Defining Groundwater-Dependent Ecosystems and Assessing Critical Water Needs for their Foundational Plant Communities

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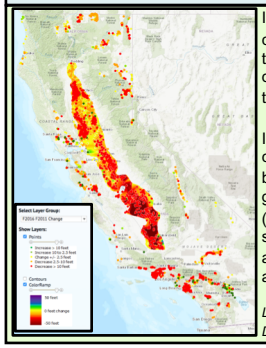
1. Threats to Groundwater-Dependent Ecosystems (GDEs)



In many water-limited regions, human water use in conjunction with increased climate variability threaten the sustainability of groundwater-dependent plant communities and the ecosystems that depend on them (GDEs).

Identifying vulnerable GDEs and determining their critical functional thresholds has proved challenging, but recent research in several disciplines shows great promise for defining water stress indicators (WSIs) across a range of spatial and temporal scales. Here, we describe a multidisciplinary approach for using WSIs to improve groundwater and ecosystem management.

Left: Groundwater change from 2011 – 2016 in California. Data source: California Department of Water Resources

2. Which organisms should we focus on?

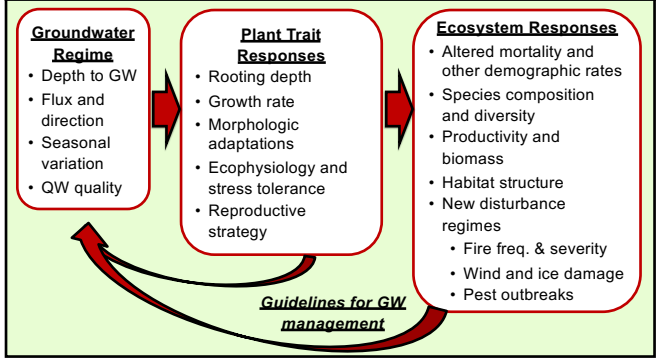
Groundwater-dependent plant classifications

- *Obligate* phreatophytes
  - Roots need constant contact with the water table and capillary fringe
  - Poor drought tolerance
  - Springs, wetland and many riparian communities
- *Facultative*, or proportional, users
  - Use a combination of groundwater and vadose zone water
  - Can switch water sources when groundwater is not available
  - Physiological water-use adaptations

Prioritize plants with important roles in the riparian ecosystem

- *Foundational* species
  - Structure the ecosystem; unique qualities
  - Provide the greatest benefits (and potential losses) to GDEs
- *Indicator* species
  - Particularly sensitive to GW change
  - Early sentinels of ecosystem vulnerability ('canaries in the coal mine')

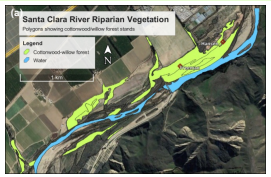
3. Identify key indices of groundwater dynamics, plant trait responses and ecosystems functions



4. Approaches for quantifying groundwater change and plant water stress indicators (WSIs)

Groundwater well records

- Direct measure of GW dynamics
- Simple, inexpensive measures
- But doesn't assess ecosystem response to groundwater change



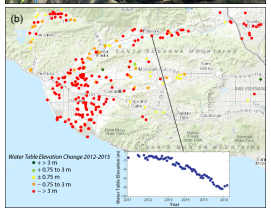
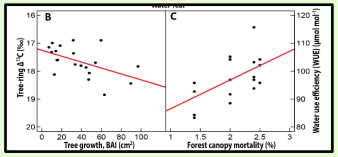
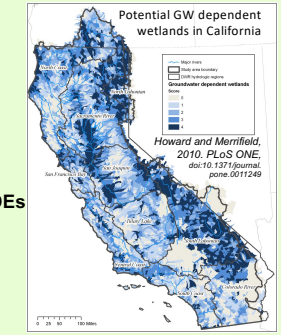


Fig. 2. Santa Clara River corridor showing (a) native riparian woodlands (green polygons) and several proposed field sites (red symbols); and (b) recent groundwater decline at wells distributed throughout the lower basin (DWR-GICIMA Program



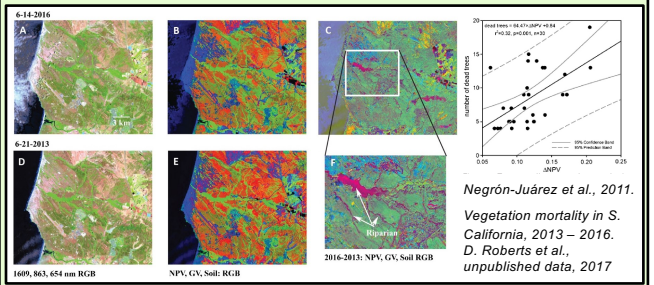
Ecophysiological responses using tree rings and stable isotopes

- Multi-decadal records of tree-ring growth response to water supply
- ^{18}O ratios to assess water sources
- ^{13}C ratios to assess water use efficiency and plant physiological stress
- These measures have high resolution but are costly and time-intensive



Landscape modeling of potential GDEs

- Combines disparate data layers
- Hydrology/hydrography
- Vegetation maps and cover classes
- Topographic indices
- Can model over large spatial scales, but often coarse resolution and uncalibrated

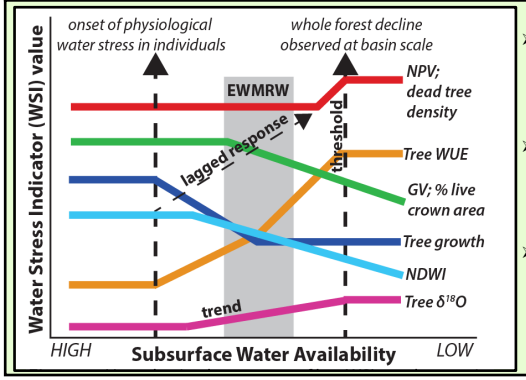


Negrón-Juárez et al., 2011. *Vegetation mortality in S. California, 2013 – 2016. D. Roberts et al., unpublished data, 2017*

Remote sensing change detection

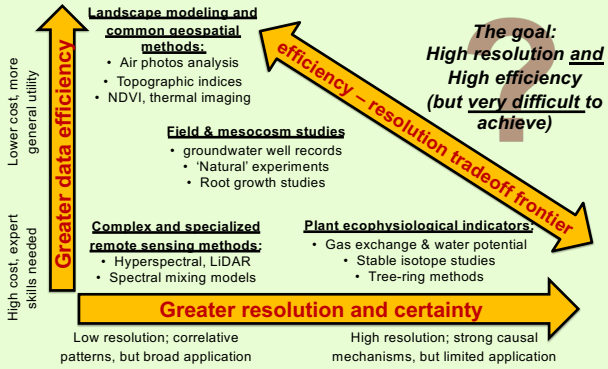
- Applied over large spatiotemporal scales
- Requires good correlation with groundwater change and veg response
- Common indices from long-term satellite data (e.g. NDVI and NDWI)
- Novel spectral mixing models from hyperspectral data (e.g., AVIRIS)
- Non-Photosynthetic Vegetation (NPV, proxy for dead plants)
- Greenness Vegetation Index (GV, proxy for photosynthetic activity)

5. Compare multiple WSIs: early warning signs ('canaries'), thresholds, and lagged responses



- Identify seasonal, annual and decadal signals
- Compare individual plants to forest stands to landscapes
- Evaluate interactions between water stress indicators

6. Acknowledging tradeoffs between data resolution and efficiency of data acquisition



7. Conclusions and steps forward

Emerging methodologies and increased data resolution are improving our ability to focus on individual plant species, including foundational and/or sensitive taxa that serve as early warning indicators of ecosystem impairment. Combining and cross-calibrating these approaches will provide insight into the full range of GDE response to environmental change, including increased climate variability and drought, human groundwater extraction, and flow regulation. In collaboration with project partners, we are analyzing GDE responses to water stress in semi-arid regions of the U.S. Southwest and southern Europe.

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