# Projecting reponses of major North American vegetation types to climate change

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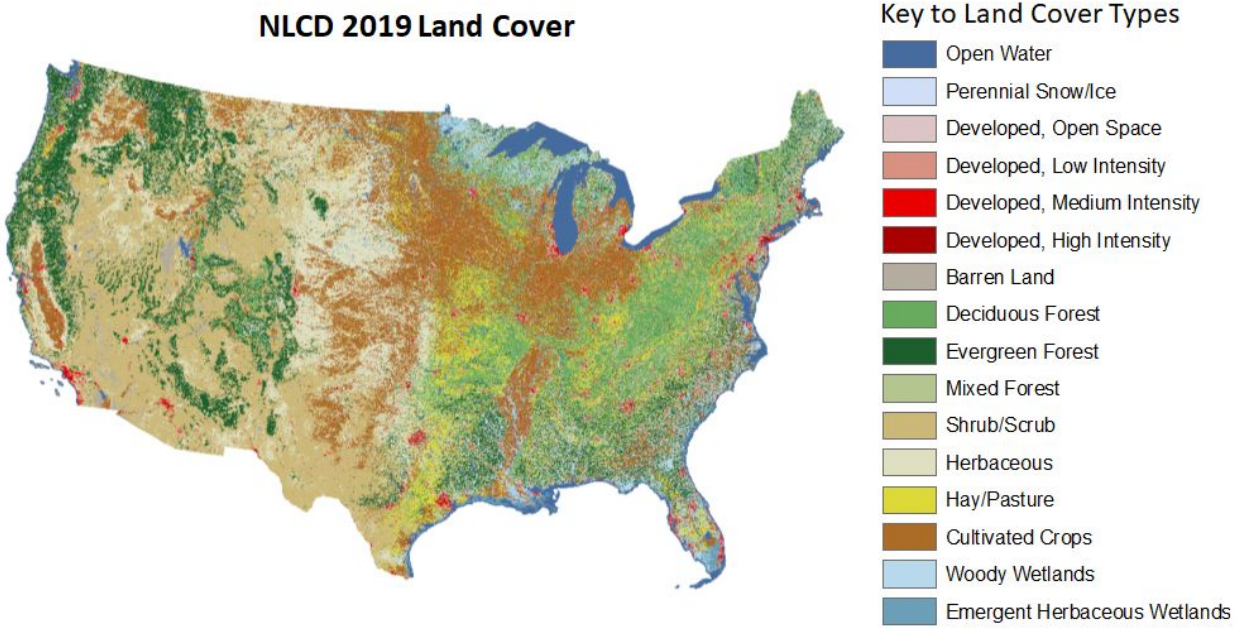
# Problem Background

- Climate is a primary driver of the distributions of plant species
- How will different vegetation types respond to climate change?
- Relevant question to land managers, foresters, ranchers, policymakers, outdoor recreationists, etc.



# Research Questions

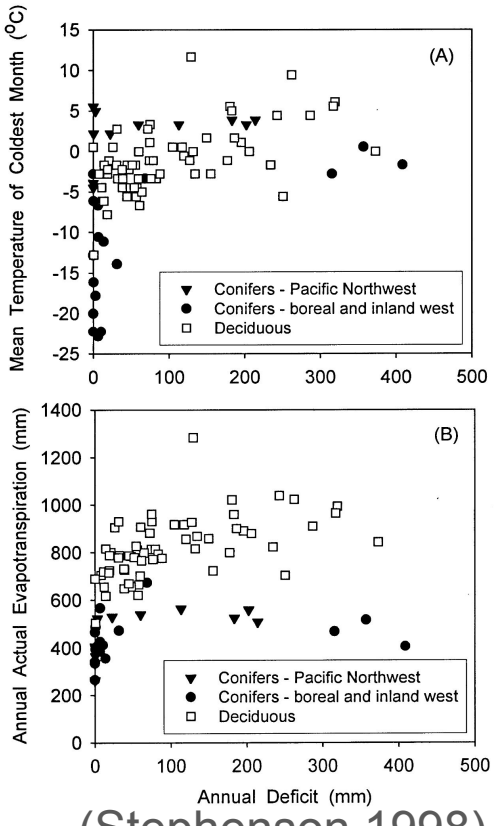
- What are the climatic drivers of distributions of major vegetation types across the Contiguous United States (CONUS)?
- How are the distributions of vegetation types likely to shift under future climates?

# Climatic Water Balance

Views climate in a way closer to the mechanisms that affect plants and animals than temperature and precipitation lone

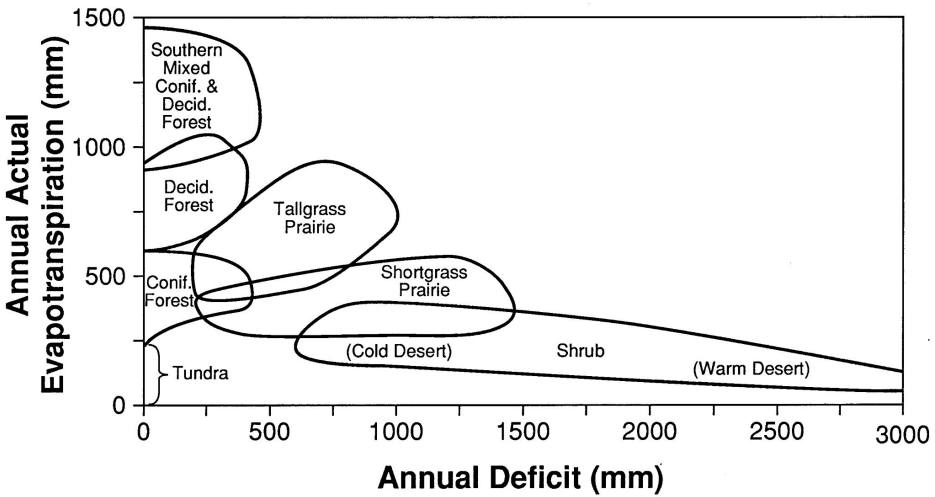
The NPS Gridded Water Balance Dataset (Tercek 2021) provides historical and projected:

- Actual Evapotranspiration (AET) - magnitude and length of growing conditions favorable to plants
- Climatic Water Deficit (CWD) - measure of drought stress
- Potential Evapotranspiration (PET)
- Rain - Liquid water fraction of Precipitation
- Runoff
- Soil Water

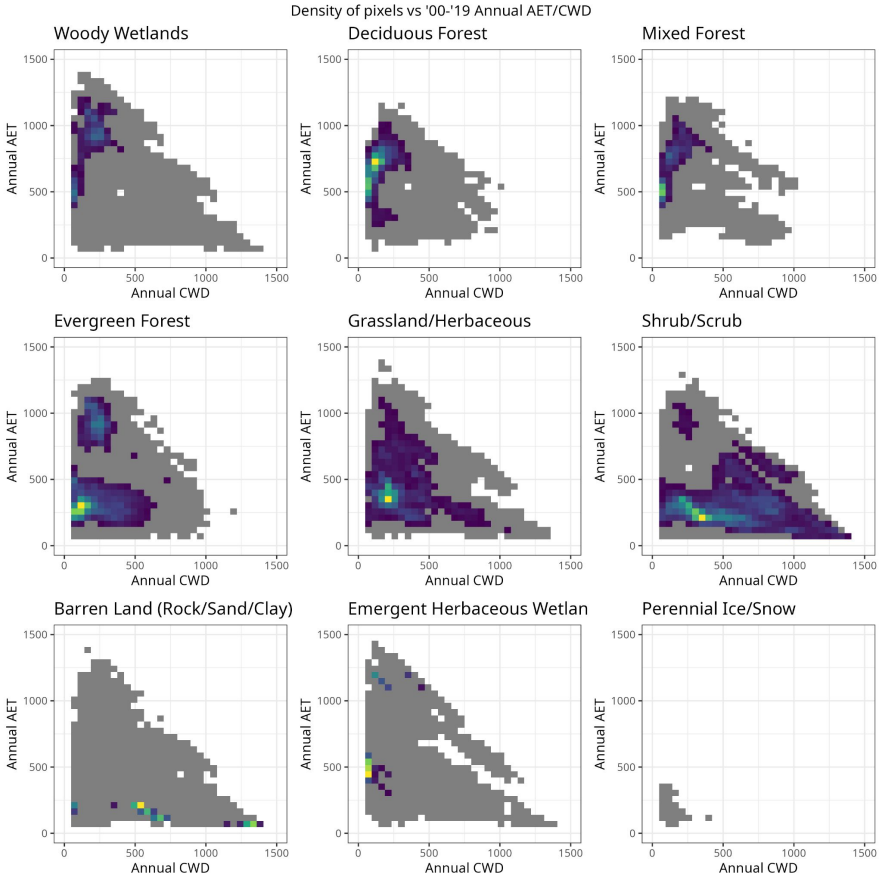



(Stephenson 1998)

# Climatic Water Balance




Distributions of major North American Vegetation types vs CWD and AET from Stephenson 1998




Our data

# Random Forest

Fit using R package `ranger`

Predictors:

- NPS Gridded Water Balance Model 2000-2019 Mean:
  - Spring/Summer/Fall/Winter AET, PET, CWD, Rain, Runoff, Soil Water
  - Annual Accumulated Snow Water Equivalent
- Soil Water Holding Capacity

Response:

- Current Land Cover (2019 NLCD Land Cover class), Artificial land cover types and water cover removed

```
Type:                             Classification
Number of trees:                  500
Sample size:                      4851134
Number of independent variables:  26
Mtry:                             5
Target node size:                 1
Variable importance mode:         impurity
Splitrule:                        gini
OOB prediction error:             25.85 %
```

# Confusion Matrix for Historical Data

| True ↓ \ Predicted → | Perennial Ice/Snow | Barren Land | Decid. Forest | Evergr. Forest | Mixed Forest | Shrub/ Scrub | Grassland | Woody Wetlands | Emergent Herbaceous Wetlands |
|---|---|---|---|---|---|---|---|---|---|
| Perennial Ice/Snow | 145 | 254 | 0 | 103 | 0 | 61 | 23 | 0 | 0 |
| Barren Land | 194 | 37937 | 4614 | 4699 | 717 | 20473 | 4192 | 1514 | 781 |
| Decid. Forest | 0 | 893 | 529102 | 31509 | 41874 | 12533 | 21883 | 30880 | 4242 |
| Evergr. Forest | 45 | 2239 | 40637 | 571069 | 31592 | 111521 | 32485 | 49149 | 1769 |
| Mixed Forest | 0 | 318 | 80829 | 38768 | 56313 | 6984 | 4068 | 20793 | 616 |
| Shrub/Scrub | 45 | 11181 | 14667 | 127315 | 6899 | 1426354 | 91684 | 10425 | 3119 |
| Grassland | 18 | 2300 | 21885 | 49183 | 4979 | 94499 | 729565 | 9205 | 5304 |
| Woody Wetlands | 0 | 706 | 42599 | 53515 | 18077 | 12472 | 8915 | 196872 | 10184 |
| Emergent Herbaceous Wetlands | 0 | 571 | 7295 | 4096 | 1008 | 8330 | 14756 | 15397 | 49896 |

Number of pixels classified as land cover types. Orange diagonal indicates correct predictions

# Variable Importance (Impurity)

| Variable | Importance |
|---|---|
| aet_summer | 275533.6221 |
| rain_summer | 270917.5229 |
| cwd_summer | 224760.0964 |
| runoff_spring | 209007.051 |
| runoff_fall | 182627.9193 |
| runoff_winter | 175450.0742 |
| rain_spring | 165814.9098 |
| rain_fall | 164605.5208 |
| aet_fall | 159639.7219 |
| pet_summer | 145584.6716 |
| rain_winter | 138920.4598 |
| cwd_spring | 137486.0428 |
| cwd_fall | 137112.0661 |
| pet_spring | 128640.0846 |
| pet_fall | 125718.196 |
| aet_spring | 121946.8688 |

...

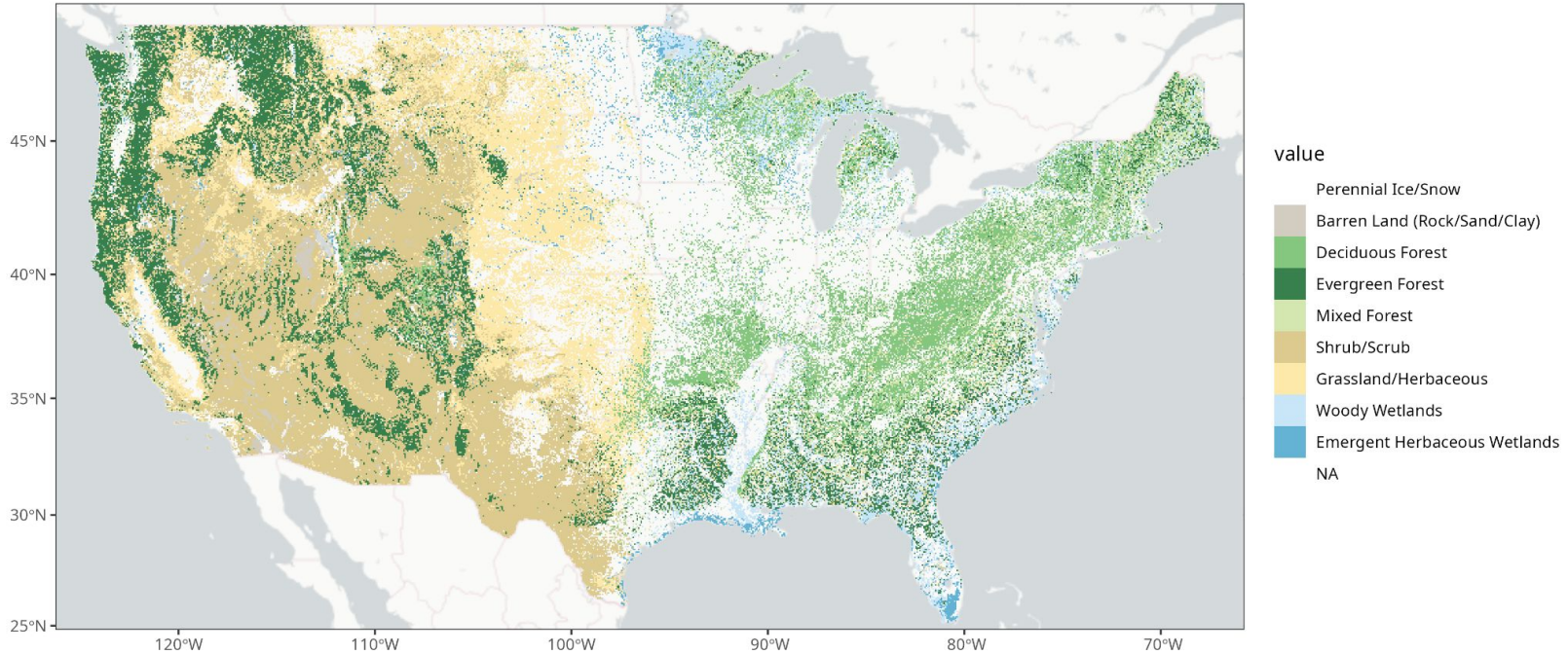
...

| | |
|---|---|
| runoff_summer | 117401.8019 |
| cwd_winter | 109382.6815 |
| aet_winter | 108529.4888 |
| pet_winter | 108344.3547 |
| soil_water_summer | 103570.0563 |
| soil_water_winter | 98123.11789 |
| soil_whc | 98066.31854 |
| soil_water_fall | 93224.37371 |
| accumswe | 92594.93893 |
| soil_water_spring | 88778.36474 |

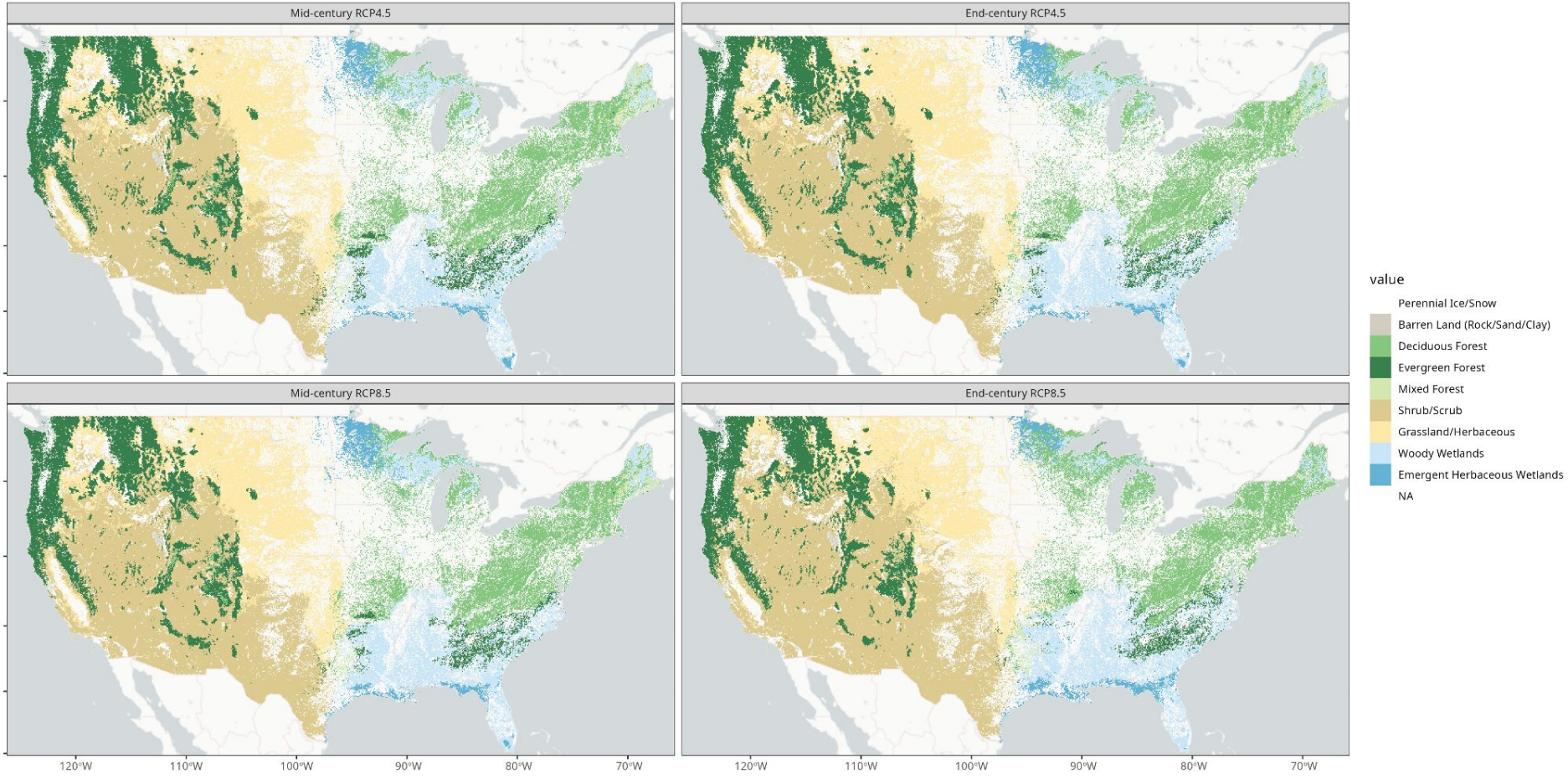
# Projecting Vegetation Distributions under Climate Change

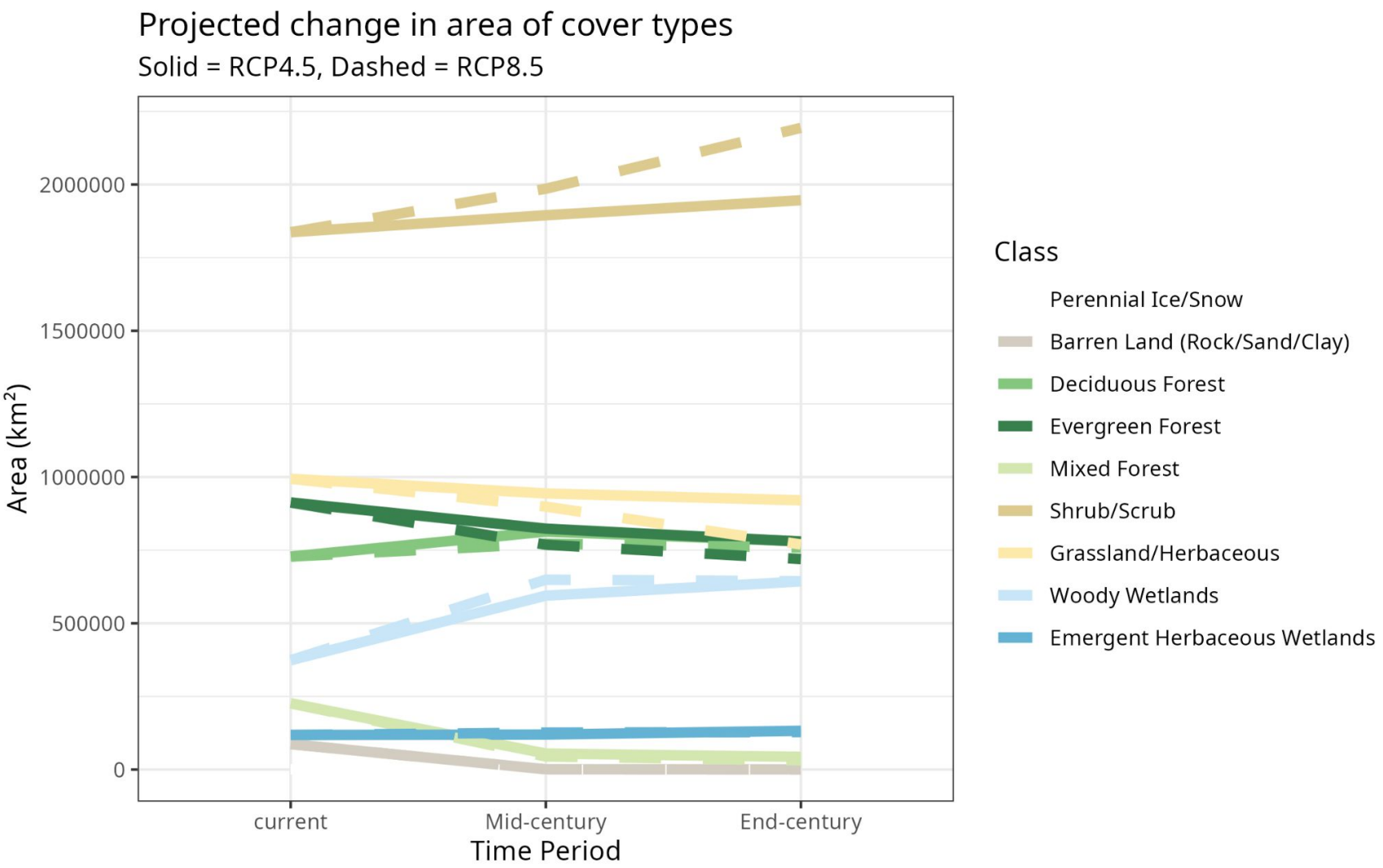
- Use Random Forest model fit to historical water balance data (gridMET) to predict cover types on projected water balance data (MACA)
- MACA is downscaled using gridMET so the historical and projected data can be compared without bias correction
- Two scenarios for projections based on plausible greenhouse gas emissions pathways (see IPCC 2023 for more details)
  - **RCP 4.5** - **Intermediate scenario**: Emissions decrease by ~2045
  - **RCP 8.5** - **Worst-case scenario: “**Business as usual”
- Projections were made for two future time periods
  - **Mid-century (2040-2069)**
  - **End-century (2070-2099)**

Current CONUS Cover Types on non-developed land



Projected CONUS Cover Types




Projected change in area of cover types
Solid = RCP4.5, Dashed = RCP8.5
2000000
1500000
1000000
500000
0
Area (km²)
current
Mid-century
End-century
Time Period
Class
Perennial Ice/Snow
Barren Land (Rock/Sand/Clay)
Deciduous Forest
Evergreen Forest
Mixed Forest
Shrub/Scrub
Grassland/Herbaceous
Woody Wetlands
Emergent Herbaceous Wetlands

# Conclusions

- The climatic water balance predicts distributions of some vegetation types well but is not sufficient to accurately predict all major vegetation types across CONUS alone.
  - An expansion of shrub/scrubland is likely under both emissions scenarios
  - Apparent stability of forest types at continental scale masks shifts in populations at finer scales
  - Projected expansions of woody wetlands and decline in mixed forest should be viewed with caution due to poor model performance in classifying these cover types.
- Projections were made using *ensemble* average conditions. Individual GCMs may reveal more variability in plausible future scenarios.

# References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