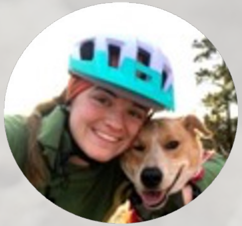
CLIMATE IMPACTS ON DROUGHT

Daniel Schlaepfer


John Bradford


Daniel Schlaepfer


Martin Holdrege


Alice Stears


Adam Noel

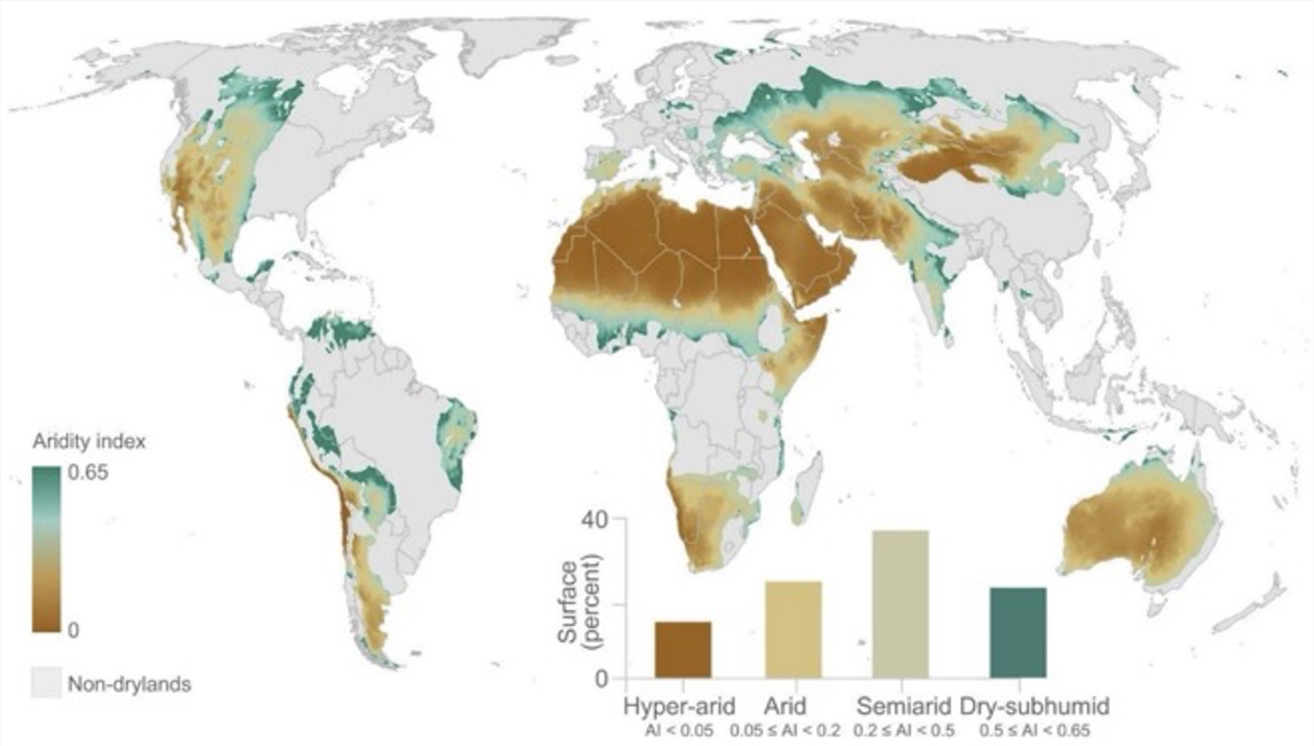

Gregor Siegmund

USGS Northwest Climate Adaptation Science Center
USGS Southwest Biological Science Center
Northern Arizona University

Drought is especially important in water-limited drylands

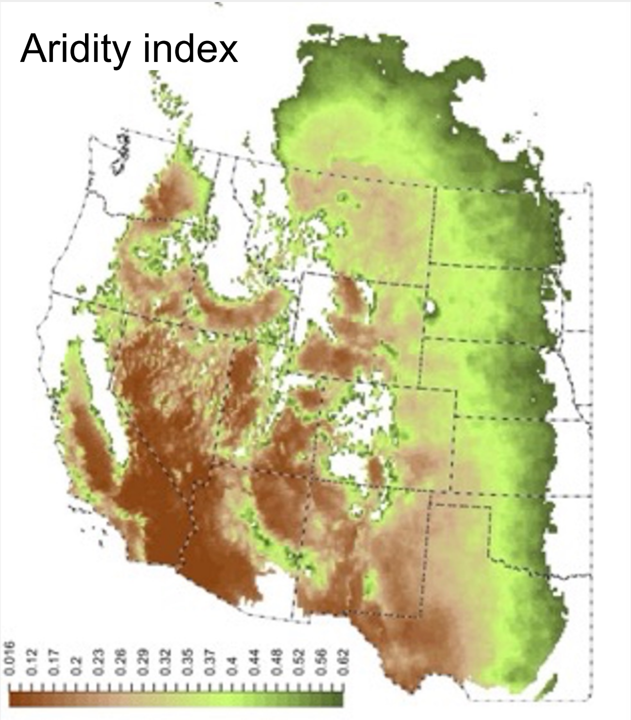
Drylands

- Climatological aridity (PPT/PET)
- 40% of terrestrial surface
- 44% of global cropland area
- 50% of global livestock

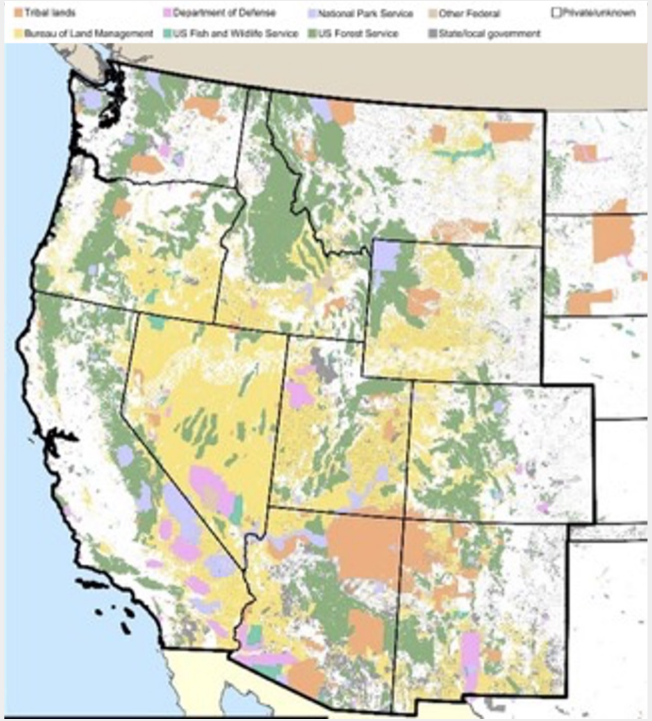


Maestre et al. (2021) New Phytology

Drylands: much of public & tribal lands, all of sagebrush



Bradford et al. (2020) GCB



Carter et al. (2020) Landscape Ecol

Access to moisture

- Plant communities
- Ecosystems services
  - Habitat quality
  - Grazing
  - Soil stabilization
  - Carbon, etc.

Outline

1. Ecological drought: balance between water demand & supply
2. Historical trends in ecological drought
3. Future projections of ecological drought
4. What does this mean for sagebrush ecosystems?

Ecological drought: water demand vs. supply

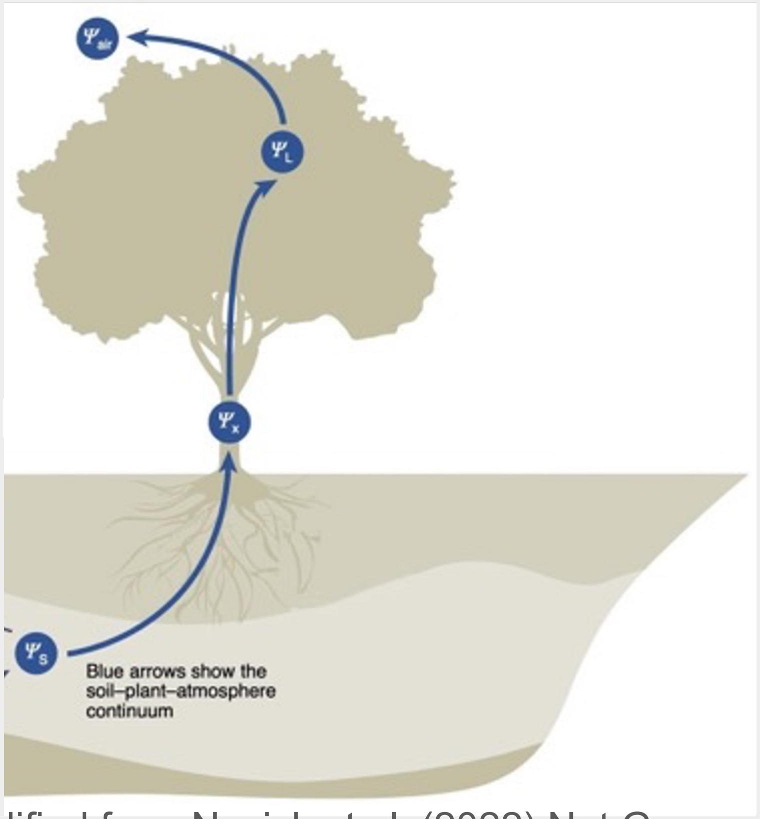
Water demand

- "Dryness" of atmosphere
- Temperature is primary driver (warm air holds more moisture)

Demand metrics include

- Vapor pressure deficit (VPD)
- Potential evapotranspiration (PET)

Demand is met by evapotranspiration (ET)



Modified from Novick et al. (2022) Nat Geosc

Ecological drought: water demand vs. supply

Water supply

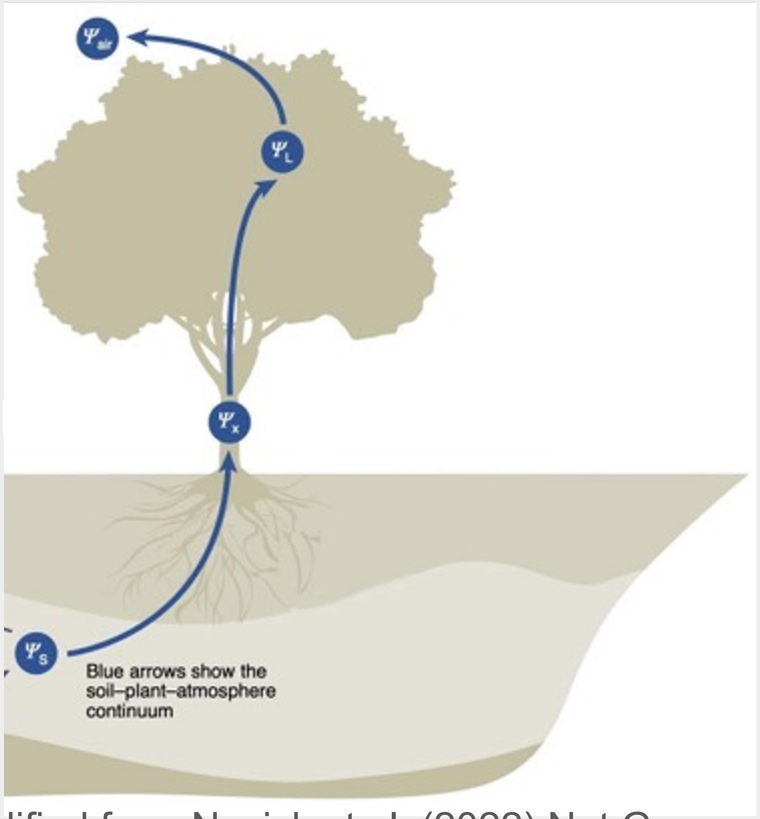
- Soil moisture available for plants
- Precipitation is primary input (but actual supply is complex)

Metrics include

- Soil moisture (where, when, how much)
- Metrics based on meteorological conditions: PDSI, SPEI (approximations)

Understanding water demand & supply

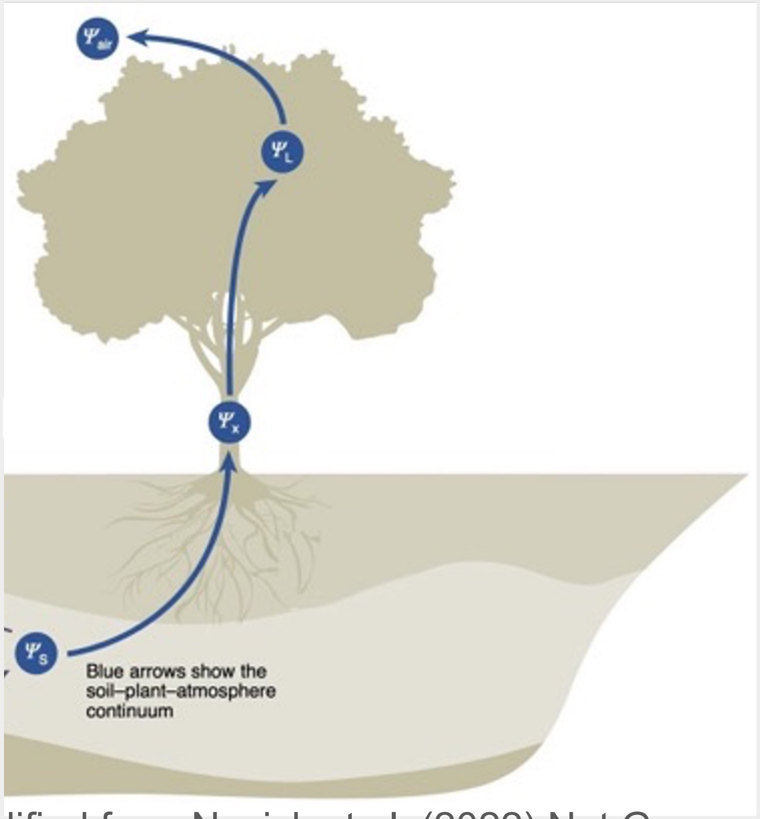
- Drought shapes dryland vegetation
- Climate change impacts



Modified from Novick et al. (2022) Nat Geosc

Ecological drought: water demand vs. supply — complexity

- Plants vary in rooting depth & depth of moisture utilization
  - Herbaceous generally shallow
  - Woody generally deeper
- Availability of moisture across depth varies – deep moisture promoted by
  - Coarse soil textures
  - Cool season precipitation
  - Large precipitation events
  - Melt of snowpack
- Water use by vegetation (transpiration) is modulated by CO2-fertilization

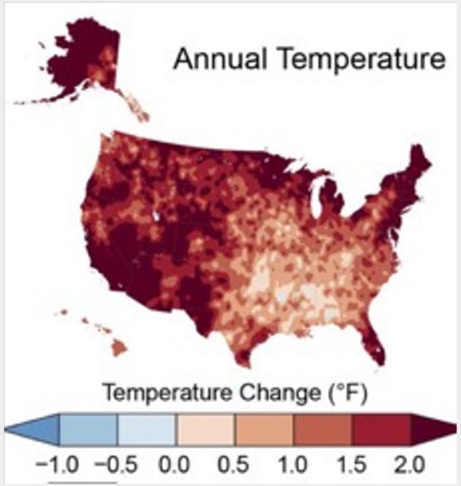


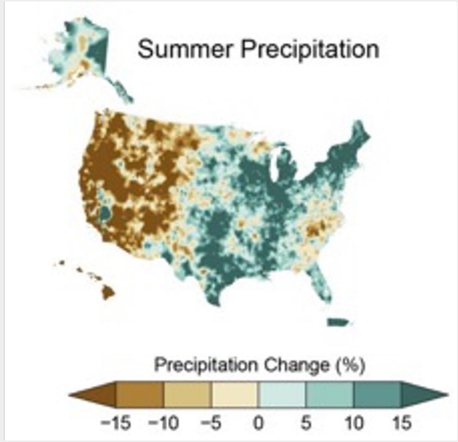
Modified from Novick et al. (2022) Nat Geosc

Historical trends in drought

Climate trends
(last 20 years vs. early 20th century; NCA5)

- Temperatures are rising
  → Increasing atmospheric moisture demand
- Precipitation: less/similar annual amounts, but shifts toward cool season in west
  → Drier soils at surface during warm season



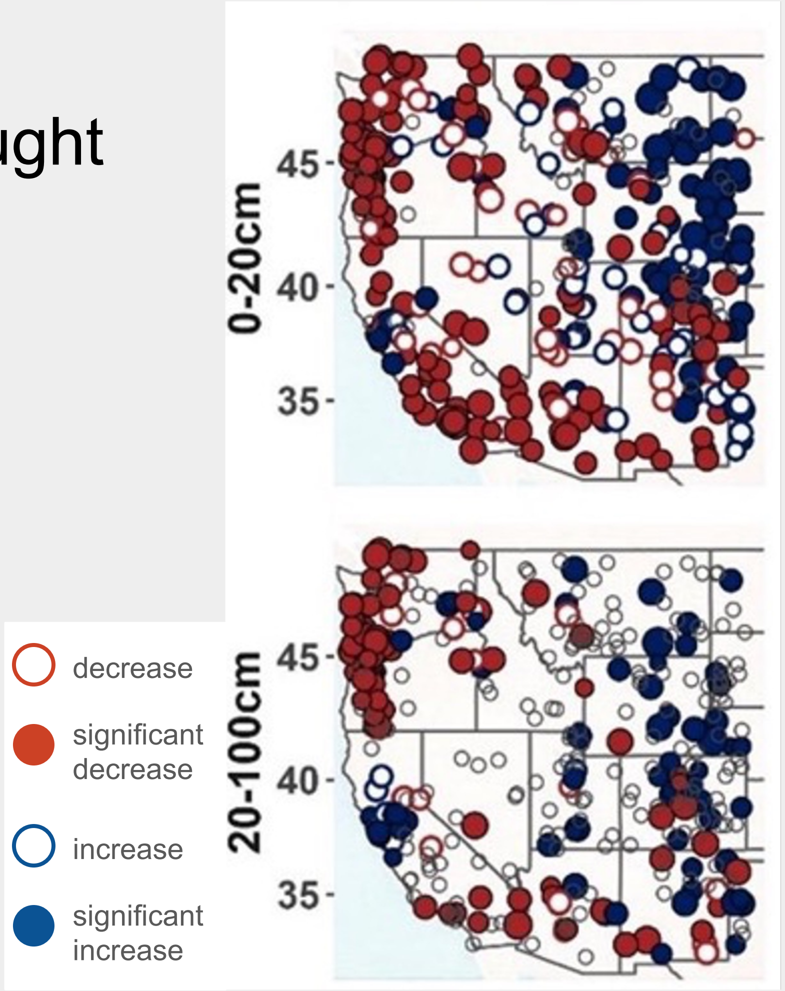


NCA5 (2023) ch. 2

Historical trends in ecological drought

Trends of soil moisture over 1976-2019 (Zhang, Biederman et al., 2021, in review)

- Widespread decrease in soil moisture (matches overall trends in T & PPT)
- Stronger decreases in shallow soil moisture (matches shift of PPT towards cool season)
  - Relative shift of moisture towards greater depth may favor deep-rooted species

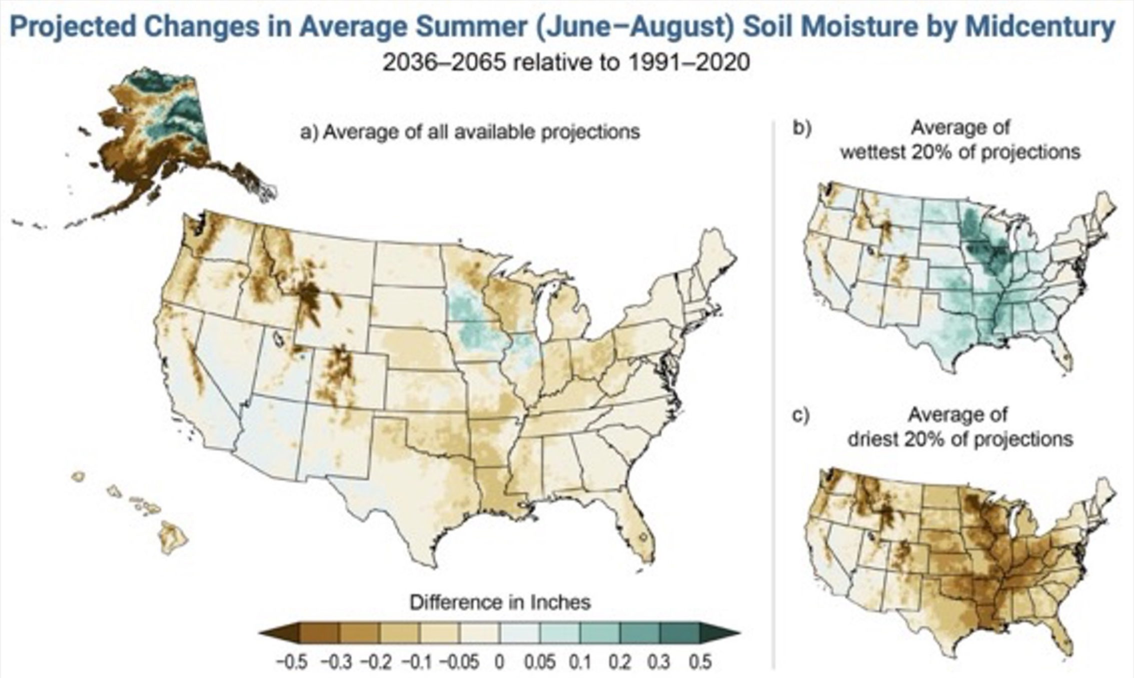


Zhang, Biederman et al. (in review)

Future changes in ecological drought

Summer soil moisture projections (NCA5)

- Mostly modest decreases
- Projections for soil moisture vary among models, scenarios and studies



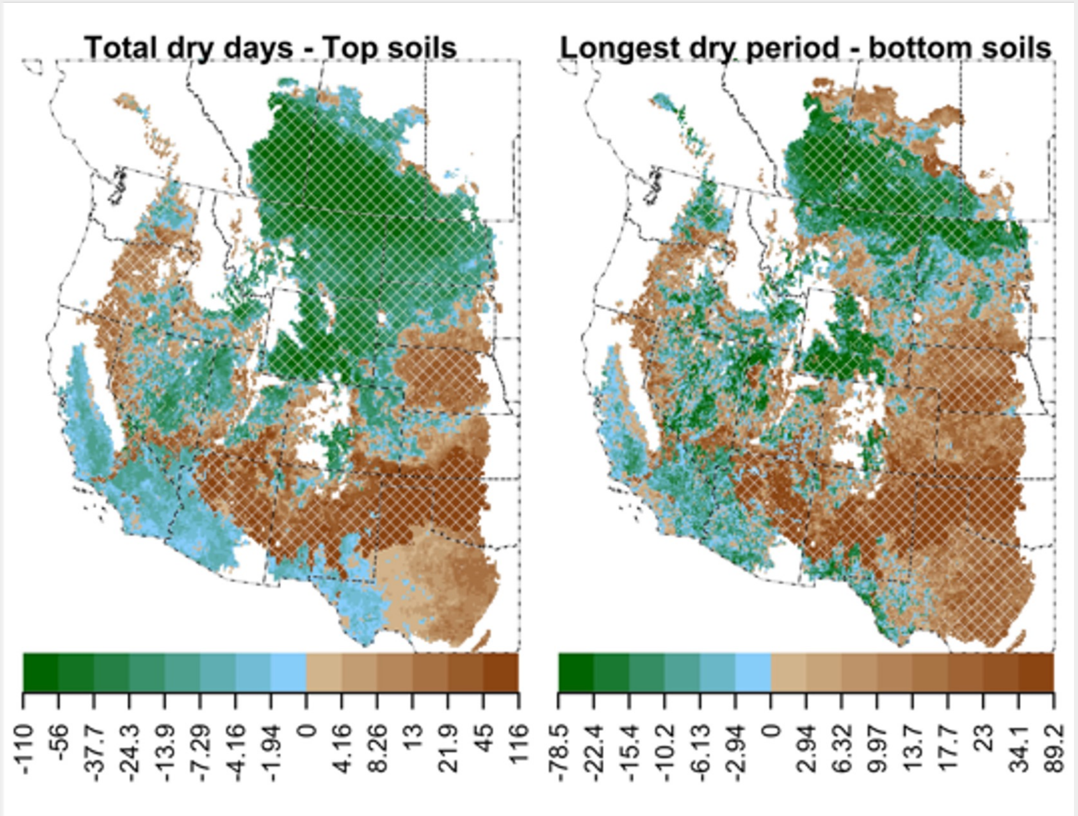
NCA5 (2023) ch. 4

Future changes in ecological drought

Robust signals in soil moisture drought (Bradford et al. (2020) GCB)

- Robustness across climate models

→ Some areas of increase, some areas of decrease

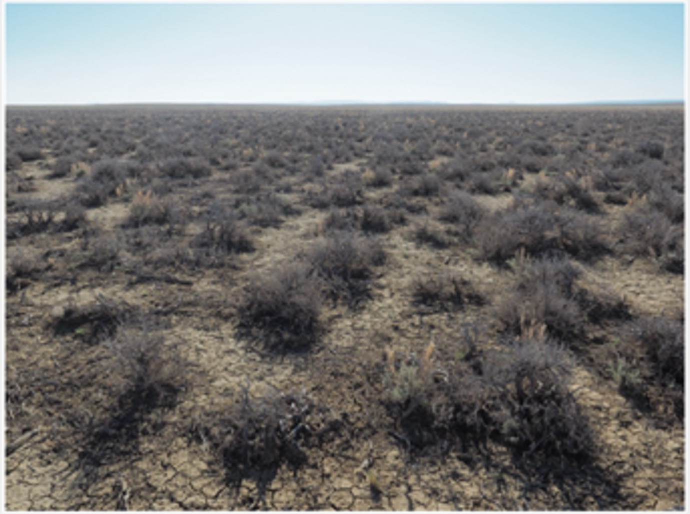


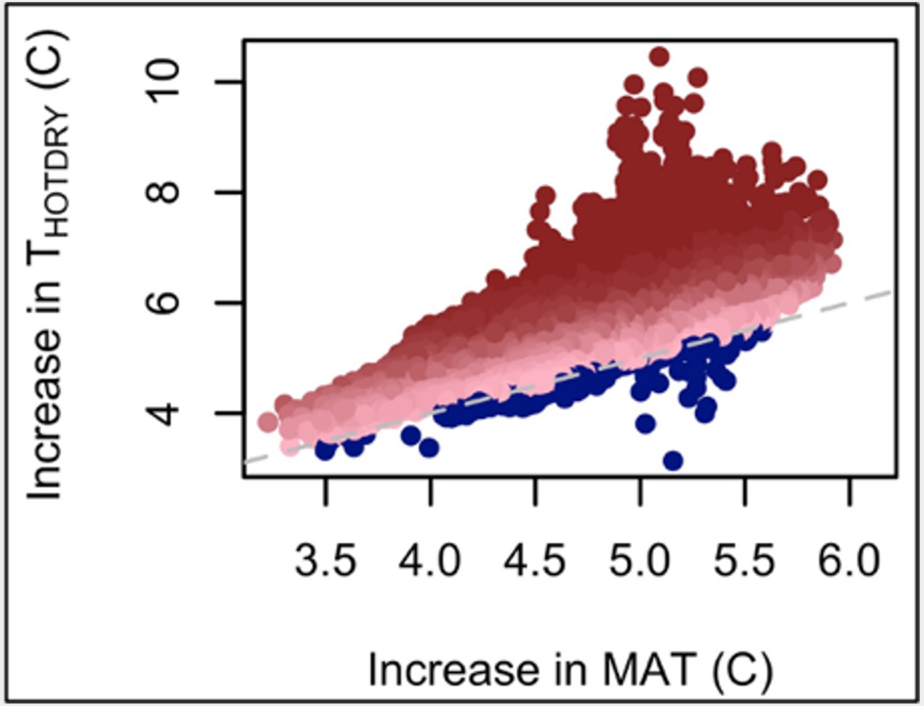
Bradford et al. (2020) GCB

What does this mean for sagebrush ecosystems?

Rising temperature → Greater demand

And larger increase of temperature when soils are dry → Greater stress



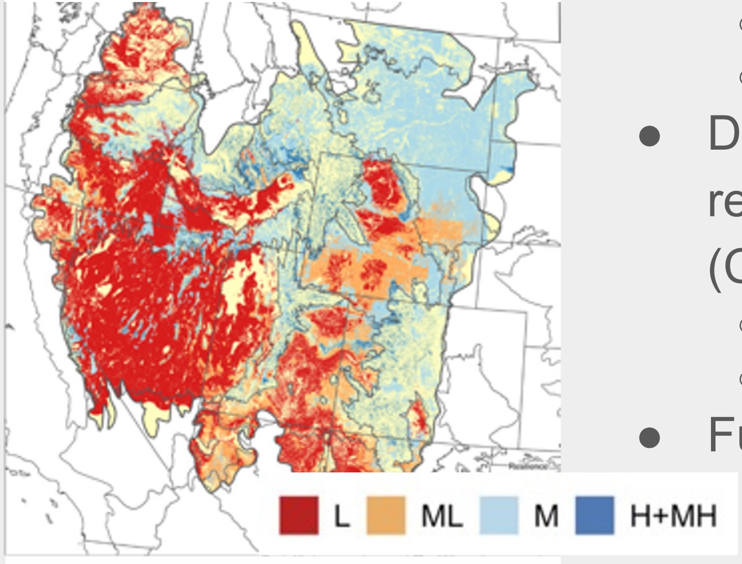


Bradford et al. (2020) GCB

Climate change impacts on the restoration challenge

Resilience & Resistance (R&R) indicators

Resilience (historical)

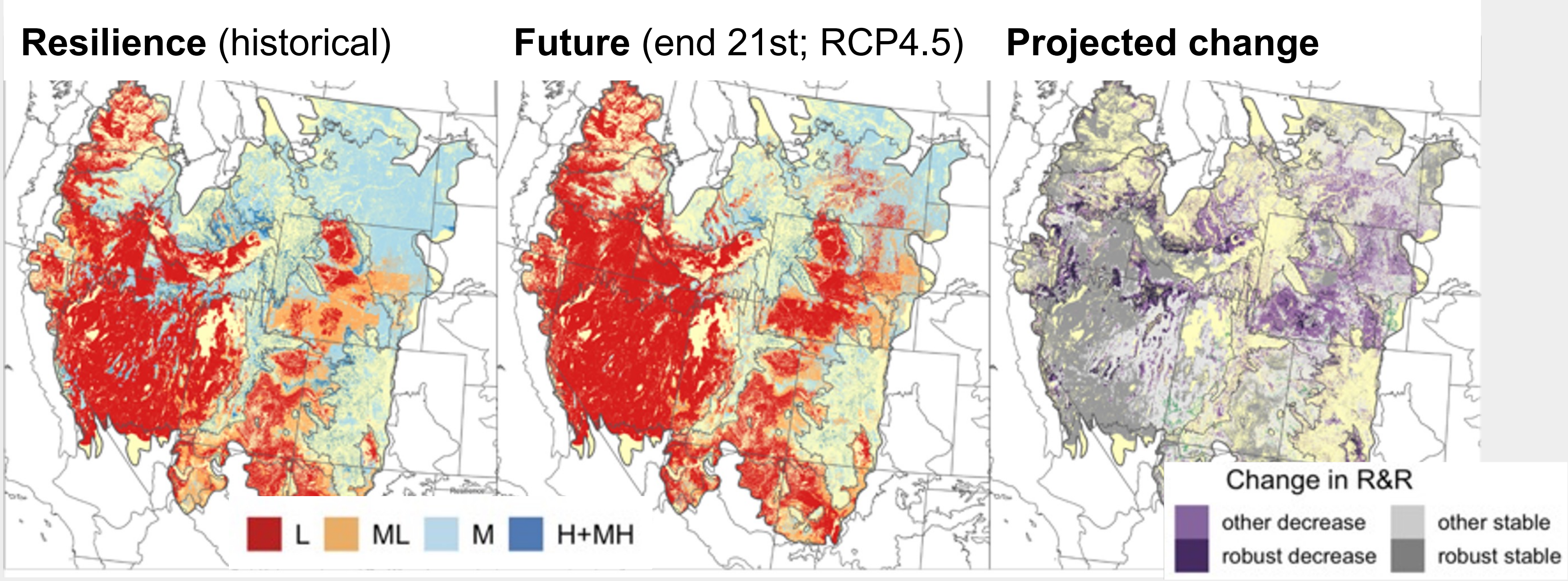


- Defined set of metrics
  - Ecological drought
  - Responsive to climate change
- Developed predictive models of ecological resistance and resilience indicators (Chambers et al. 2023)
  - Resistance to cheatgrass invasion
  - Resilience to recover from stress (e.g., drought, fire)
- Future projections based on climate models

Schlaepfer et al. (in review)

Climate change impacts on the restoration challenge

Future Resilience & Resistance (R&R) indicators



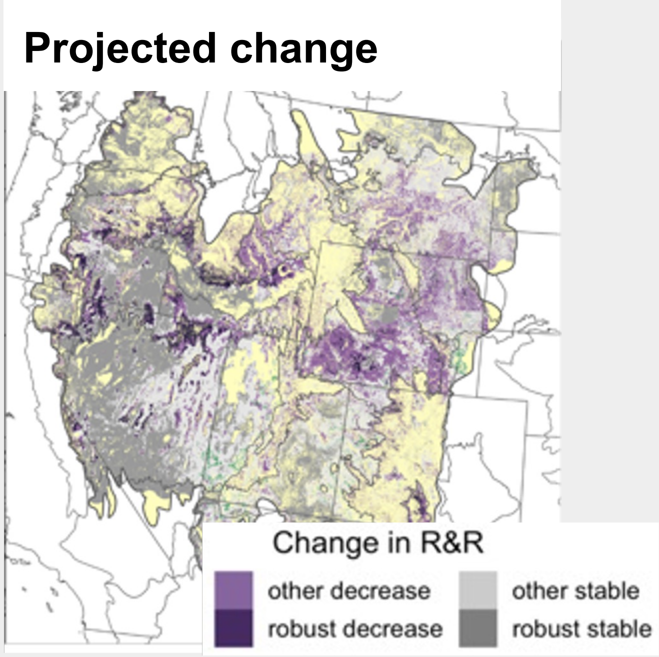
Schlaepfer et al. (in review)

Climate change impacts on the restoration challenge

Future Resilience & Resistance (R&R) indicators (Contact us, data not yet published)

- Most of the area that is historically Low remains Low (gray)
- Other categories either decreased (purple) or remained the same (gray)
- The Moderate R&R category had the most widespread decreases

→ Climate change amplifies restoration challenge



Schlaepfer et al. (in review)

What does this mean for sagebrush ecosystems?

- Sagebrush ecosystems are drylands with seasonal soil moisture conditions
- Observed increases in moisture demand (e.g., temperature) and shifts/decreases in supply (e.g., precipitation, soil moisture)
- Continued changes are expected in coming decades….some aspects are robust across models because of links to temperature
  - Some areas expected to remain, on average, climatically suitable
  - More extreme heat events exacerbate stress
- Restoration challenges expected to increase
- Land uses that add stress to vegetation may need to be carefully considered

Questions? — dschlaepfer@usgs.gov — www.drylandecology.org

- Sagebrush ecosystems are drylands with seasonal soil moisture conditions
- Observed increases in moisture demand (e.g., temperature) and shifts/decreases in supply (e.g., precipitation, soil moisture)
- Continued changes are expected in coming decades….some aspects are robust across models because of links to temperature
    - Some areas expected to remain, on average, climatically suitable
    - More extreme heat events exacerbate stress
- Restoration challenges expected to increase
- Land uses that add stress to vegetation may need to be carefully considered

Cited Literature

Bradford, J. B., D. R. Schlaepfer, W. K. Lauenroth, and K. A. Palmquist. 2020. Robust ecological drought projections for drylands in the 21st century. Global Change Biology 26:3906–3919. https://doi.org/10.1111/gcb.15075

Carter, S. K., D. S. Pilliod, T. Haby, K. L. Prentice, C. L. Aldridge, P. J. Anderson, Z. H. Bowen, J. B. Bradford, S. A. Cushman, J. C. DeVivo, M. C. Duniway, R. S. Hathaway, L. Nelson, C. A. Schultz, R. M. Schuster, E. J. Trammell, and J. F. Weltzin. 2020. Bridging the research-management gap: landscape science in practice on public lands in the western United States. Landscape Ecology 35:545–560. https://doi.org/10.1007/s10980-020-00970-5

Chambers, J. C., J. L. Brown, J. B. Bradford, D. I. Board, S. B. Campbell, K. J. Clause, B. Hanberry, D. R. Schlaepfer, and A. K. Urza. 2023. New indicators of ecological resilience and invasion resistance to support prioritization and management in the sagebrush biome, United States. Frontiers in Ecology and Evolution 10:1–17. https://doi.org/10.3389/fevo.2022.1009268

Fifth National Climate Assessment [NCA5]. Crimmins, A.R., C.W. Avery, D.R. Easterling, K.E. Kunkel, B.C. Stewart, and T.K. Maycock, Eds. 2023. U.S. Global Change Research Program, Washington, DC, USA. https://nca2023.globalchange.gov

Maestre, F. T., B. M. Benito, M. Berdugo, L. Concostrina-Zubiri, M. Delgado-Baquerizo, D. J. Eldridge, E. Guirado, N. Gross, S. Kéfi, Y. L. Bagousse-Pinguet, R. Ochoa-Hueso, and S. Soliveres. 2021. Biogeography of global drylands. New Phytologist 231:540–558. https://doi.org/10.1111/nph.17395

Novick, K. A., D. L. Ficklin, D. Baldocchi, K. J. Davis, T. A. Ghezzehei, A. G. Konings, N. MacBean, N. Raoult, R. L. Scott, Y. Shi, B. N. Sulman, and J. D. Wood. 2022. Confronting the water potential information gap. Nature Geoscience 15:158–164. https://doi.org/10.1038/s41561-022-00909-2