Assessing Riparian Woodland Response to Shallow Groundwater Availability

Spring 2024

Hector Leal Ibarra, Leah Makler, Vivian Phan, Leslie Serafin, Hannah Vaughn-Hulbert

Faculty Advisor: Scott Jasechko
Client: Restoration Science, LLC.

ENVIRONMENTAL PROBLEM

Groundwater dependent ecosystems are ecological communities that depend on groundwater emerging from or near the surface. Therefore, these ecosystems are vulnerable to excessive groundwater pumping for domestic use and irrigation. California's Sustainable Groundwater Management Act requires agencies to plan for the long-term sustainable management of groundwater basins, including local groundwater dependent ecosystems. However, the state does not provide guidelines for conserving and managing these sensitive ecosystems. Additionally, there is a knowledge gap regarding the complex exchanges between surface water, shallow groundwater, and riparian vegetation in groundwater dependent ecosystems. To fill this knowledge gap, we analyzed the relationship between precipitation, groundwater, and vegetation health in East Grove, a "likely groundwater-dependent ecosystem," located in the Fillmore Subbasin of the Santa Clara River Groundwater Basin. Quantifying the interactions between surface water, groundwater, and riparian vegetation within East Grove and other groundwater dependent ecosystems will be crucial for sustainable groundwater management in this region.

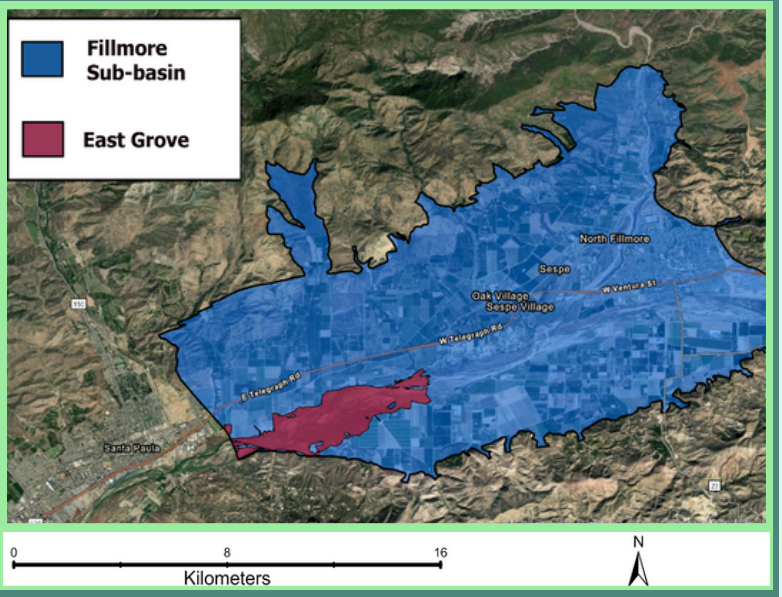

Figure 1. *The East Grove riparian woodland is located within the Fillmore Sub-basin of the Santa Clara River Groundwater Basin. The Fillmore Sub-basin supplies domestic water to the city of Fillmore and irrigation water to local agricultural operations.*

Figure 2. *Simplified diagram of a groundwater dependent ecosystem, displaying two aquifers (shallow and deep), different subsurface materials, and a riparian community. We utilized this framework to determine the effect of shallow groundwater levels on East Grove, a "likely groundwater dependent ecosystem."*

APPROACH & RESULTS

We completed four distinct analyses focused on characterizing (i) subsurface geology, (ii) groundwater flow direction, (iii) shallow groundwater levels and their variations with climate, and (iv) plant water content variations over time via remote sensing. Due to data availability, shallow groundwater and plant water content were analyzed from 2016-2023.

(i) We characterized the subsurface geology by digitizing historical well-completion reports in the Fillmore Subbasin. In the Fillmore Subbasin, 74% of the well's uppermost 60 meters consist of coarse material, such as sand and gravel.

(ii) We used groundwater-level data from a nested monitoring well to determine the direction of groundwater flow. Groundwater appears to flow upward from deep to shallow aquifers near East Grove.

(iii) We assessed fluctuations in shallow groundwater availability using local precipitation data and water-level data from monitoring wells in East Grove. We determined that East Grove's shallow groundwater levels increased following precipitation events and shallowed on average during our study period.

(iv) We used remote sensing methods to calculate the riparian ecosystem's Normalized Difference Moisture Index (NDMI) at different time steps. NDMI is an estimate of plant water content that we used as a proxy measurement of ecosystem health. Plant water content (NDMI) in East Grove increased on average from 2016 to 2023. Furthermore, plant water content (NDMI) positively correlates with groundwater availability, especially in summer.

UC SANTA BARBARA
Bren School of Environmental Science & Management

KEY FINDINGS

Coarse material in the soil's upper layers may increase groundwater recharge following precipitation events. Groundwater rises from deep to shallow depths near East Grove due to subsurface pressure gradients.

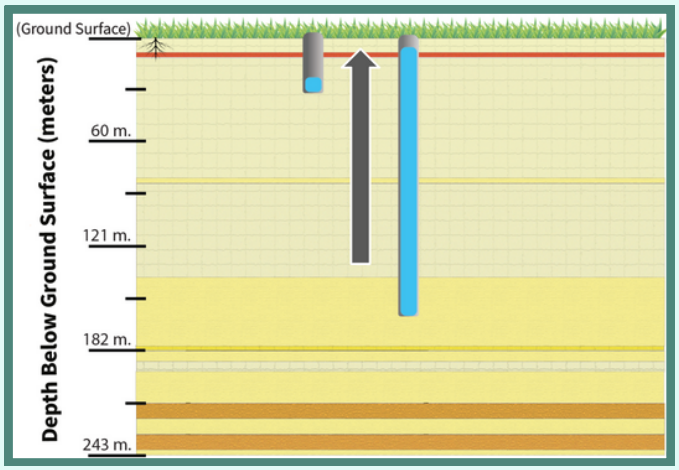

Figure 3. A 2-D cross-section of a nested well depicts an upward-oriented hydraulic gradient, with groundwater flowing upwards from deep to shallow depths..

During our study period, groundwater levels in East Grove shallowed. Plant water content (NDMI)—a proxy variable for vegetation health—increased simultaneously. In East Grove, increases in groundwater availability correlate with vegetation health year-round, but especially in summer. During summer, when there is little precipitation or surface flow, plant water content improves when groundwater levels are shallow. Thus, it appears that phreatophytes in this system utilize shallow groundwater when other water sources are unavailable, allowing them to thrive and support the ecosystem.

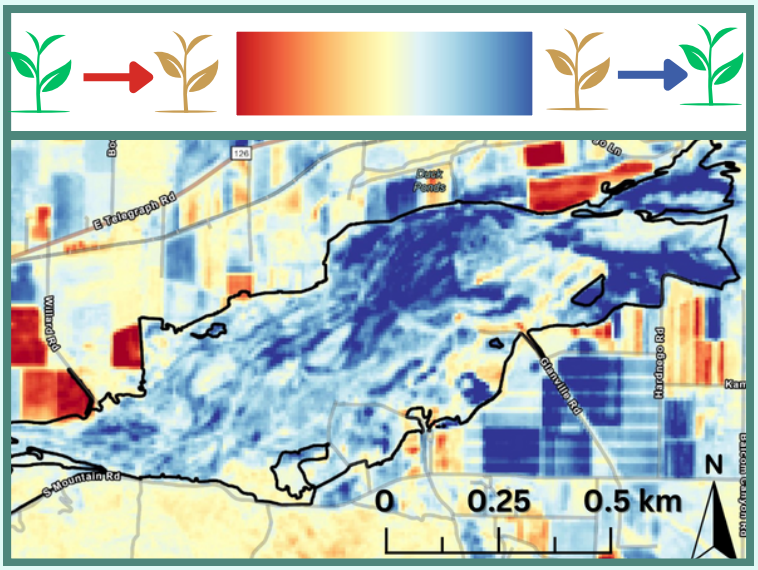

Figure 5. Changes in NDMI within East Grove between summer 2016 and 2023. Changes in plant water content range from -1 to 1, where negative values (red) represent a decrease, and positive values (blue) indicate an increase. The majority of East Grove is shades of blue, indicating an overall increase in plant water content between summer 2016 and summer 2023.

CONCLUSION

We conclude that East Grove is a groundwater dependent ecosystem for the following reasons:

1. There is evidence of groundwater upwelling from deep to shallow depths, a key indicator of groundwater dependent ecosystems.
2. The ecosystem's vegetation benefits from increased availability of shallow groundwater when it coincides with dry periods, suggesting the dominance of phreatophytes.

IMPACT

The results of this study suggest that East Grove is a groundwater dependent ecosystem. Given Ventura County's minimal summer precipitation and the intermittent dryness of the Santa Clara River, the ecological community of East Grove relies heavily on shallow groundwater availability during the dry season. The ecosystem's resilience allows East Grove to provide critical habitat for several threatened and endangered species, such as southwestern willow flycatchers and southern steelhead trout. Thus, East Grove has "high ecological value," meaning that agencies are particularly concerned with its conservation. To protect threatened and endangered species under the Endangered Species Act, agencies must prioritize the maintenance of shallow groundwater levels in the Fillmore Subbasin.

Southwestern willow flycatcher. Photo by Jim Rorabaugh/USFWS.

Southern steelhead trout. Photo by Michael Humling/USFWS.

The Sustainable Groundwater Management Act requires that agencies consider the impacts of groundwater extraction on groundwater dependent ecosystems. Our results provide a potential baseline evaluation of East Grove's condition that managers can use to assess the effects of future drought or groundwater extraction on the system. Stakeholders can implement our methodological framework to identify and evaluate other groundwater dependent ecosystems.

RECOMMENDATIONS

- Prioritize gathering data on local surface water flows: conservation releases, runoff, and river flow.
- Complete on-the-ground assessments of vegetation health to validate remote-sensing findings.
- Evaluate the effect of groundwater extraction on shallow aquifers and groundwater dependent ecosystems.
- Determine a safe threshold of depth-to-groundwater to sustain a healthy ecosystem in East Grove.

UC SANTA BARBARA
Bren School of Environmental Science & Management