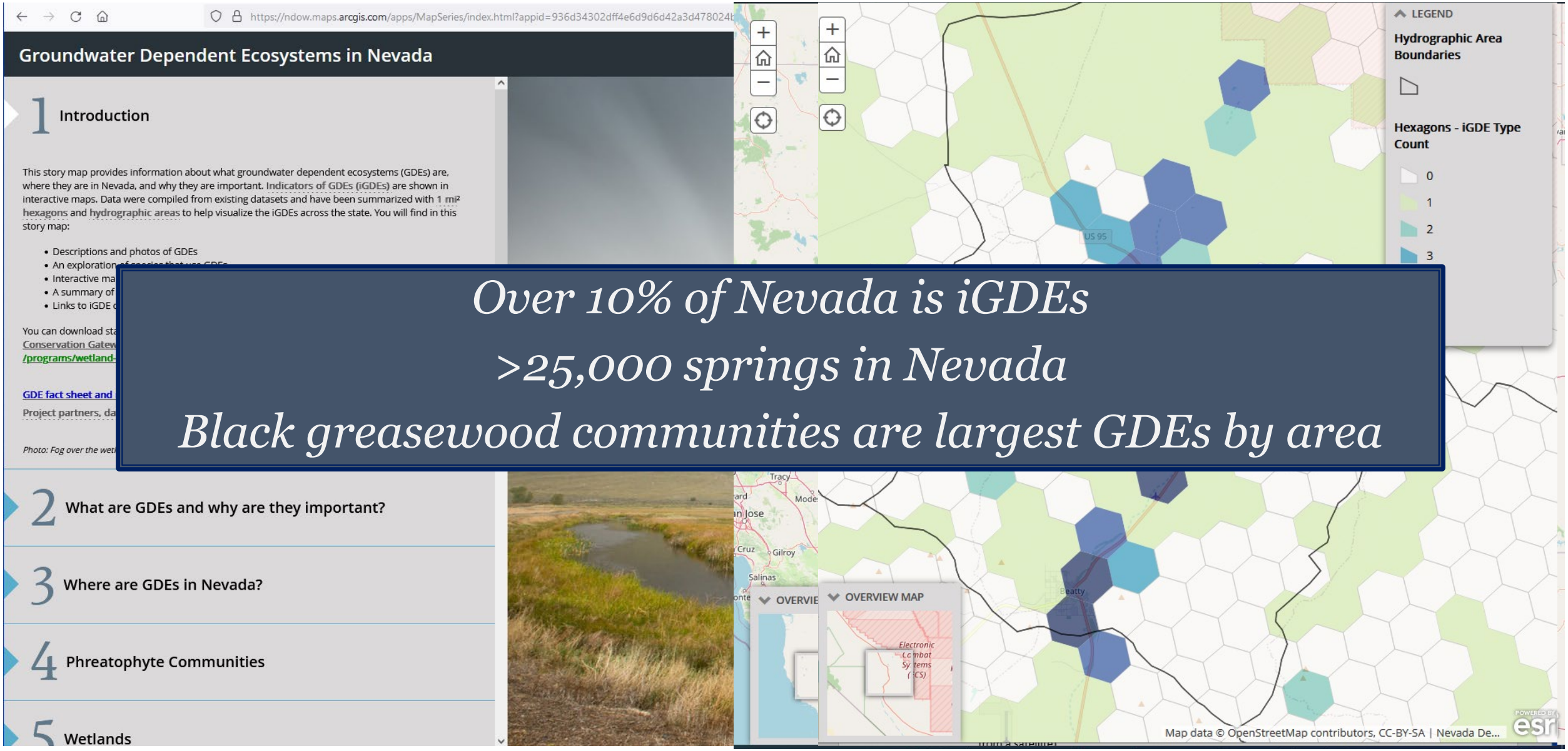


- Almost half of water withdrawals in NV in 2015 were from groundwater (Dieter et al. 2018)
- Over 50% of groundwater hydrographic basins are over-appropriated
  - Total NV perennial yield is ~ 2M AF
  - Total groundwater appropriated is ~3M AF

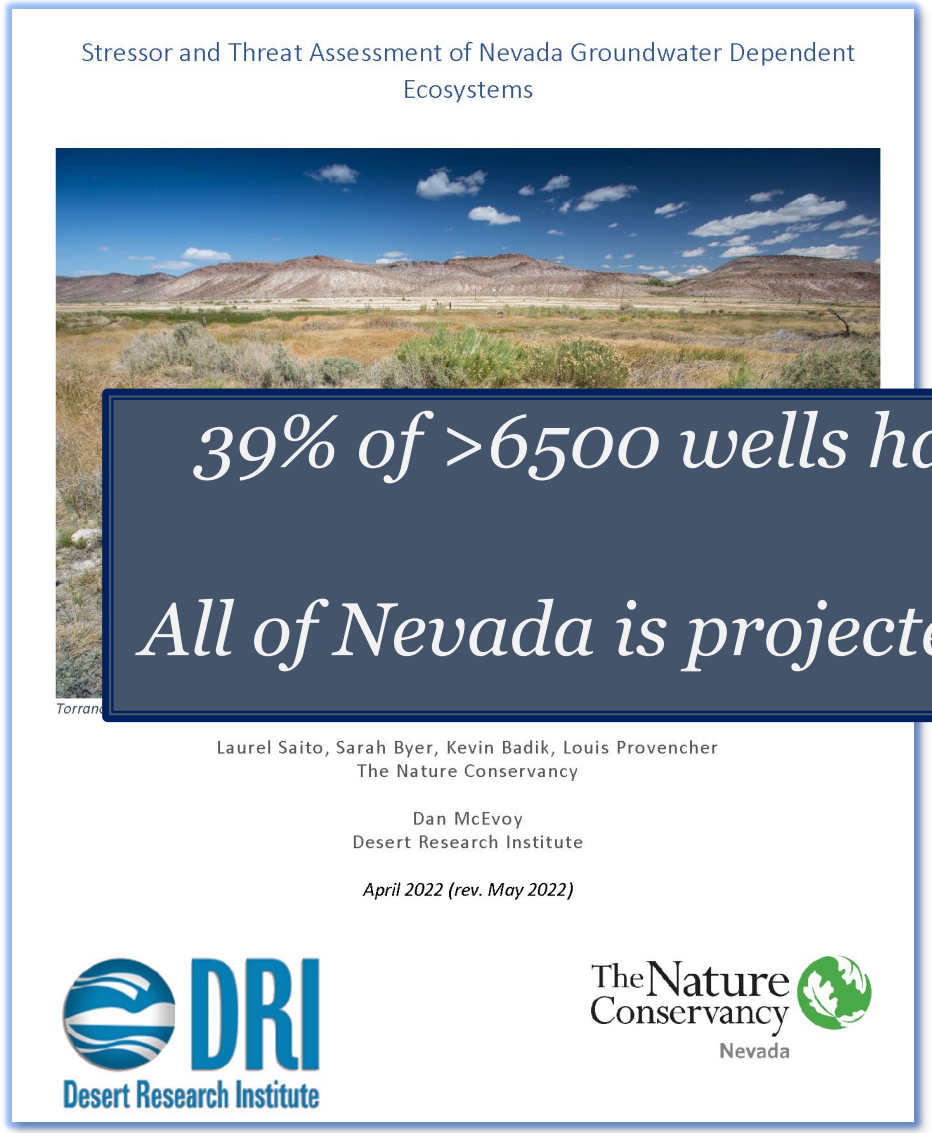
Dieter CA, Maupin MA, Caldwell RR, Harris MA, IVahnenko TI, Lovelace JK, Barber NL, Linsey KS. 2018. US Geological Survey Circular 1441. 65 pp. https://pubs.usgs.gov/circ/1441/circ1441.pdf

Story map: https://arcg.is/qyj0v

Where are GDEs in Nevada?



What are risks to GDEs in Nevada?


Stressor and Threat Assessment of Nevada Groundwater Dependent Ecosystems

Laurel Saito, Sarah Byer, Kevin Badik, Louis Provencher
The Nature Conservancy

Dan McEvoy
Desert Research Institute

April 2022 (rev. May 2022)

Desert Research Institute

The Nature Conservancy Nevada

Groundwater withdrawals

Climate

39% of >6500 wells had significantly falling groundwater level trends

All of Nevada is projected to be more "droughty" in the future

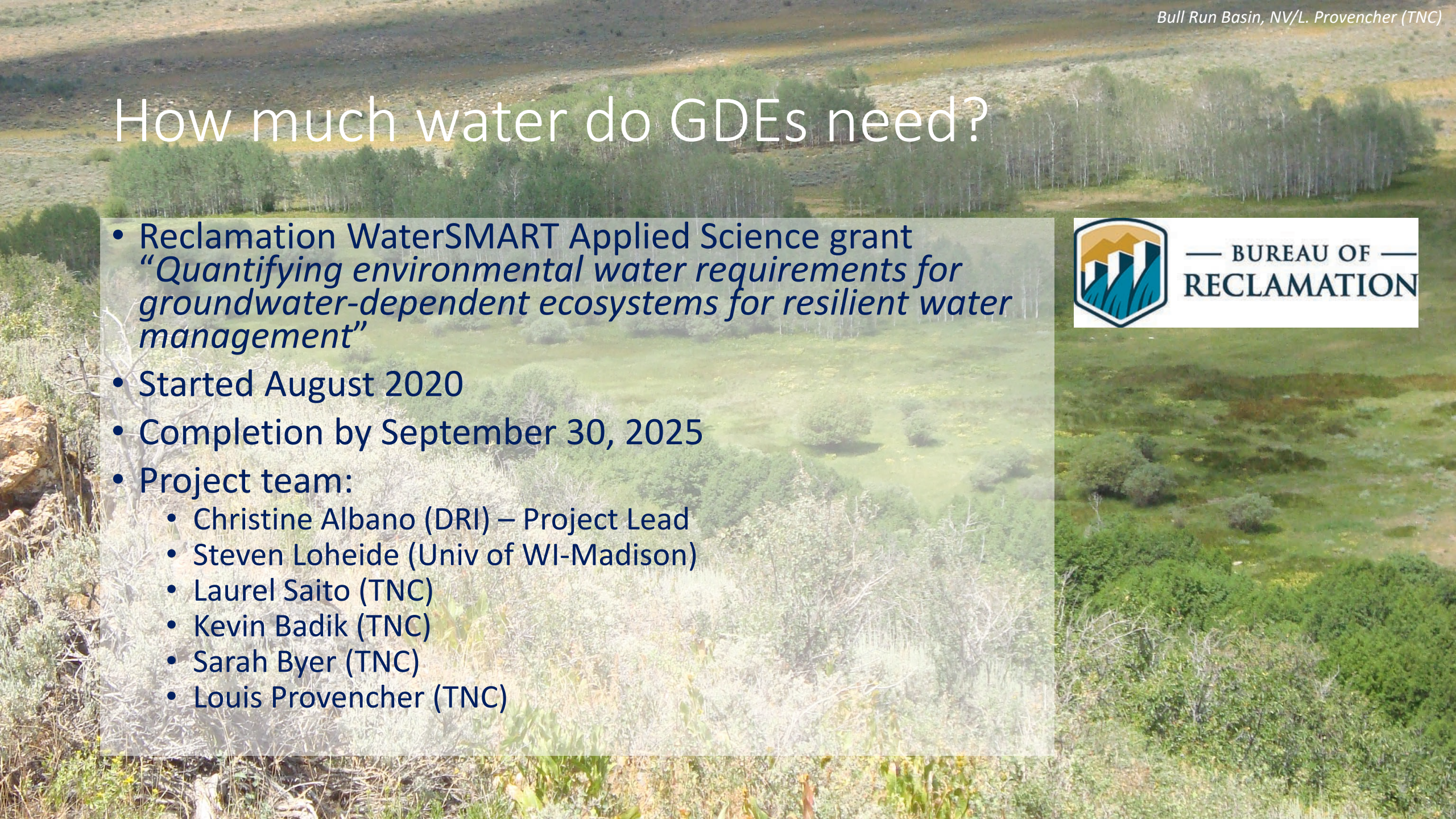
Non-native species

Additional human development impacts

How much water do GDEs need?

- Key uncertainty for sustainable water management
- Methods
  - Tracers
  - Water table fluctuations
  - Water or energy balance
  - Remote sensing
- Issues
  - Require very site-specific measurements
  - May not work for small GDEs
  - Don’t provide process understanding

Hot springs at River Fork. Ranch (B. Bushman)



Bull Run Basin, NV/L. Provencher (TNC)

How much water do GDEs need?

- Reclamation WaterSMART Applied Science grant *"Quantifying environmental water requirements for groundwater-dependent ecosystems for resilient water management"*
- Started August 2020
- Completion by September 30, 2025
- Project team:
  - Christine Albano (DRI) – Project Lead
  - Steven Loheide (Univ of WI-Madison)
  - Laurel Saito (TNC)
  - Kevin Badik (TNC)
  - Sarah Byer (TNC)
  - Louis Provencher (TNC)

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How much water do GDEs need?

- Project Tasks
  - Data collection
  - Model development, implementation and validation
  - Incorporate water-GDE relationships in state-and-transition models
  - Develop *Groundwater Requirements for GDEs* framework
  - Develop web map application

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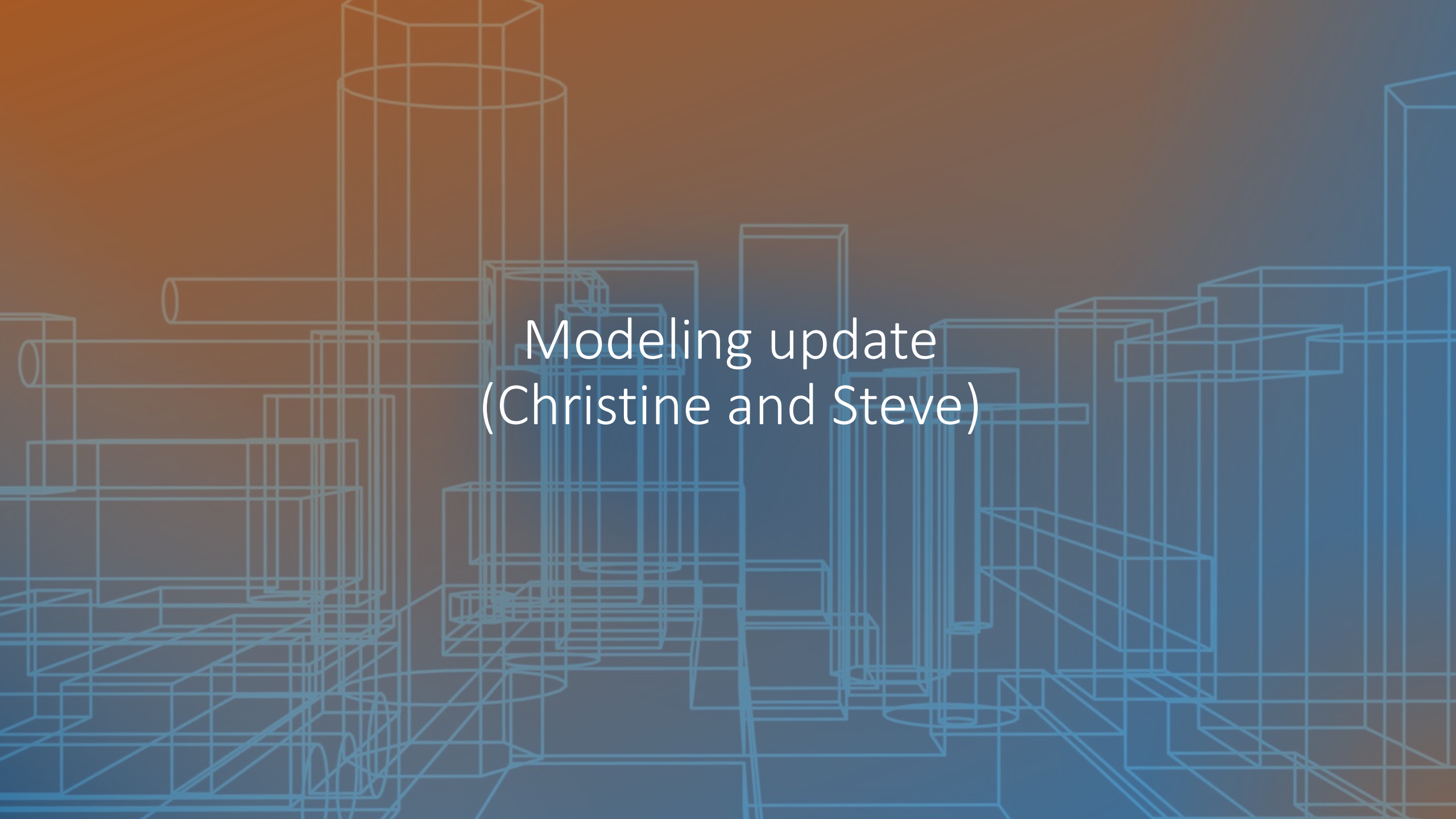


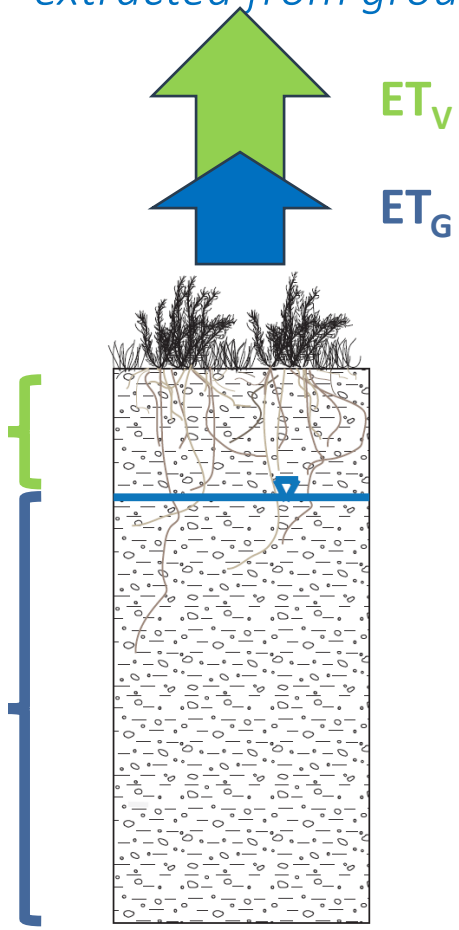
Modeling update (Christine and Steve)

How much groundwater is used by a vegetation community?

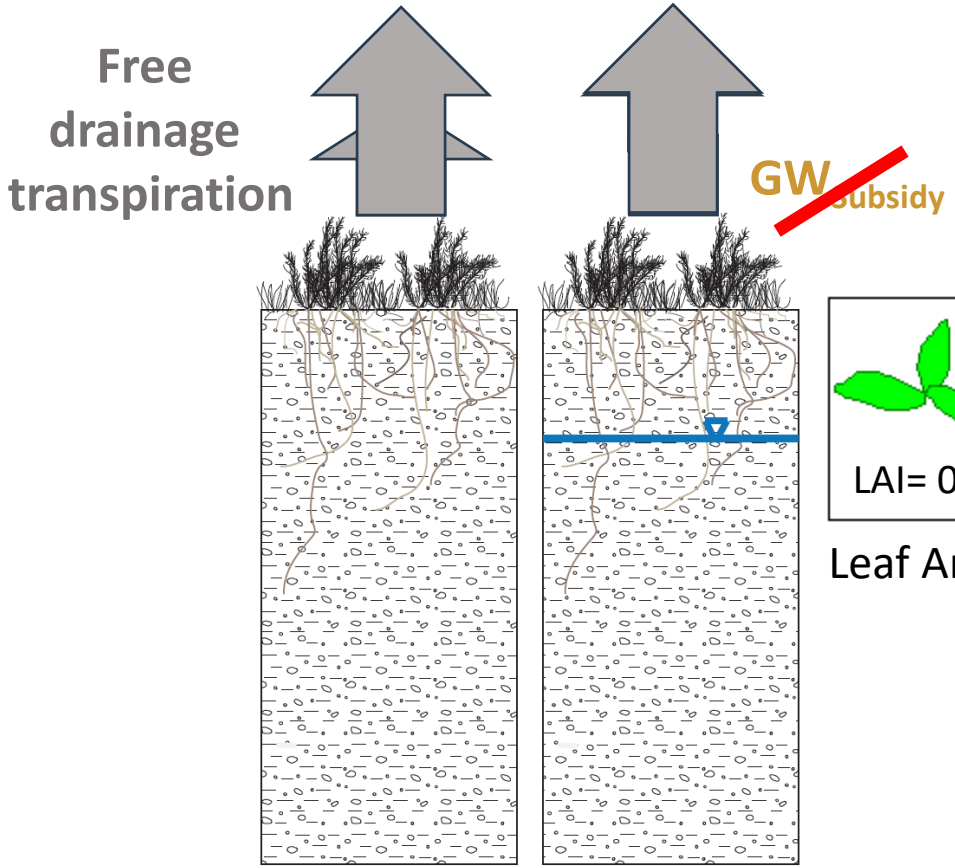
How much does a vegetation community benefit from shallow groundwater?

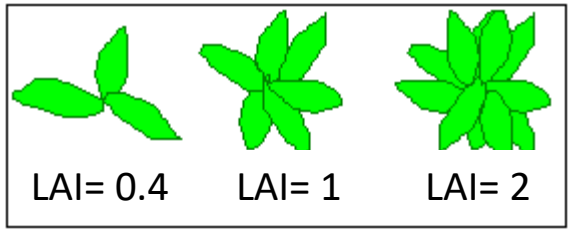
The Groundwater Subsidy Concept

Groundwater component of ET:
portion of total ET extracted from groundwater



Groundwater subsidy:
additional water available for root water uptake resulting from shallow water table conditions



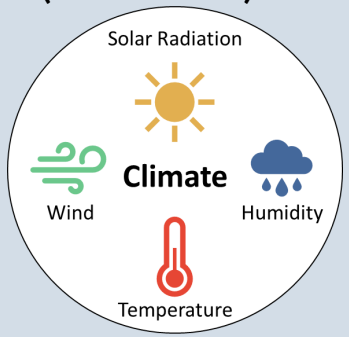


Leaf Area/Land Surface Area

Modeling Approach (Lowry and Loheide 2010)

Model Inputs

Meteorological Obs (GridMET)



Vegetation Parameters

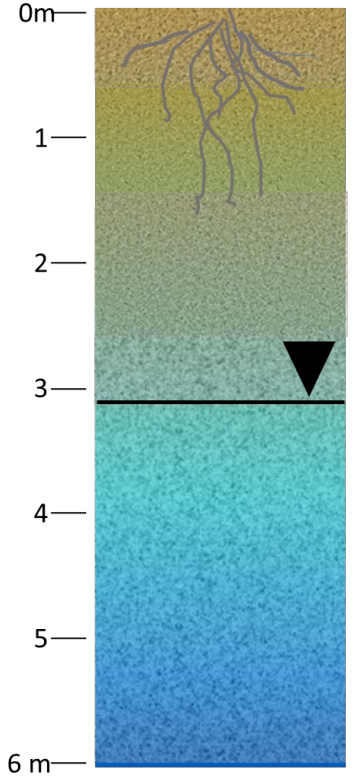
Root depth & Distribution
Water Use Efficiency
Biomass Leaf Allocation
Specific Leaf Area
Water Stress

Physical Soils Parameters (HiHydroSoils)

Water Retention Curves
Hydraulic Conductivity

Groundwater Level Obs within GDE

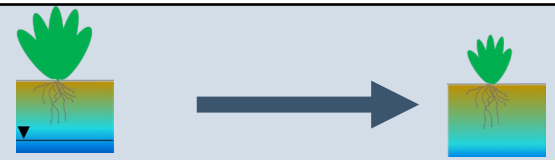
1-D Model of Soil Moisture Flow & Root Water Uptake



Implemented in Comsol Multiphysics

Model Outputs

ET_{total}
LAI



GW_{sub}

Compare to free-draining scenario

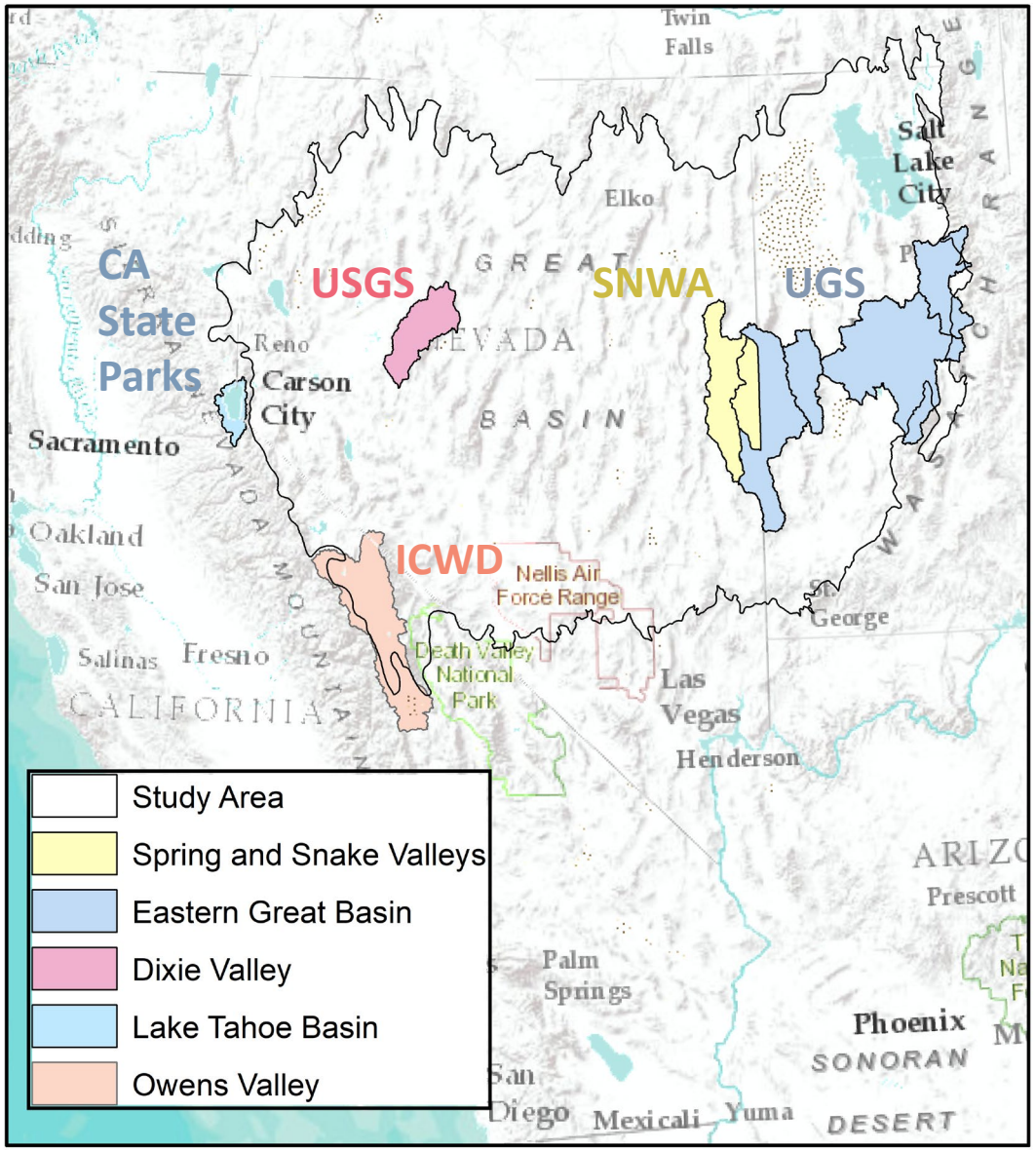
Model Calibration & Validation

Field/Remote Sensing observations:

- vegetation cover/productivity
- soil moisture
- ET

Model Calibration and Validation Sites

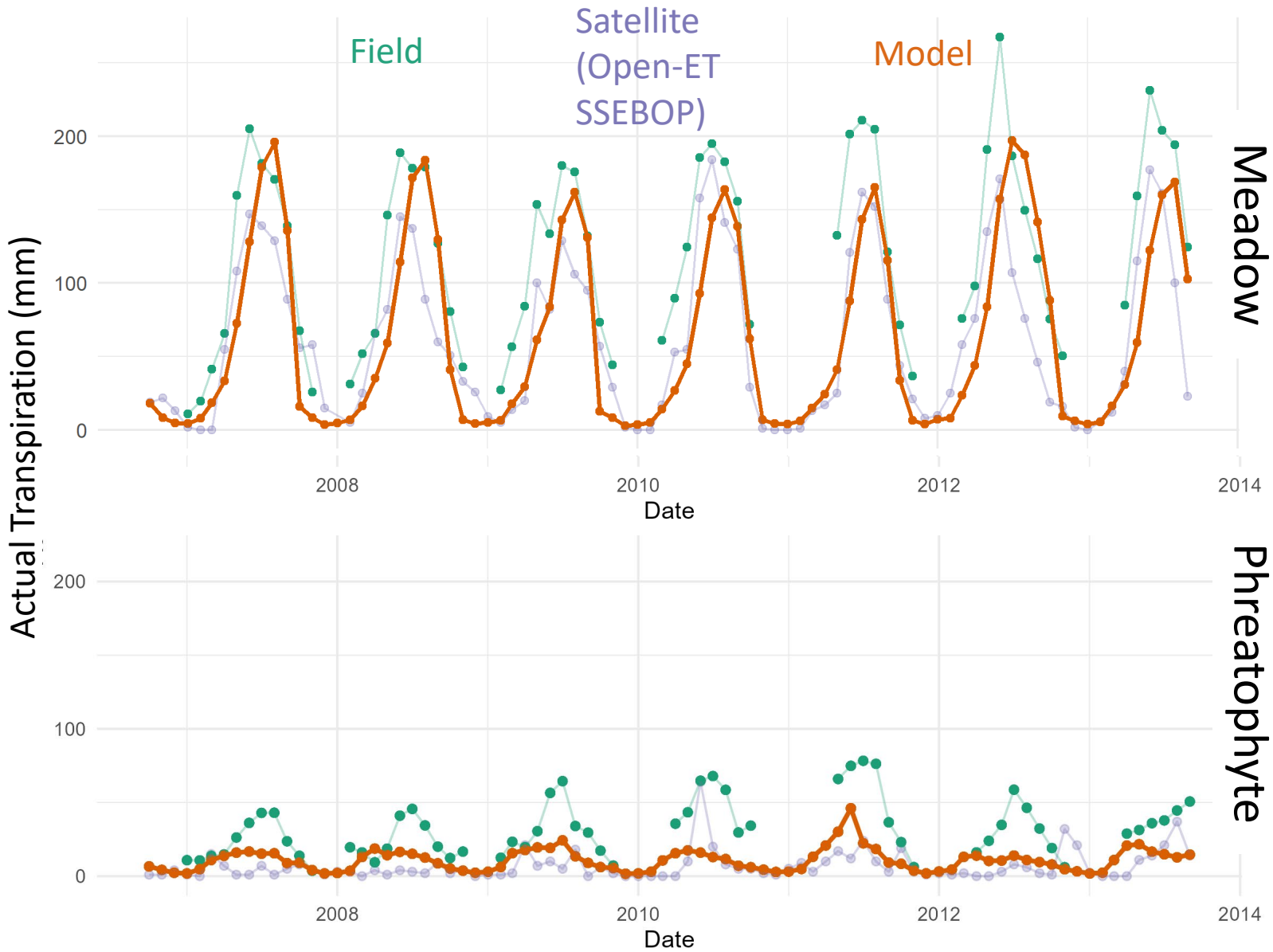
- Southern Nevada Water Authority (n=23)
  - ET Data (Eddy Covariance) @ 10 sites
- Inyo County Water Department (n=23)
  - Soil moisture, Leaf Area Index
- Utah Geological Survey (n=72)
- California State Parks (n=8)
- U.S. Geological Survey (n=5)



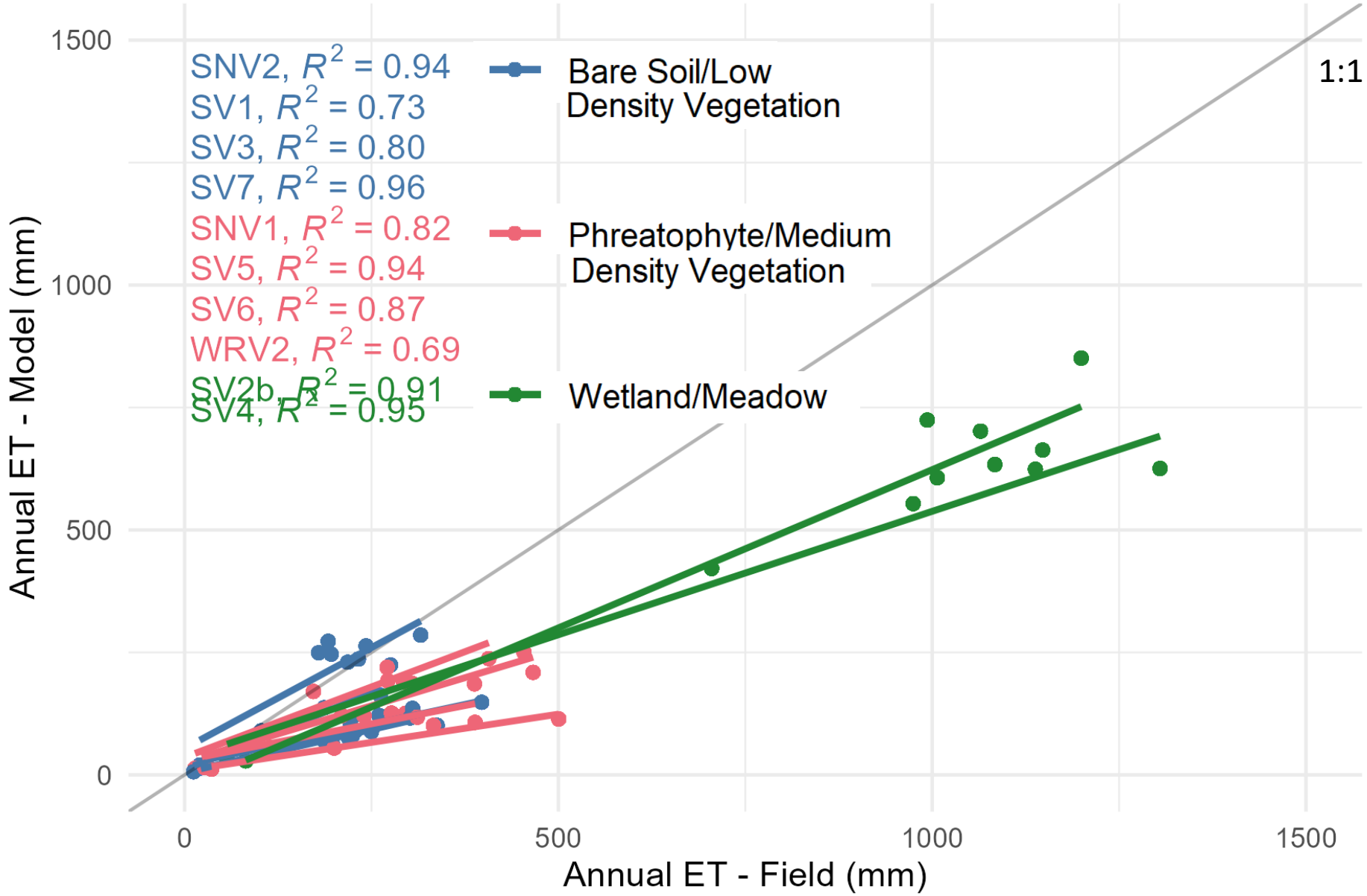
Model Validation- Evapotranspiration Spring and Snake Valley

Meadow Site (SV2B)

Phreatophyte Site (SV3)



Model Validation- Evapotranspiration Spring and Snake Valley



Laws 1

Model Validation- Soil Moisture and LAI Owens Valley

Soil Moisture

0.55
0.50
0.45
0.40
0.35
0.30
0.25
0.20
0.15
0.10
0.05
0.00

Model

Field

Leaf Area Index (LAI)

2

1

Model

Field

Landsat

Modis

0 m

-6 m

Groundwater Levels

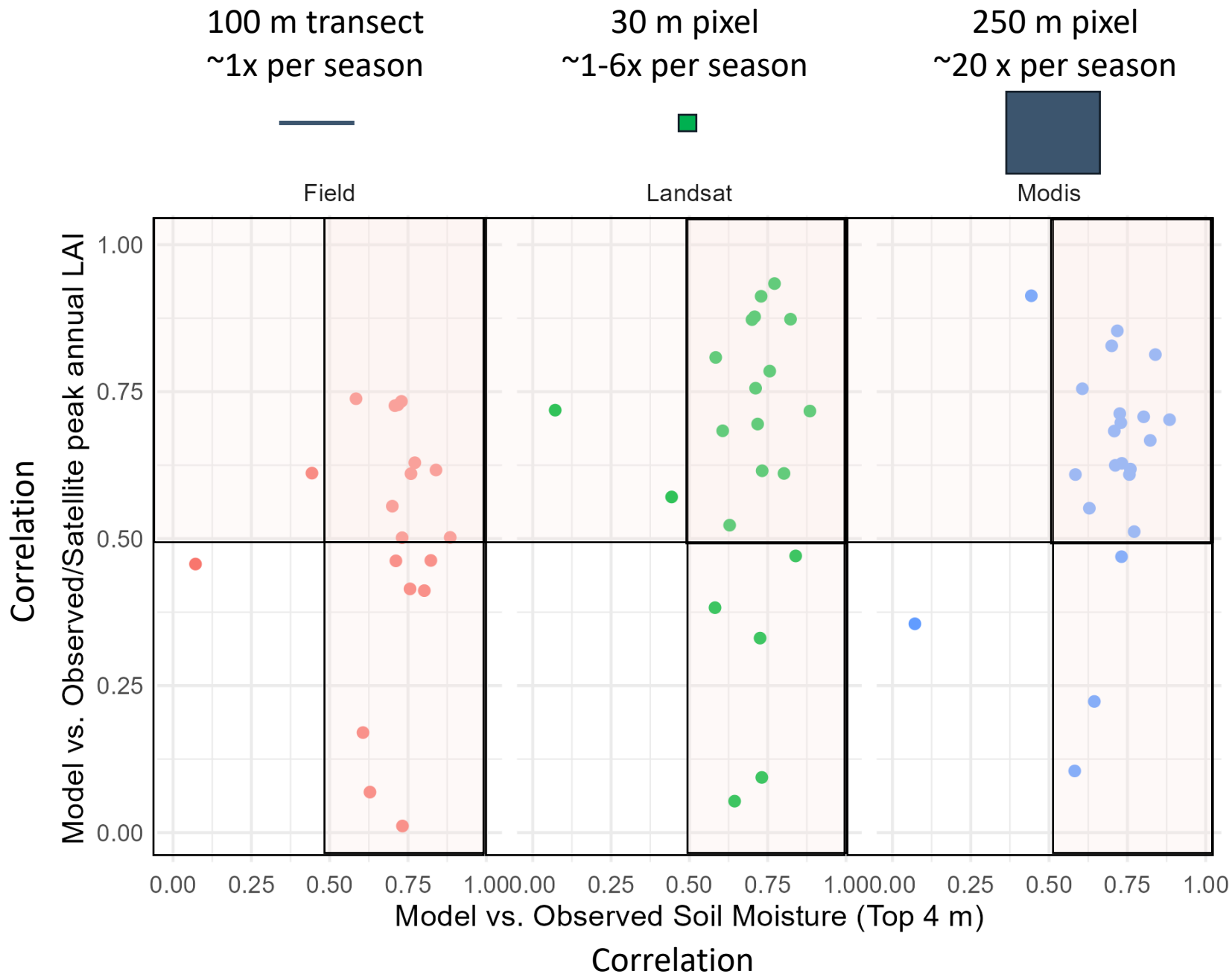
1990 2000 2010 202

date

1990 2000 2010 2020

date

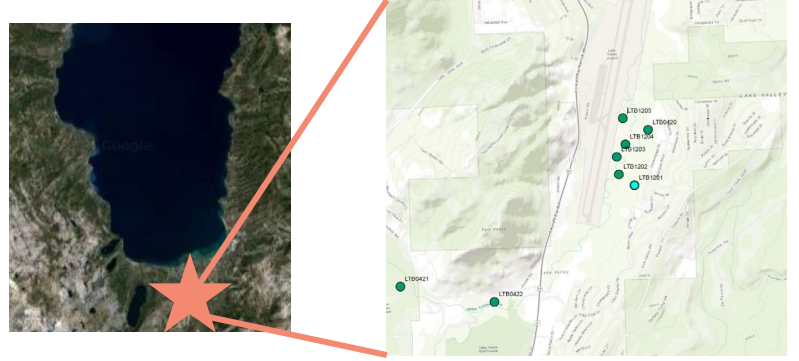
Model Validation- Owens Valley

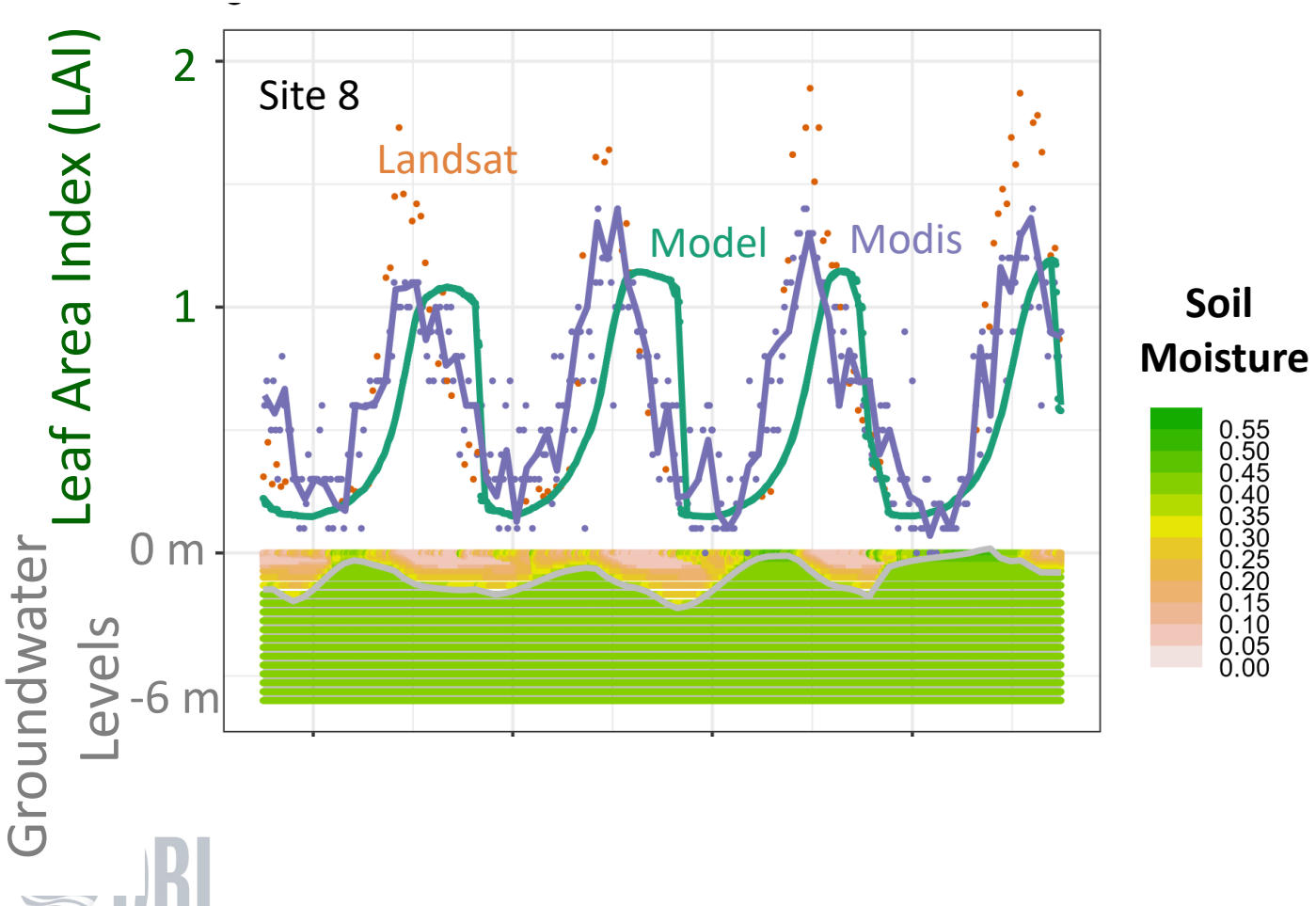


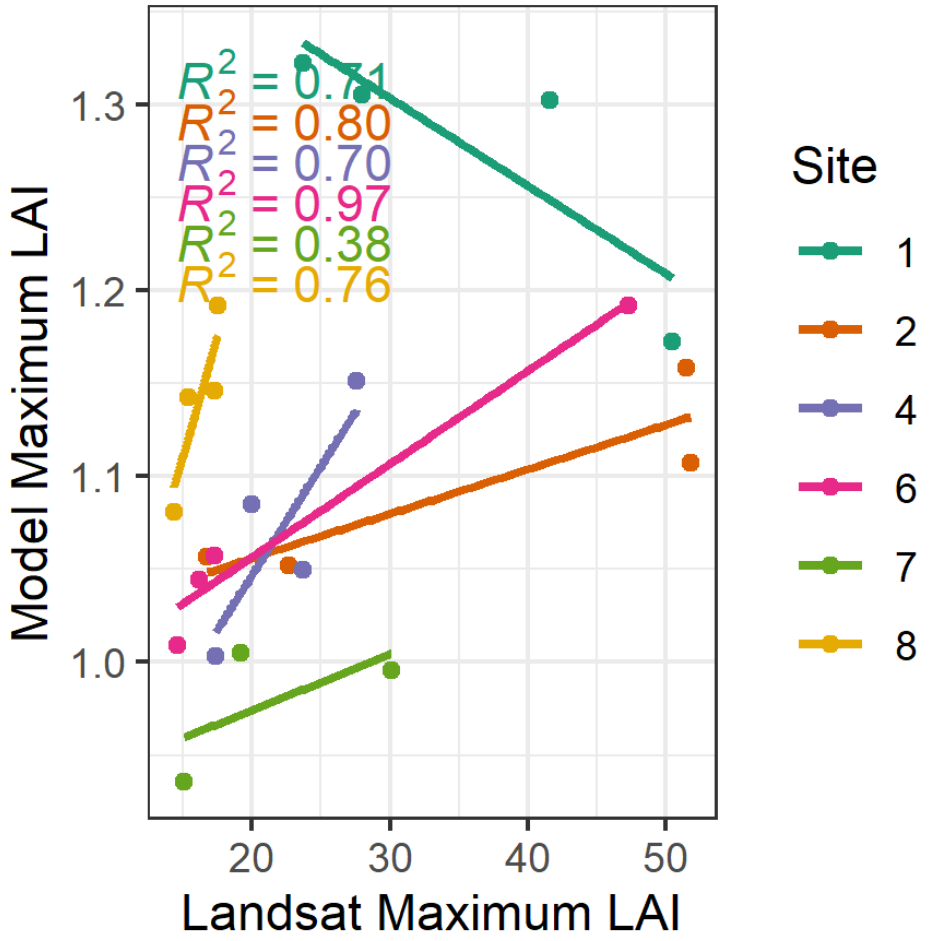
Mixed results for LAI, depending on data source

Generally strong correlations between modeled and observed soil moisture $r > 0.5$

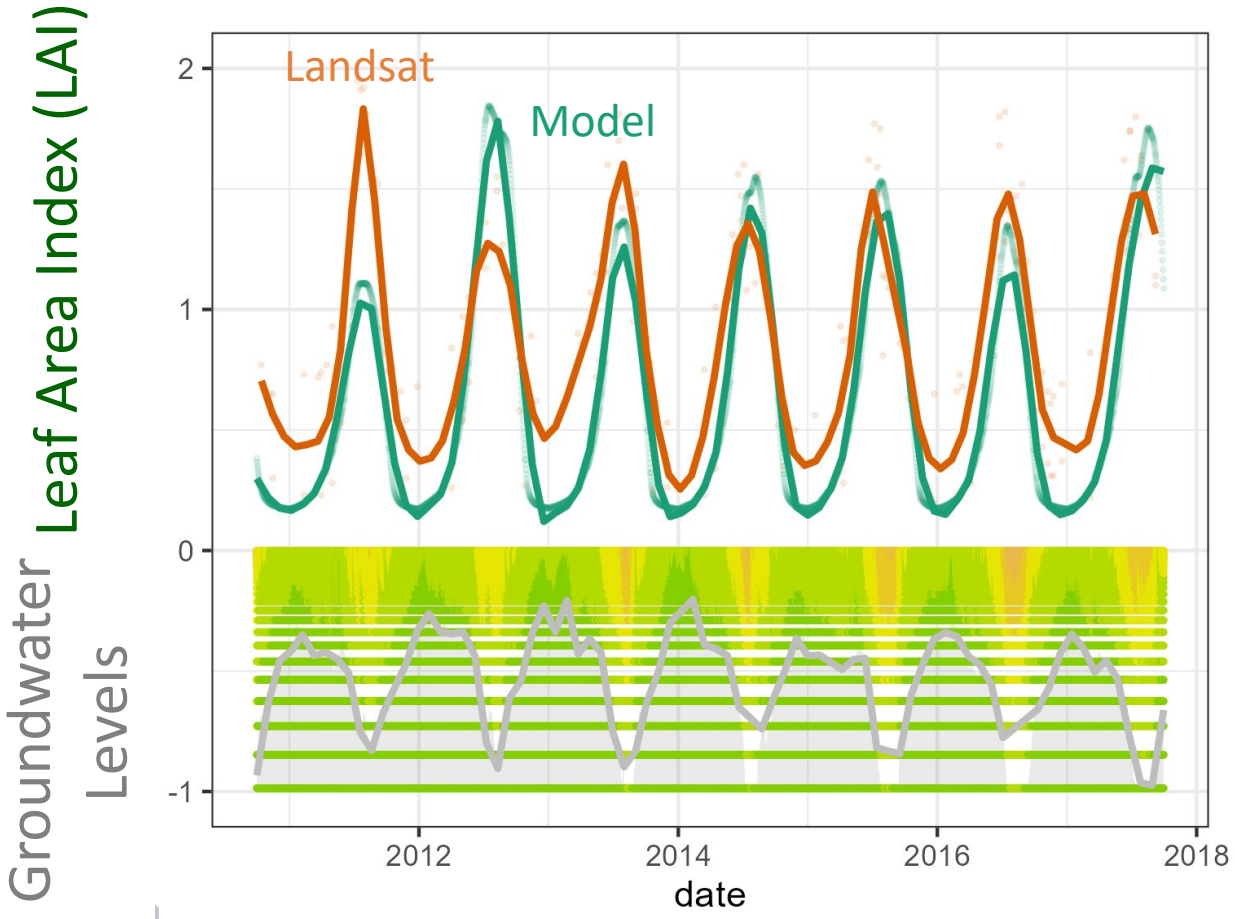
Tahoe- Upper Truckee River, Sunset Reach

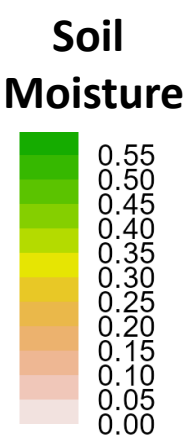


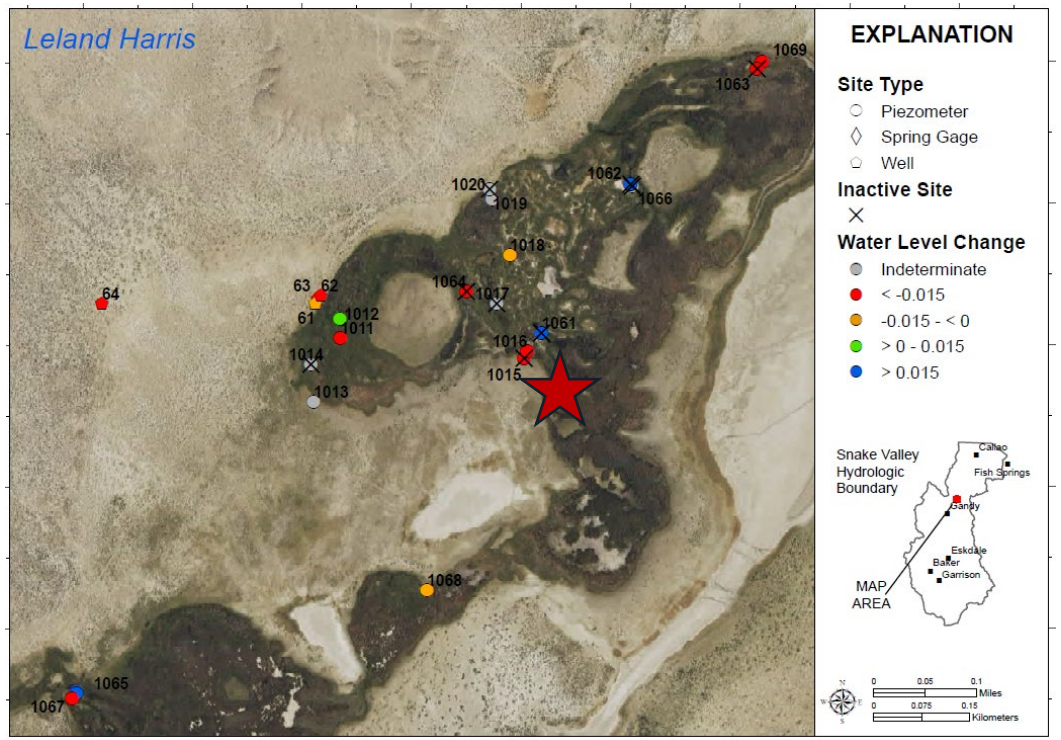




Utah Geological Survey





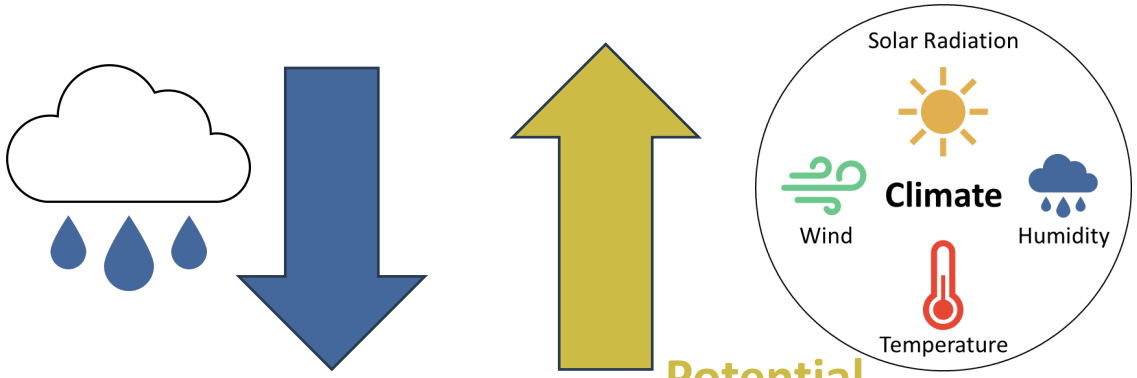


How much groundwater is used by a vegetation community?

How much does a vegetation community benefit from shallow groundwater?

Climate

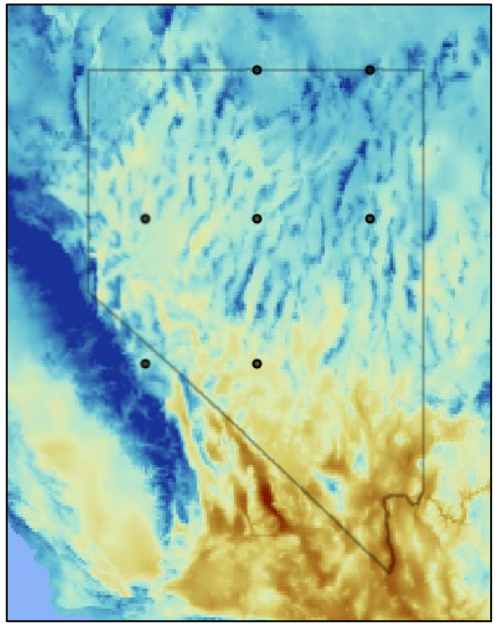
Annual Potential Water Deficit (PWD)
= Precipitation – Potential ET



Precipitation

Potential Evapotranspiration

Wettest/Coolest = +500
Driest/Warmest = -2500
Average = -1100 mm



Soil Texture

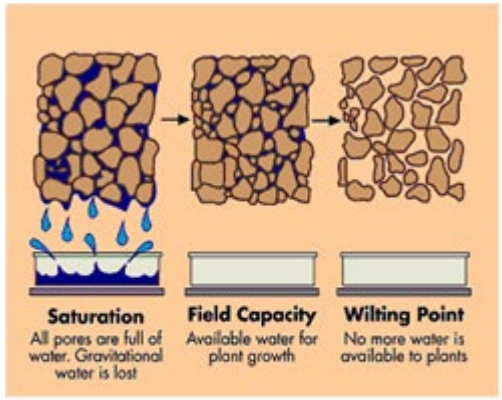
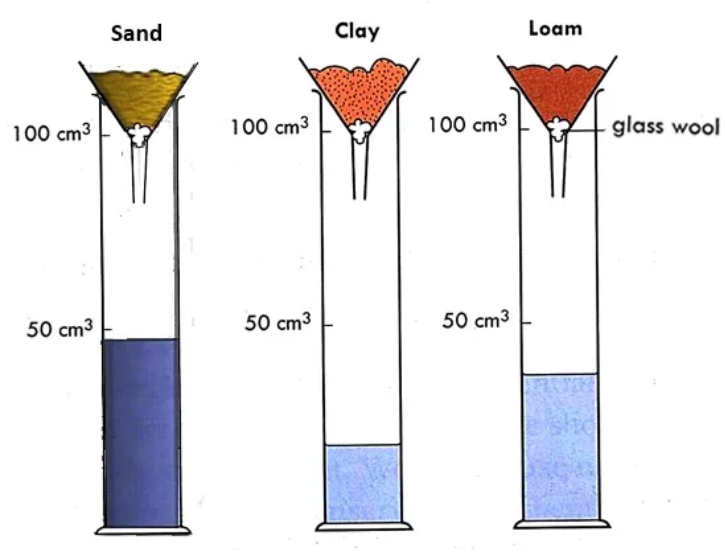
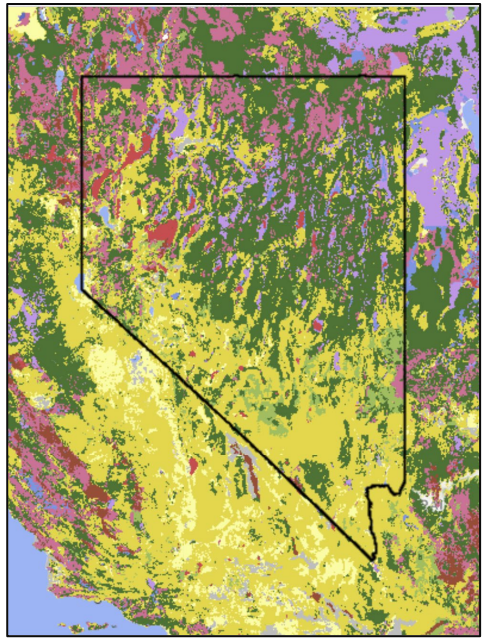


Fig 1. Stages of water availability in soil. Schoonover, J. & Crim, J. (2015)



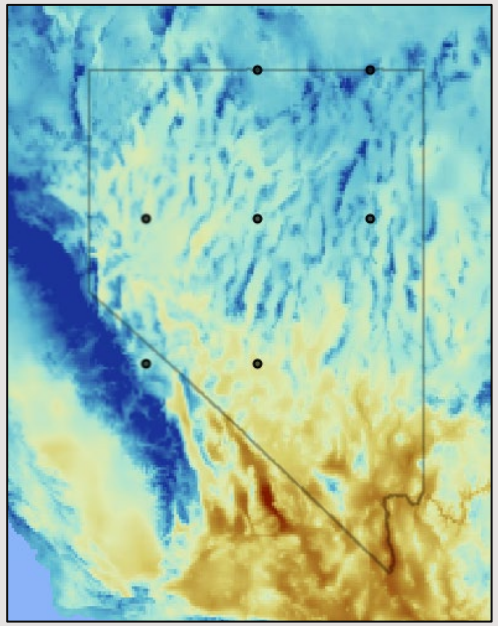
USDA Soil Texture

- Sand
- Loamy Sand
- Sandy Loam
- Loam
- Silt Loam
- Silt
- Sandy Clay Loam
- Clay Loam
- Silty Clay Loam
- Sandy Clay
- Silty Clay
- Clay



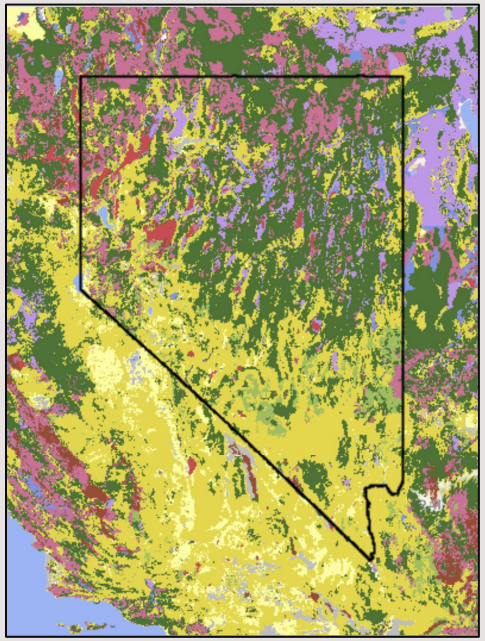
Assessing GDE Responses to Groundwater Depth in Nevada

Climate



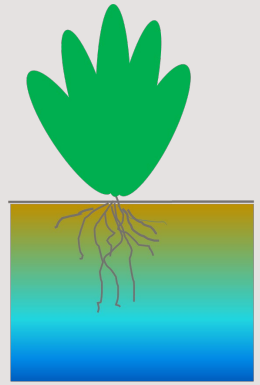
WY Potential Water Deficit (mm) = Precipitation – Potential ET

Soil Textures

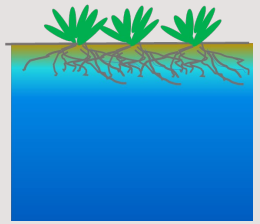


GDE Types

Dryland Phreatophyte Shrubland
Root depth = 3.6 m



Herbaceous Wet Meadow
Root depth = 2 m



Depth to Groundwater

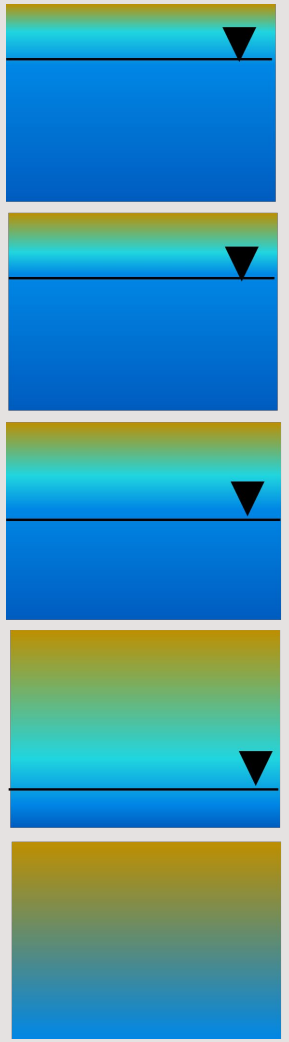
2 m

3 m

4 m

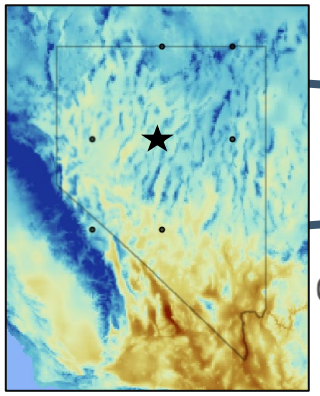
6 m

Free Drain



6 locs* 30 WYs= 180
X
11 soil textures
X
2 root depths
X
5 GW depths=

N =19,800
Water Years



Evapotranspiration vs Depth to Groundwater

Drier/Warmer

Average

Cooler/Wetter

Larger GW Subsidy

Large GW Subsidy

GW Subsidy Deep > Shallow Roots

No GW Subsidy

Smaller GW Subsidy

Annual ET

000

750

500

250

0

0

5

10

Free Drain

Depth to Groundwater

Soil Type

loamysand

sandyclay

siltloam

Meadow

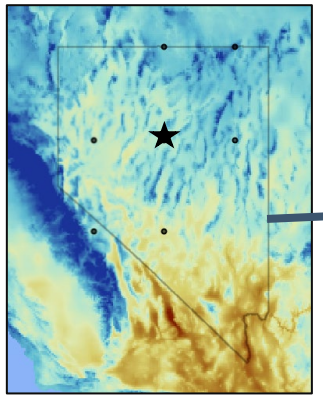
2 m root depth

Phreatophyte Shrubland

3.6 m root depth

DRI

LAI vs. Groundwater Subsidy

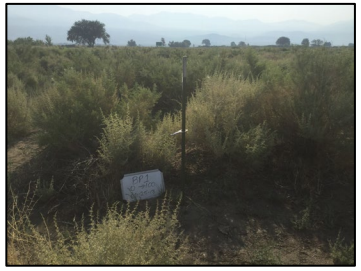


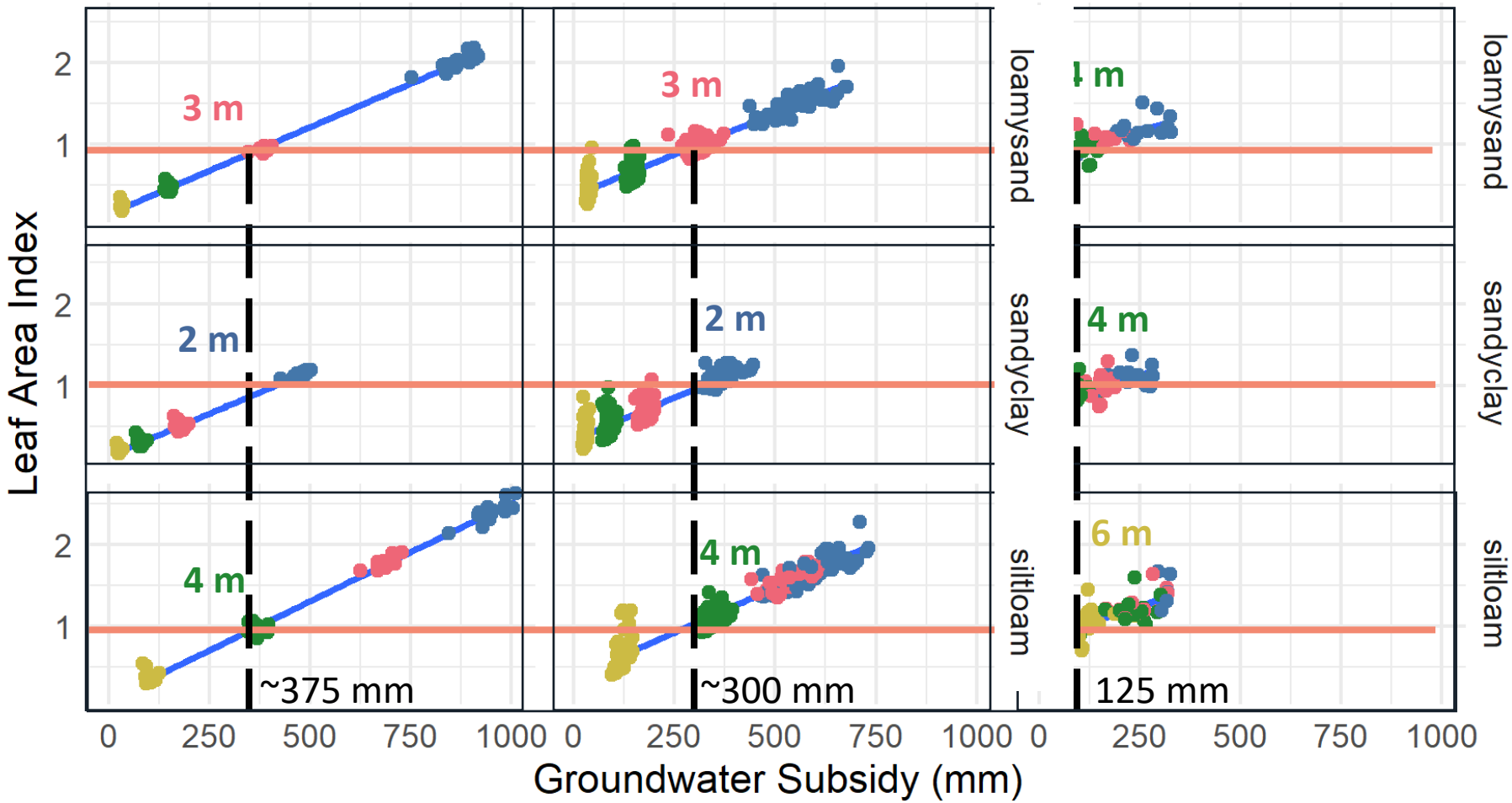
Drier/Warmer

Average

Cooler/Wetter

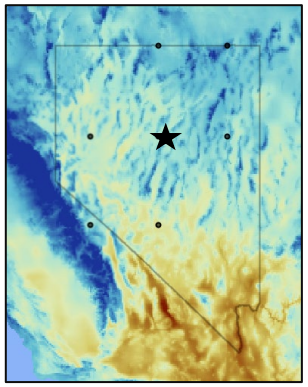
Phreatophyte Shrubland Management Target LAI = 1.0





Water Table Depth ● DTW= 2 m ● DTW= 3 m ● DTW= 4 m ● DTW= 6 m

DRI

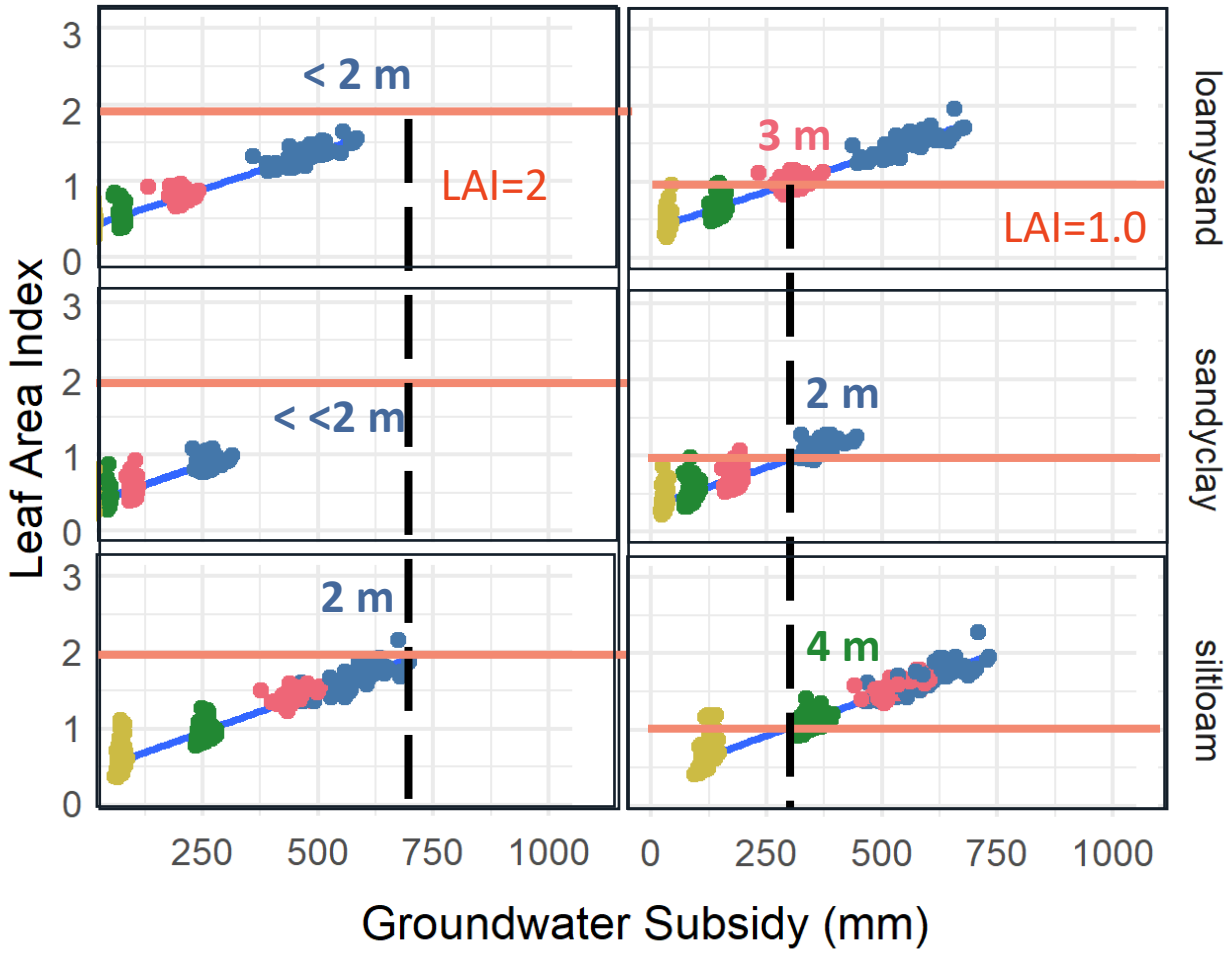


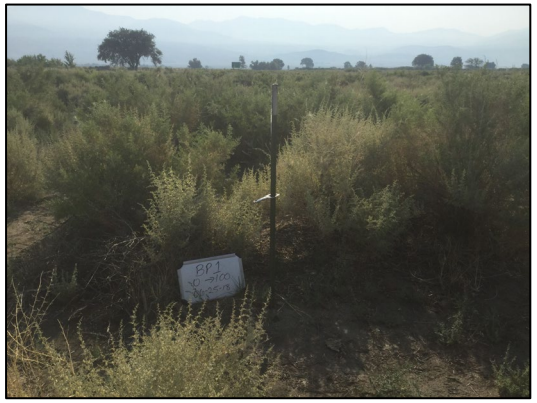
Average Annual Climate

Meadow, LAI=~2

Meadow Management Target LAI = 2.0

Phreatophyte Shrubland Management Target LAI = 1.0





Phreatophyte Shrubland, LAI=~1

Water Table Depth ● DTW= 2 m ● DTW= 3 m ● DTW= 4 m ● DTW= 6 m

DRI

How much groundwater is used by a vegetation community?

How much does a vegetation community benefit from shallow groundwater?

Conclusions

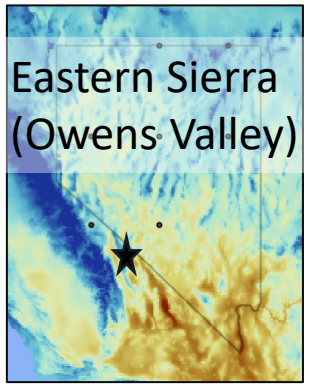
- Our model reasonably captures GDE vegetation patterns observed across the Great Basin
- GDEs in warmer and drier climates and soils with poorer water retention characteristics require shallower groundwater levels to sustain them
- Next steps include model refinement and framework design based on your feedback

Dixie Meadows, NV (Christine Albano, DRI)

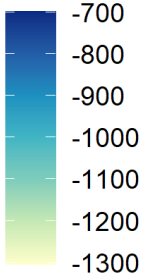
Framework for Estimating GDE GW Use and Requirements

User Inputs

Climate:

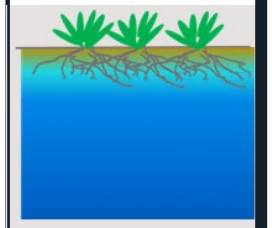


Annual PWD (Precipitation – Potential ET)

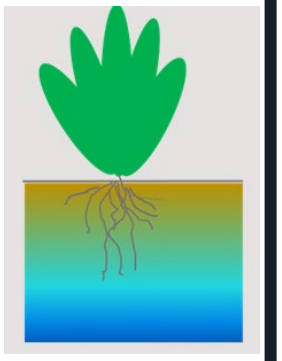


GDE Type:

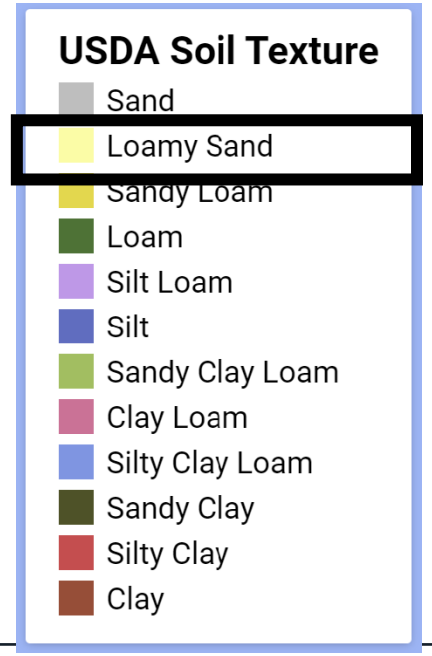
Meadow
2 m root



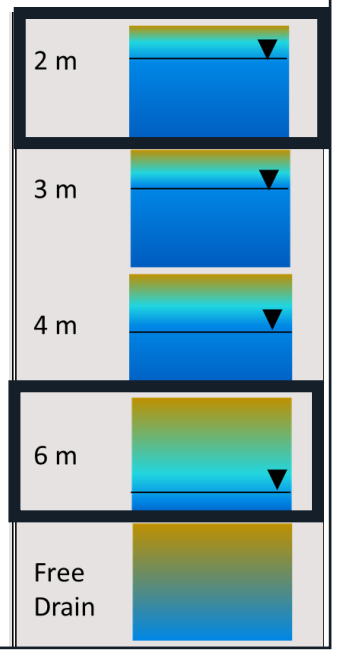
Phreatophyte Shrubland
3.6 m root



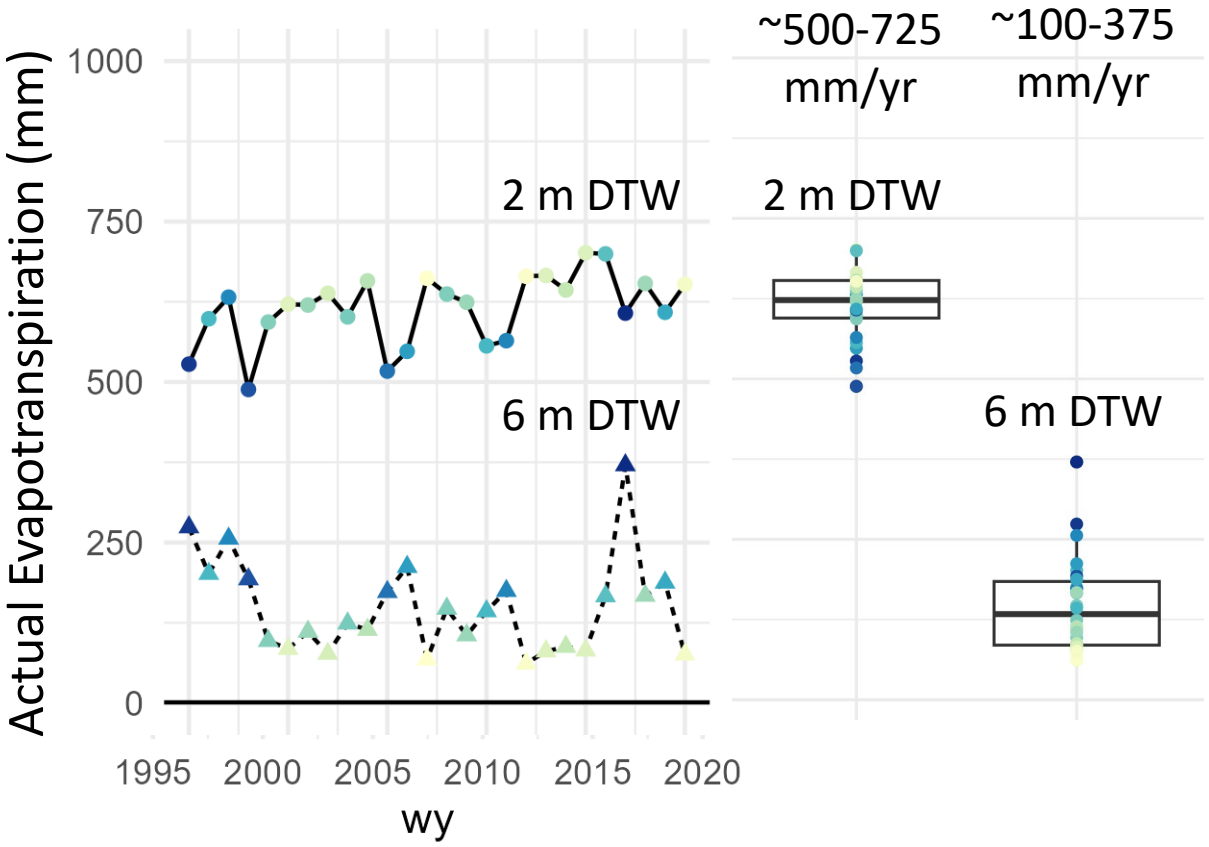
Soil Texture:



Depth to GW:



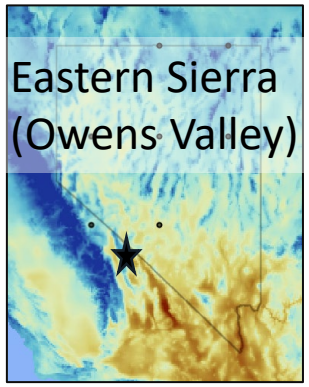
Annual Water Use (mm) (Total ET)



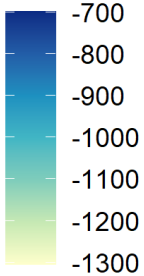
Framework for Estimating GDE GW Use and Requirements

User Inputs

Climate:

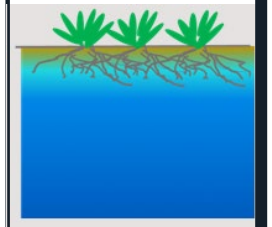


Annual PWD (Precipitation – Potential ET)

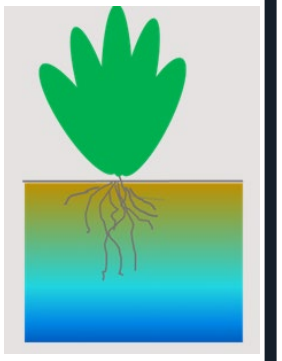


GDE Type:

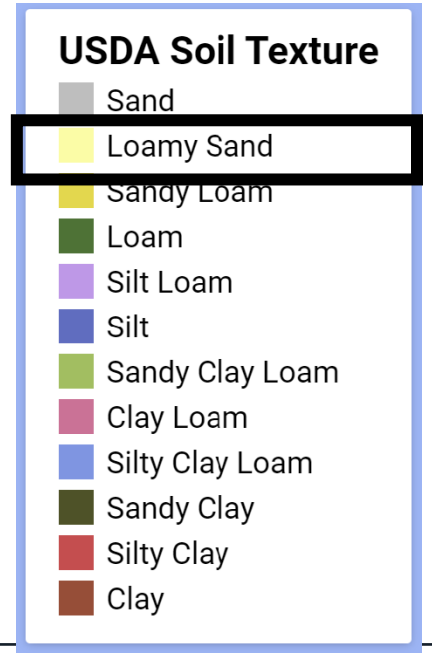
Meadow
2 m root



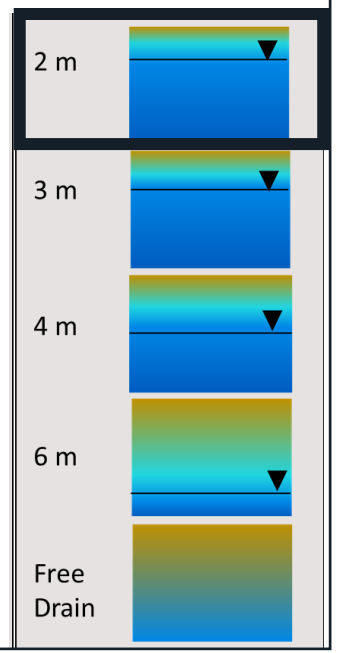
Phreatophyte Shrubland
3.6 m root



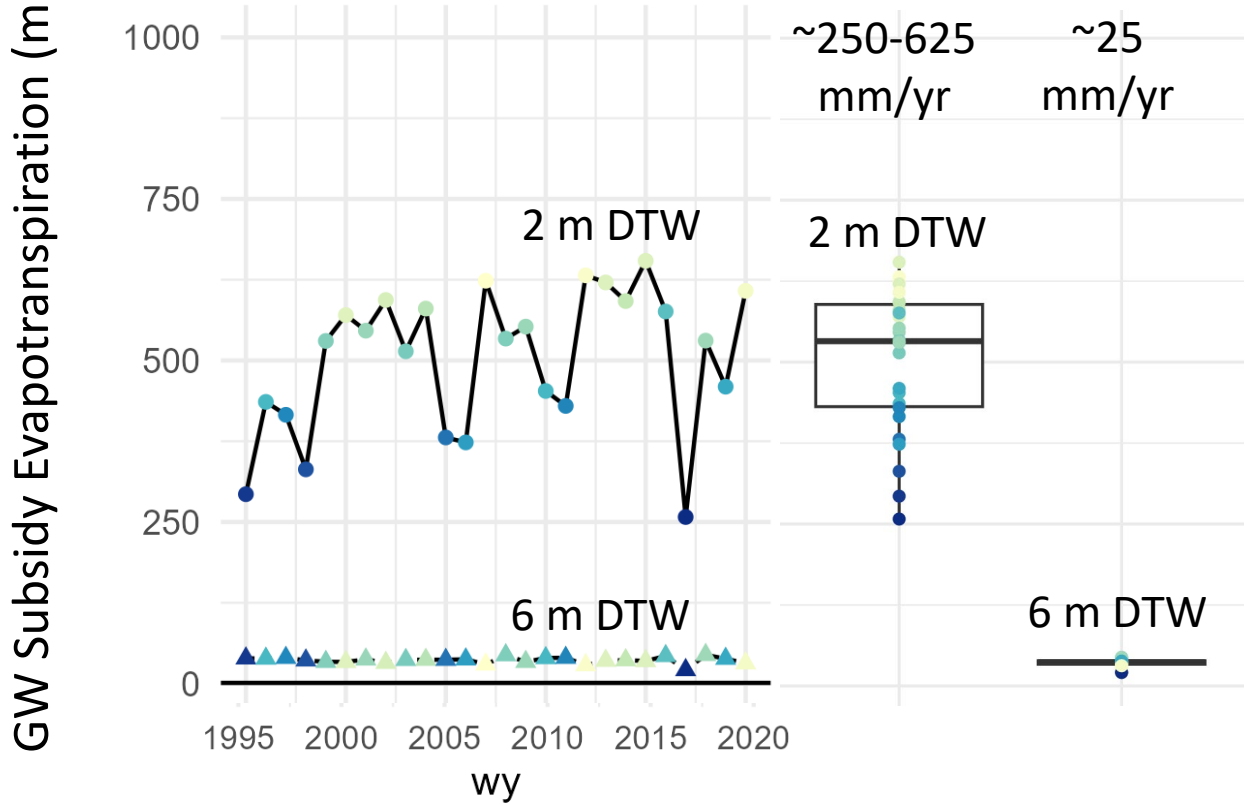
Soil Texture:



Depth to GW:



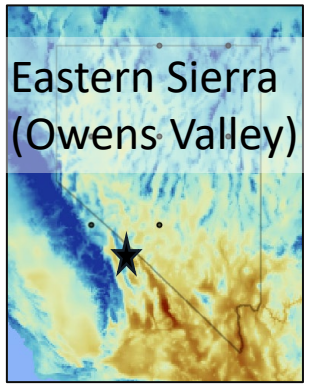
Annual Groundwater Use (mm) (GW Subsidy ET)



Framework for Estimating GDE GW Use and Requirements

User Inputs

Climate:



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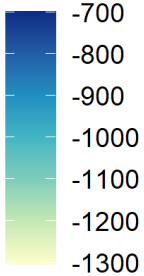

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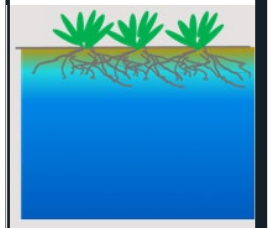
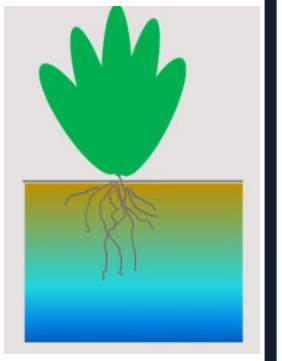
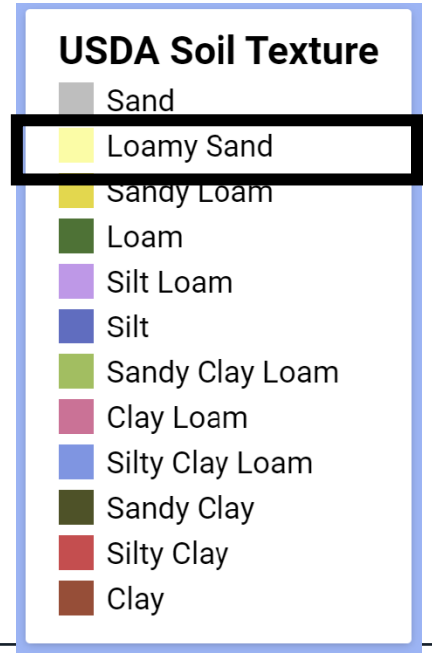
2 m root



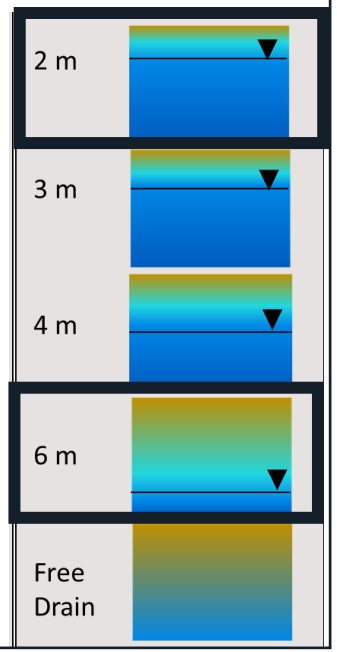
Phreatophyte Shrubland
3.6 m root



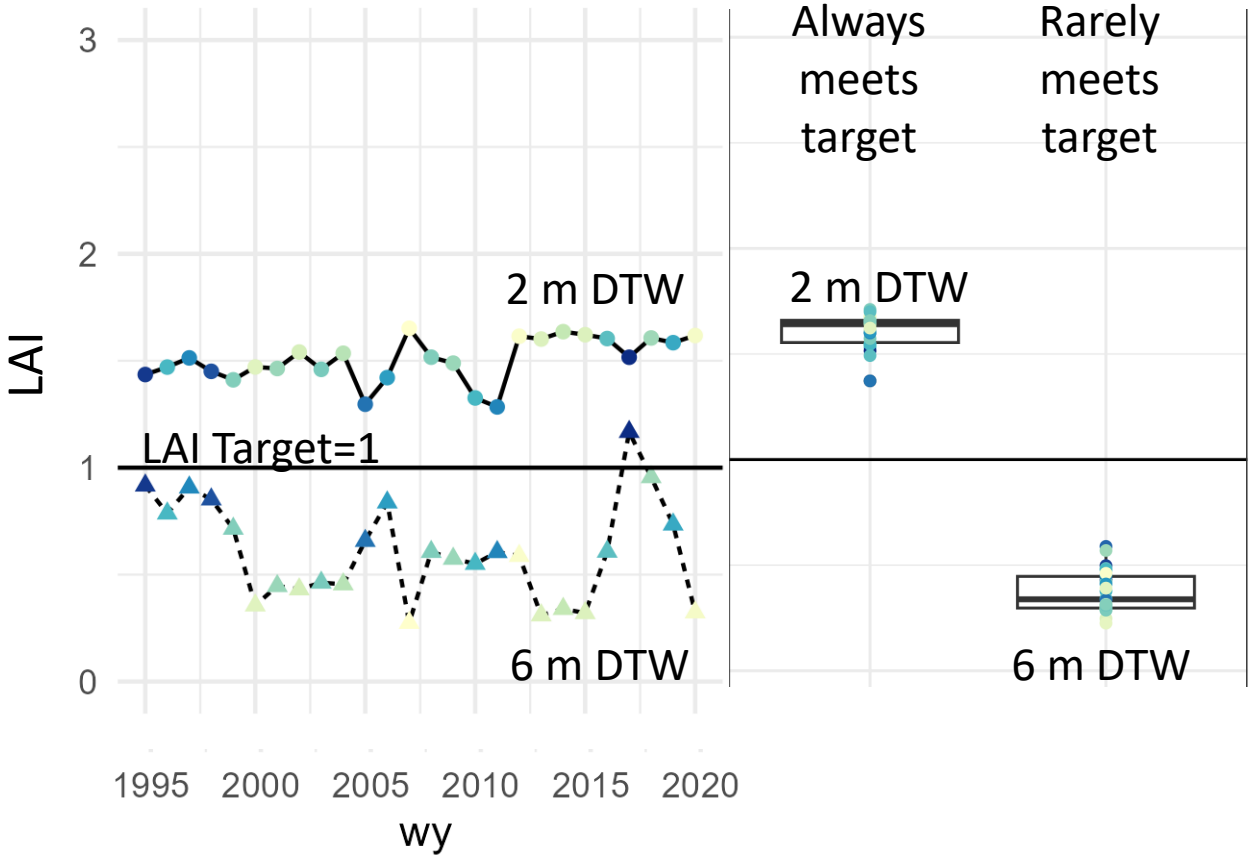
Soil Texture:



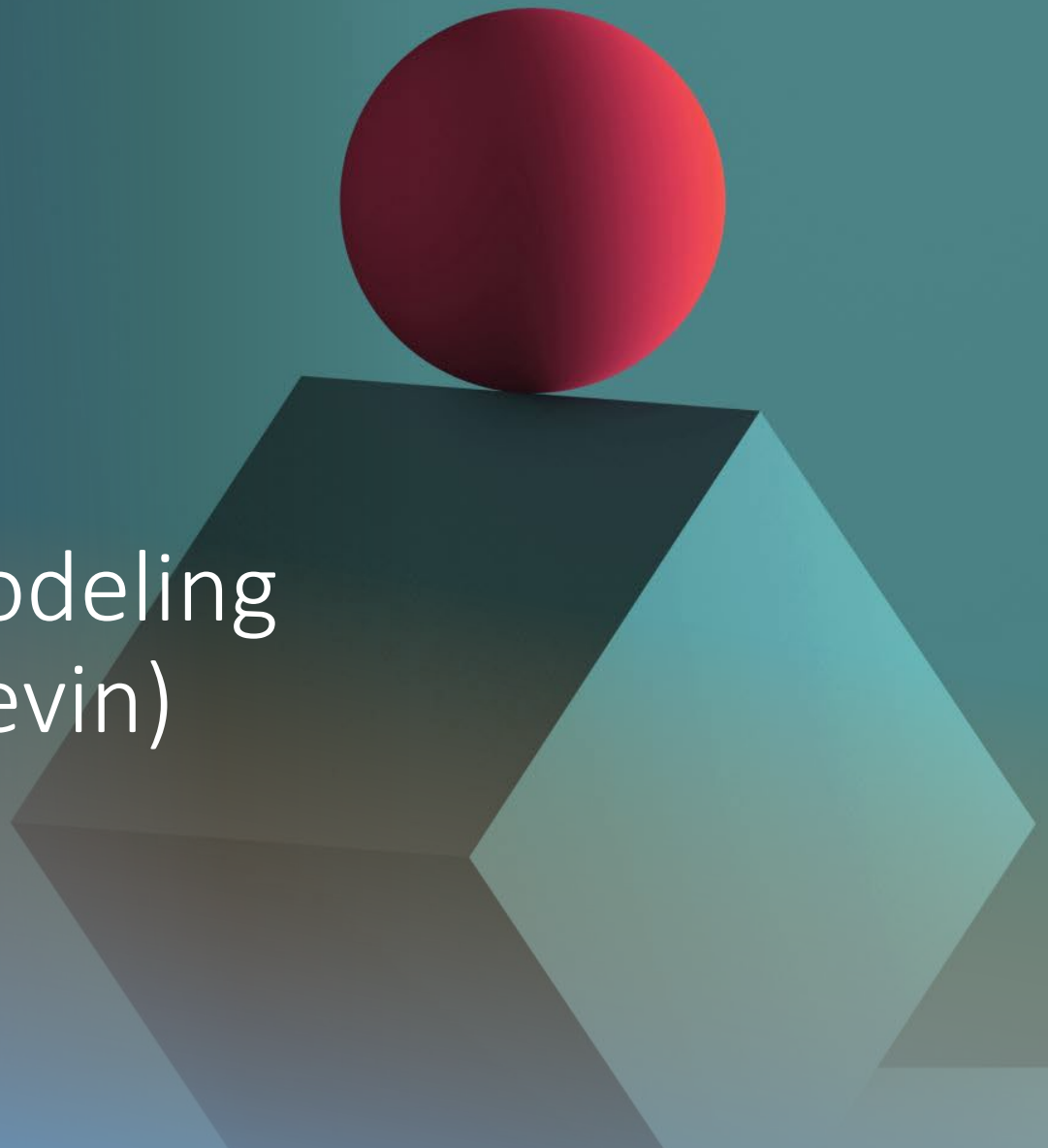
Depth to GW:



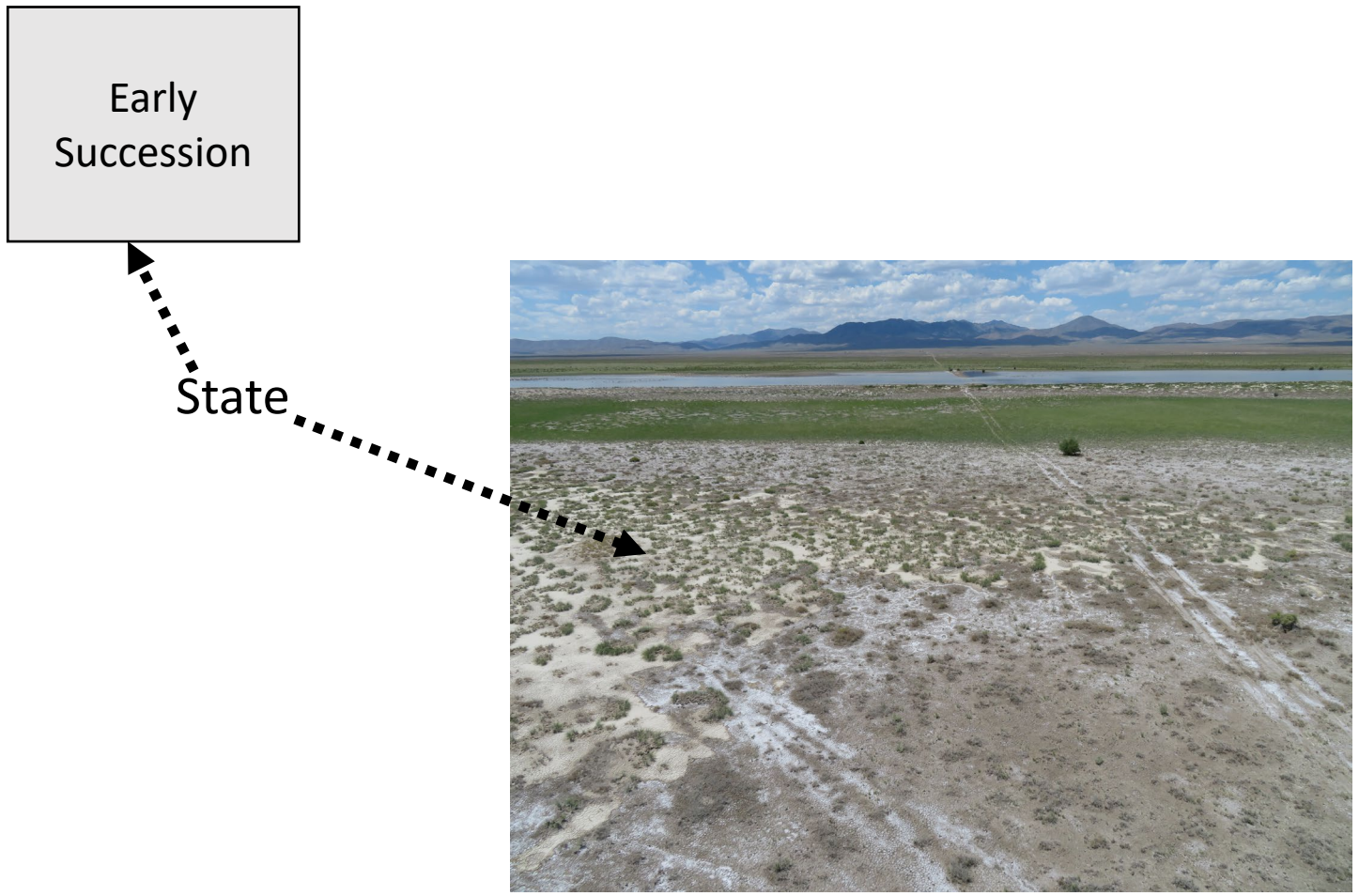
Annual Maximum Leaf Area Index (Target LAI= 1)



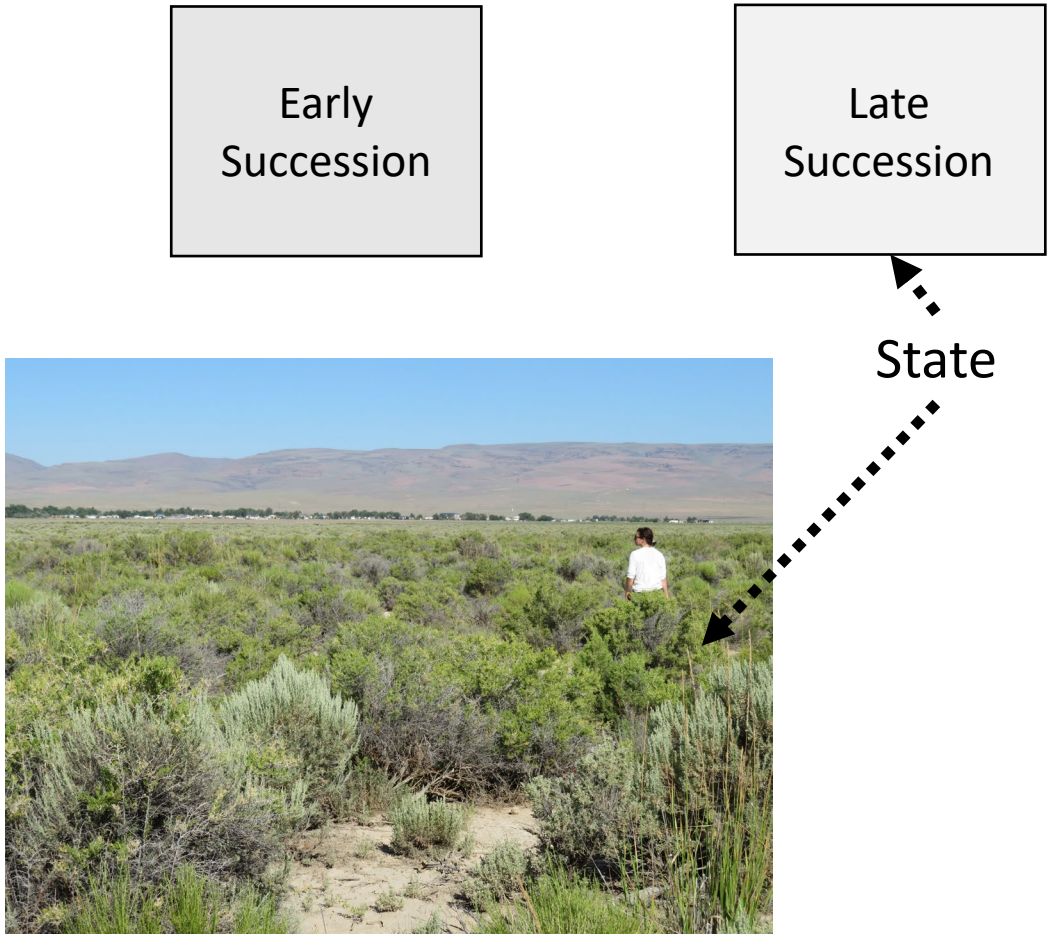
State and transition modeling and GDEs (Kevin)



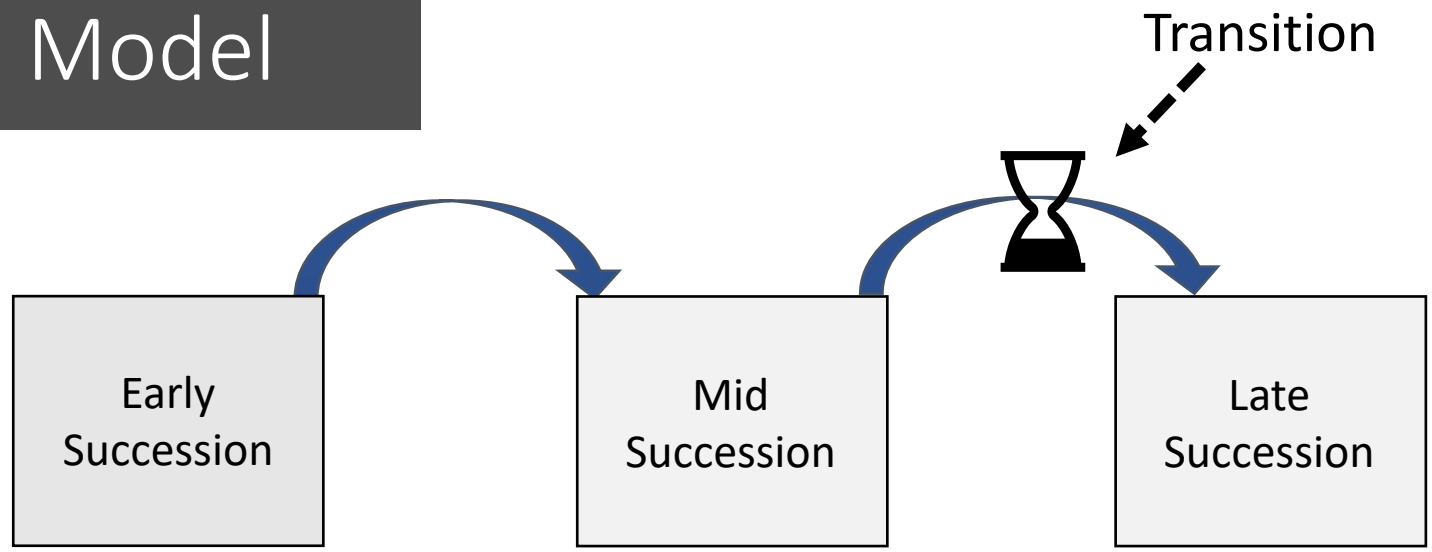
State-and-Transition Simulation Model



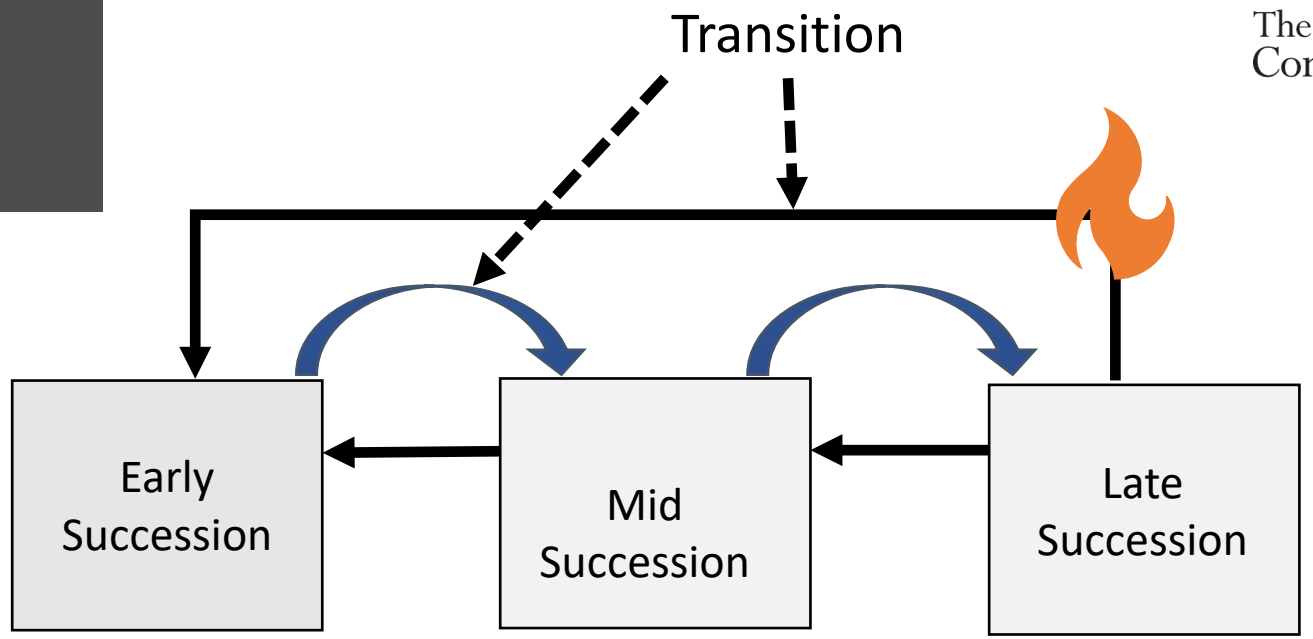
State-and-Transition Simulation Model



State-and-Transition Simulation Model

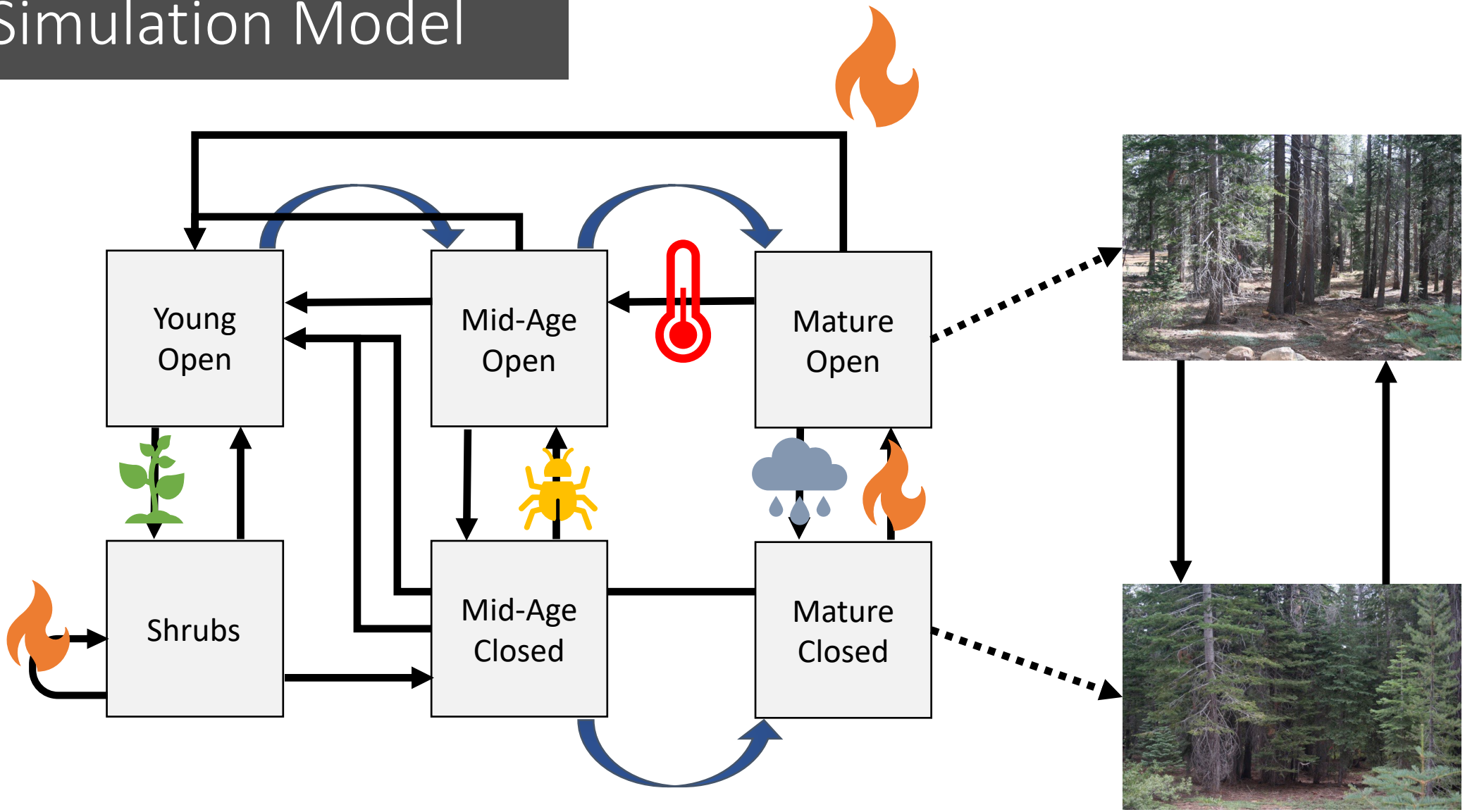


State-and-Transition Simulation Model



State-and-Transition Simulation Model

The Nature Conservancy

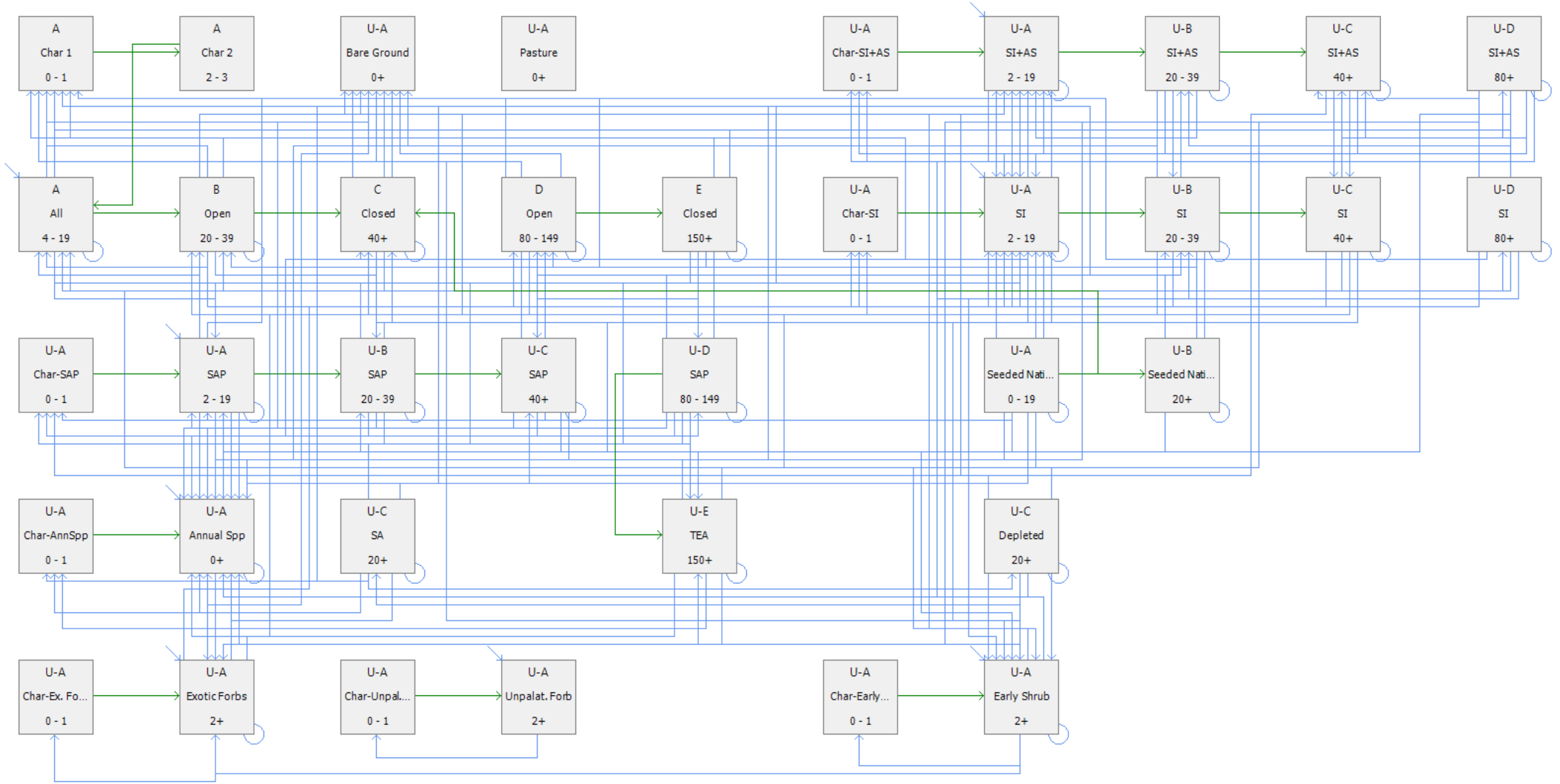


SyncroSim - [Scenario : [72] Pathways&TST - MixedFire-TST]

File Edit Project Scenario Window Help

Multiprocessing 60 Results

Summary | Run Control | Transition Pathways | Initial Conditions | Transition Targets | Output Options | Advanced | Data Sources



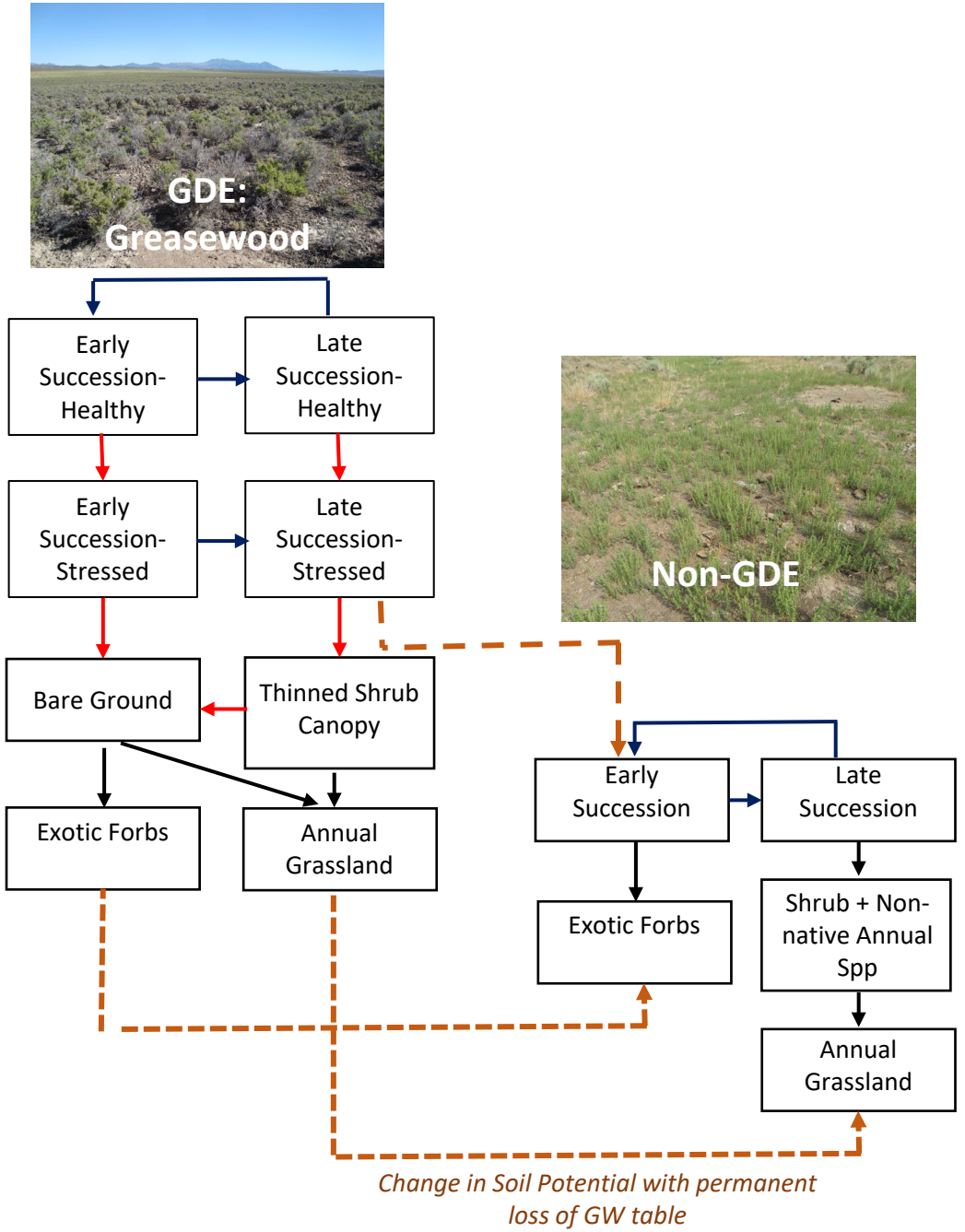
Upper Montane Grassland | Subalpine-Upper Montane Riparian | Water | Wet Meadow-Montane | Wetland | **Wyoming Sagebrush** | States | Transitions

TruckeeMASTER

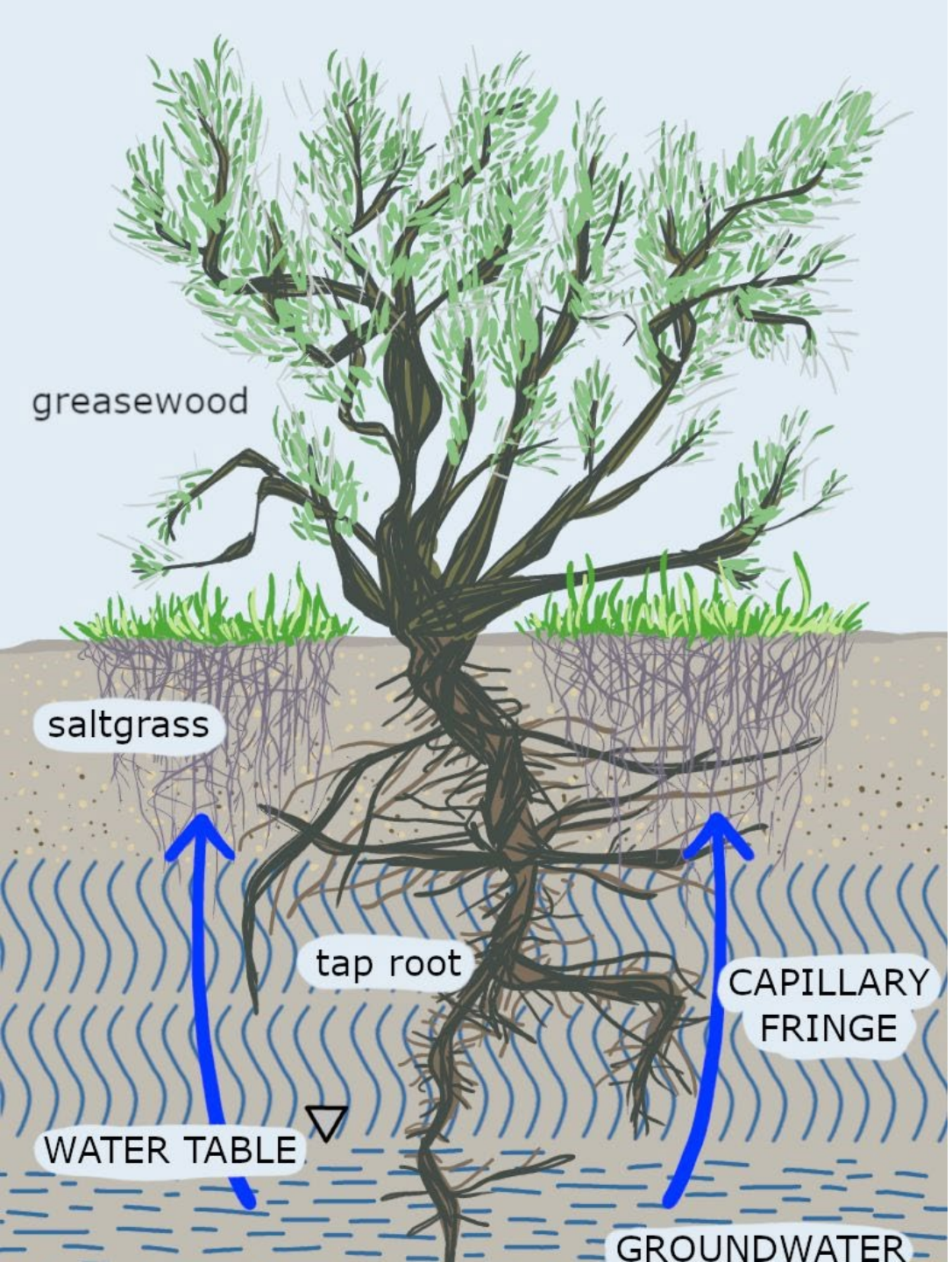
8:13 AM
10/19/2018

STSMs and groundwater

- Focus on transition between healthy, water stressed, and non-GDE states through drop in groundwater depth
- Can combine with other ecological processes (e.g. exotic species invasion)
- Different STSMs based on rooting depth and soil texture



Modified from Provencher et al. 2020; greasewood picture: L. Provencher;



Provencher et al. 2020; Art by S. Byer

Could impose different management, climate, or other ecological scenarios to explore potential outcomes

Potential Scenarios:

Current GW levels + Increased Evapotranspiration Demand

Reduced GW levels + Increased Evapotranspiration Demand

Reduced GW levels + No change in Evapotranspiration Demand

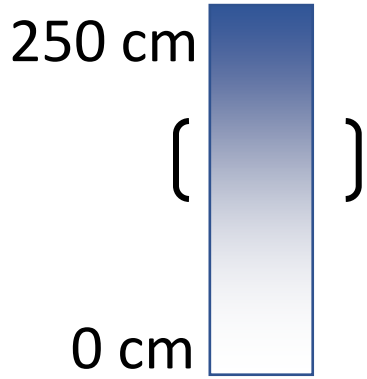
BREAK

Soldier Meadows (D. Page / DRI)

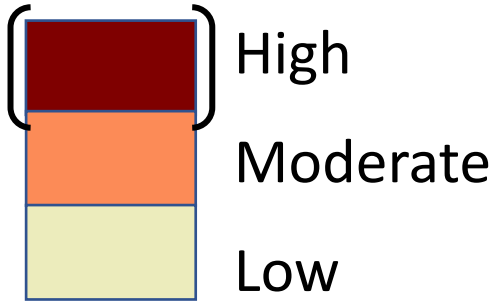
Groundwater Requirements for GDEs Framework

1. User identifies GDE and its attributes using readily available data
   - Type (meadow/phreatophyte)
   - Soil texture/depth (field obs, GIS data)
   - Climate (annual potential water deficit; station or gridded)
   - Depth to GW
2. Framework provides a look-up table of model-based estimates of GDE GW subsidy and sensitivity based on those attributes

Estimated ranges of annual GW_{sub} per area



Index of relative sensitivity of veg production to groundwater availability



DRI
Desert Research Institute

Question 1: How important is it for you to understand…

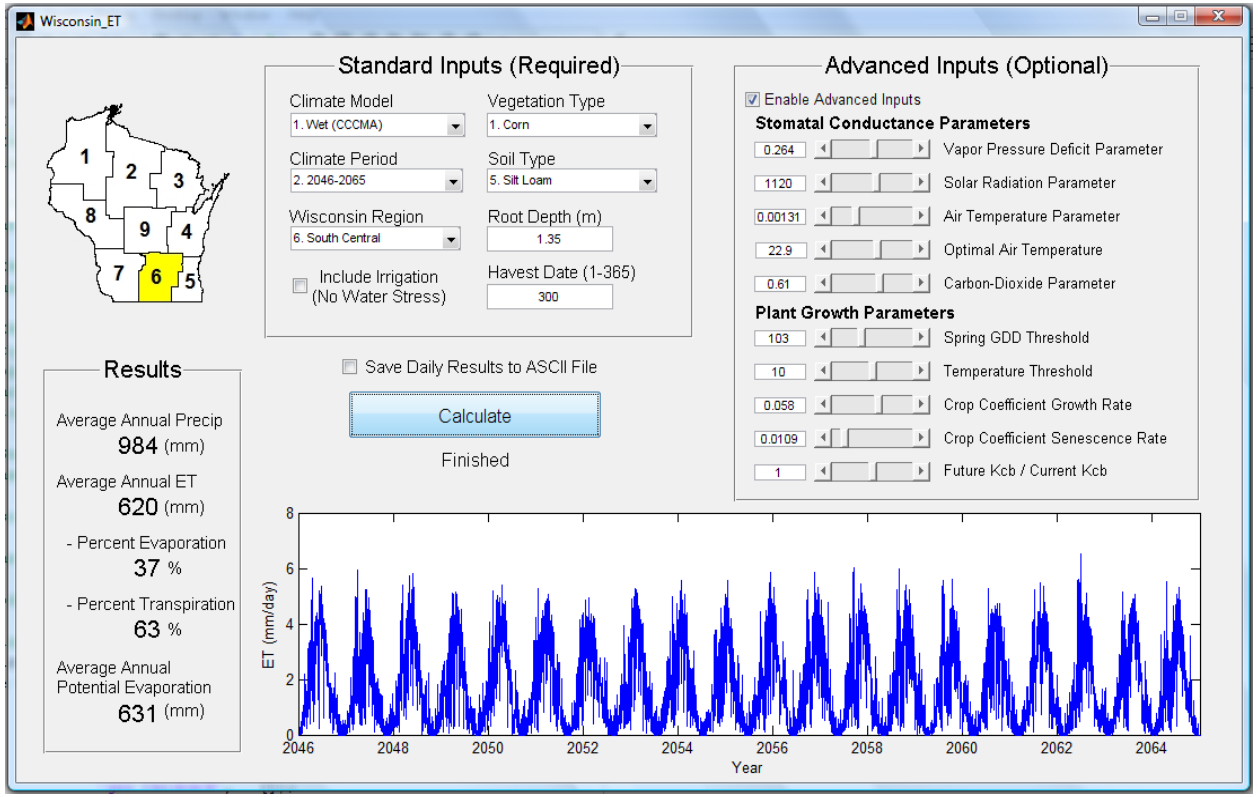
- Go to menti.com and use code
  - How much groundwater a GDE is typically using
  - what depth to groundwater is typically required to support a specific GDE
  - how soil type affects GDE groundwater use
  - how climate affects GDE groundwater use
  - how GDE groundwater use varies interannually
  - how GDE groundwater use varies seasonally
  - what the groundwater availability tipping point is that causes a transition from one vegetation type to another

Framework and web map discussion

- Tool available for accessing estimates of
  - plant water use (ET)
  - Groundwater subsidy (GWsubs)
  - Leaf area index(LAI)
- User inputs to get these estimates
  - Location which will provide default information on climate and soils
  - GDE type (i.e., deep-rooted (phreatophyte), shallow-rooted (meadow))
- User can toggle some inputs
  - Climate (wet, dry, average)
  - Soil textures (11 USDA types – e.g., silt loam, sandy clay)
  - GDE type
  - Depth to groundwater

Framework and web map discussion

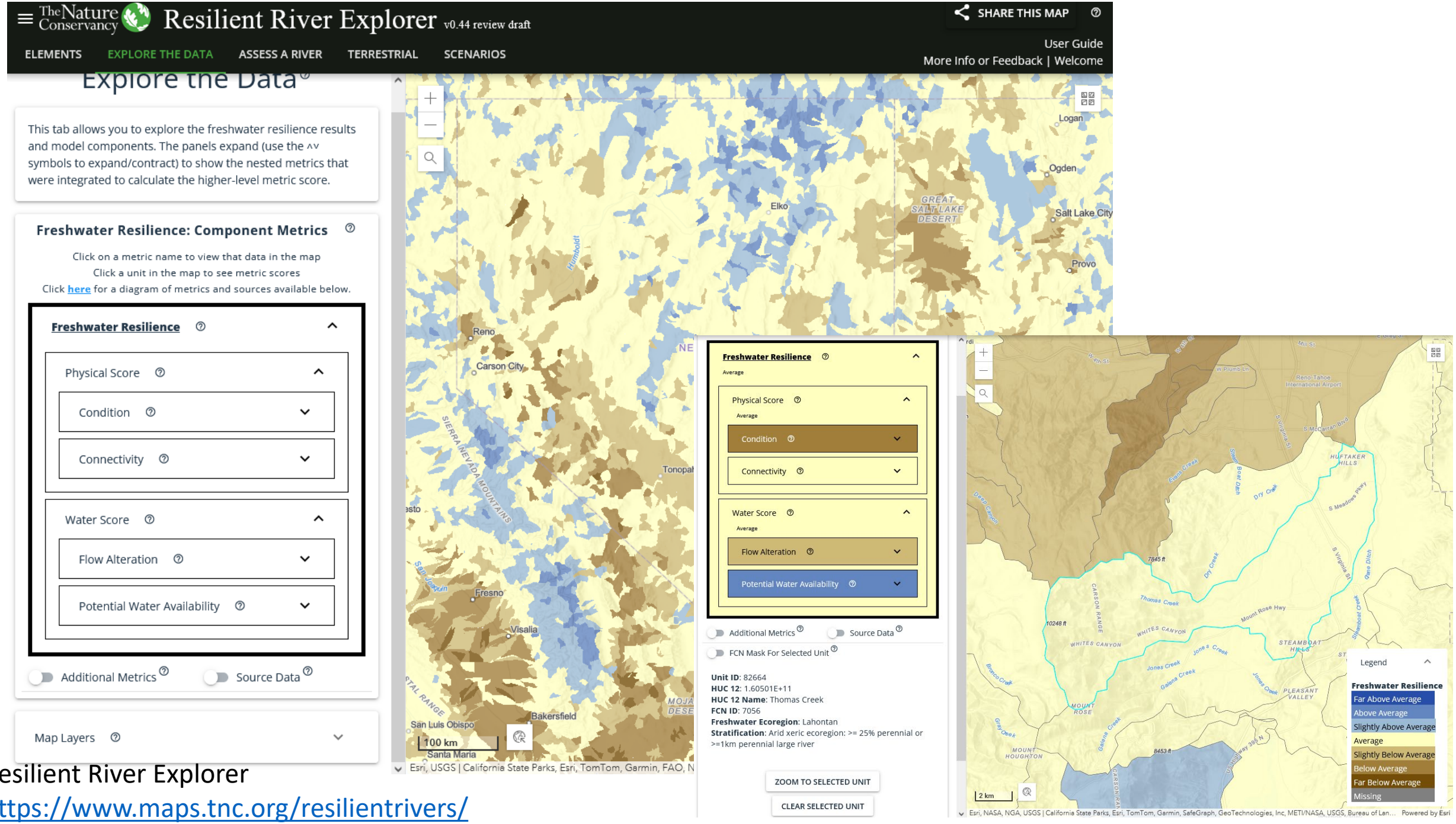
- Examples



Framework and web map discussion

- Examples

BLM drought and site characterization reports
https://reports.climateengine.org/



Resilient River Explorer

https://www.maps.tnc.org/resilientrivers/

Framework limitations

- Not a map of existing GDEs
- Requires an input of hypothetical depth to groundwater and GDE type
- Groundwater use estimates (ranges) are based on model outputs but have uncertainty
- Model estimates are based on many simplifications
  - Assumes entire soil column is of uniform soil texture
  - Does not account for variations in root distribution
  - Does not account for species-level differences in water use efficiency, leaf shape, carbon allocations
  - Groundwater depths are constant across time

Question 2: What data would you like to get out of a framework tool?

- Go to menti.com and use code
  - GDE groundwater use ranges (inches)
  - Preferred depth to groundwater for a GDE (feet)
  - Seasonal GDE groundwater use preferences (inches)
  - Preferred GDE groundwater use in dry years (inches)
  - Preferred GDE groundwater use in wet years (inches)
  - GDE groundwater use ranges at a particular location (inches)

Question 3: How would you like to use the framework? (open-ended)

- Go to menti.com and use code

Question 4: Preferences for framework outputs

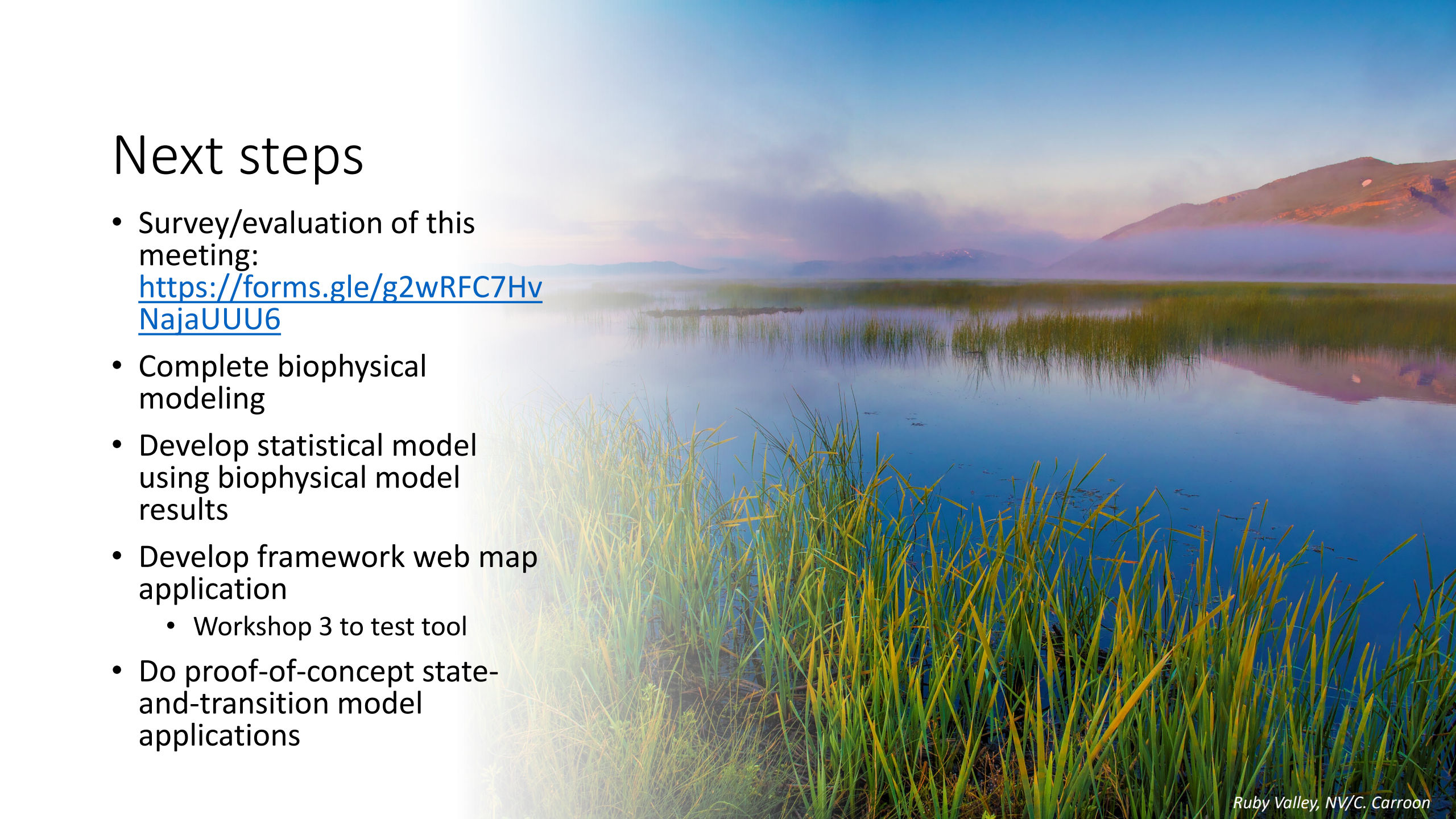
- Go to menti.com and use code
  - Spreadsheet or text downloads (e.g., .csv)
  - Map downloads (e.g., .png, .jpg)
  - Report downloads (e.g., .pdf)
  - Graphical user interface (GUI) to interact with data and outputs
  - Other

Question 5: How could this project support your work?

- Go to menti.com and use code 8920 3352
- You can upvote other responses
- If there are other things you need about GDE water requirements that we haven’t discussed or aren’t on the mentimeter slides, please comment on that too.

Next steps

- Survey/evaluation of this meeting: https://forms.gle/g2wRFC7HvNajaUUU6
- Complete biophysical modeling
- Develop statistical model using biophysical model results
- Develop framework web map application
  - Workshop 3 to test tool
- Do proof-of-concept state-and-transition model applications



Ruby Valley, NV/C. Carroon