Groundwater Recharge and Environmental Enhancement Opportunities in Grasslands in Arizona

ATUR Workshop Brief: Grasslands Hydrology | **December 2024**

INTRODUCTION

Arizona's grasslands occur at multiple elevations across the state and are positioned between the higher elevation woodlands and lower elevation deserts. These areas support high biodiversity and important ecosystem services, such as flood and soil erosion control, which benefit groundwater recharge in downstream riparian areas. However, unlike areas along mountain fronts, karst (limestone) topography, or floodplains, grasslands in Arizona are not known for their high recharge potential. In fact, experts believe that in some regions of the state, significant infiltration past the rooting depth in grasslands has not occurred on a regular basis since the transition from the Ice Age to the Holocene period (Walvoord et al., 2002). However, during a one-day workshop hosted by The Nature Conservancy and the Arizona Tri-University Recharge and Water Reliability Project in December 2024, the panel noted that there are exceptions to the rule about recharge potential in grasslands. This brief details the discussions of the state of knowledge of grassland hydrology, including opportunities for recharge, human and climate impacts, cross-sector partnership opportunities for sustainable grasslands management, and additional research needs.

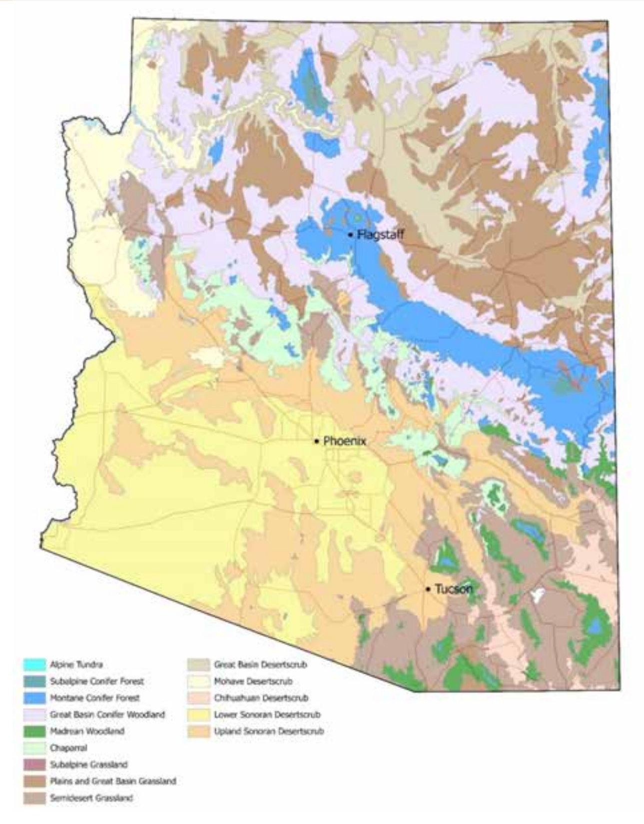

Figure 1. Map showing locations of semidesert and Plains and Great Basin grasslands across Arizona. Figure adapted from Brown and Lowe's Biotic Communities of the Southwest (1994) by AZ Game & Fish (n.d.a.).

ARIZONA'S PHYSIOGRAPHIC PROVINCES

Infiltration and recharge opportunities in grasslands vary with the hydrogeology of Arizona's diverse physiographic provinces. These high-level province characteristics should be considered alongside site specific conditions when evaluating the feasibility of recharge in grasslands.

- *The Plains and Great Basin grasslands of the Colorado Plateau* in northeastern Arizona are found at elevations between 5,000 and 7,000 feet and are dominated by perennial, sod-forming grasses (AZ Game & Fish, n.d.b.). Geologically, this area consists of ancient sedimentary rock layers such as limestone and sandstone, and depth to groundwater can be hundreds or even thousands of feet below the land surface. The karst topography found in this region may allow for higher recharge rates than other areas with lower permeability geology.
- *The semidesert grasslands of the Basin and Range Province* are found primarily in southeastern Arizona, although they also occur in the Central Highlands Transition Zone and in the northwestern part of the state. Semidesert grasslands can be found abutting desert scrub biomes from 3,600 feet to 5,000 feet above sea level, at the transition to woodlands (AZ Game & Fish, n.d.c.). Many of these semidesert grasslands have been invaded by non-native grasses and are affected by shrub encroachment (e.g. mesquite) (AZ Game & Fish, n.d.c.),

Figure 2. Arizona's physiographic provinces (Harshbarger et al., 1966).

which may negatively affect recharge rates. The geology of the Basin and Range Province consists of sedimentary bedrock with metamorphic cores in the mountain ranges with broad valley basins between them, including some areas with alluvial sand and gravel deposits. Generally, soil types grade from coarse to finer-grained soils from the mountains to the center of the valleys. The coarser grain materials of the alluvial deposits along mountain fronts and ephemeral and intermittent streams provide opportunities for recharge.

- *The Central Highland Transition Zone*, between the Colorado Plateau and the Basin and Range Provinces, consists of both Plains and Great Basin and semidesert grasslands. This transition zone is geologically complex and consists of sedimentary and volcanic rocks with fractures and limestone features that can act as conduits to regional aquifers. Recharge in grasslands is context specific given the wide range of geological and climate contexts in this region.

WORKSHOP FINDINGS: SITE-SPECIFIC CONDITIONS AND STRATEGIES

Infiltration vs. Recharge in Grasslands

Site-specific conditions such as soil properties, plant species composition and structure, and depth to groundwater, have a significant impact on recharge capabilities in grasslands. Furthermore, the distinction between infiltration and recharge is important when considering grassland hydrologic processes and their benefits.

- Infiltration is the *process by which water enters the soil surface*, while groundwater recharge occurs when *water is added to aquifers*. Infiltration only becomes recharge when there is enough water to overcome soil adhesion forces and root water extraction (i.e. evapotranspiration) from the vadose zone (unsaturated soil layer above the aquifer), enabling infiltrated water to reach the water table. This depends on multiple factors, including climate, vadose zone depth, plant cover, and soil hydraulic properties (Goodrich et al., 2004; Coes and Pool, 2007).

Figure 3. View of a floodplain Sacaton grassland in the San Pedro Riparian National Conservation Area in southeastern Arizona. Photo: Holly Richter

- Findings from studies in the Southwest suggest that very little of the water infiltrated in upland grasslands moves beyond the root zone and may take thousands of years to travel downward through unsaturated soil layers and into regional aquifers (Coes and Pool, 2007; Walwoord et al., 2002; Scanlon et al., 2006; Scanlon et al., 2005).
- Some caveats to minor recharge in grasslands include:
  - Wetter regions with high permeability geology, such as karst topography.
  - Shallow rooted grasslands with mainly annual vegetation.
  - Areas with winter-dominated precipitation regimes. Water reaches greater depths in cool seasons when plants are inactive and evaporation is lower (Scott et al., 2000).
  - Regions where the depth to groundwater is shallow and grassland vegetation already accesses groundwater.
- While enhancing infiltration rates in upland grasslands is important to supporting habitat quality and biodiversity, it should not be confused with increasing groundwater recharge and storage. However, in floodplain settings with shallow water tables, such as sacaton grasslands, flooding can result in recharge to alluvial aquifers.

Grassland health, management, and the interconnection of riparian and upland grassland systems

Grasslands are not known for their recharge potential; however, there are several site-specific conditions and land management strategies that may contribute to enhanced infiltration and potentially increase recharge and baseflow in nearby intermittent, ephemeral or perennial streams. The following are some key considerations for grasslands management and health:

- There is a direct link between healthy soil and water storage capacity. Increases in soil carbon improve the ability of soil to capture and store water (Masters, 2019; Rawls et al., 2003). Therefore, management practices that enhance soil carbon are supportive of infiltration and healthy grasses.
- Livestock grazing management, including factors such as timing, intensity, duration, and frequency of livestock exposure to vegetation, can have significant impacts on grassland health. Overgrazing can damage grasses and lead to erosion, limiting capacity for infiltration (Jablonski et al., 2024).
- Fine sediment from eroded and degraded upland grasslands can have a significant, negative influence on streambed infiltration and recharge in active floodplains and streams, including riparian areas (Goodrich et al., 2018).

Figure 4. View overlooking the semidesert grasslands of Las Cienegas National Conservation Area in southeastern Arizona. These grasslands are experiencing mesquite encroachment. Photo: Marlana Hinkley

- The use of large branch mulch (strategically placed shrub cuttings, etc.) in small channels in upland grasslands can reduce erosion and evaporative losses, encourage infiltration, and possibly increase local recharge to riparian areas (Leger, 2020; Norman et al., 2022).
- Rock detention structures can be used in ephemeral and intermittent channels to slow down water and allow for greater infiltration. These can reduce erosion and enhance downstream flow duration and volume (Nichols et al., 2016; Norman et al., 2022).
- Capture and retention of overland sheet flow (surface runoff flowing on the ground surface rather than in a defined channel) can mitigate evaporative losses and provide a source of water for additional infiltration and recharge. (Norman et al., 2025)
- Earthen stockponds (ponds constructed to provide water for livestock) may be retrofitted to enhance infiltration and recharge. However, if they are left unmanaged, the opposite can be true (Nichols et al., 2017).

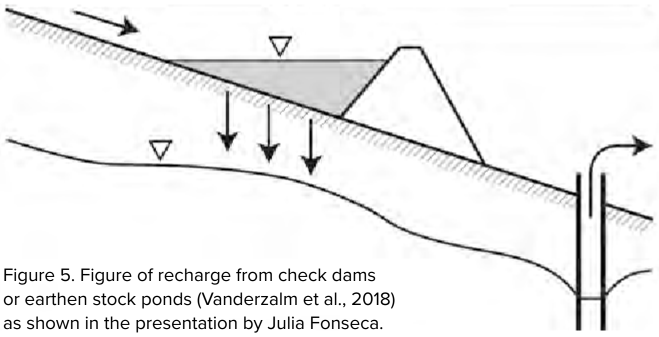

Figure 5. Figure of recharge from check dams or earthen stock ponds (Vanderzalm et al., 2018) as shown in the presentation by Julia Fonseca.

CLIMATE CHANGE AND HUMAN-RELATED IMPACTS TO GRASSLANDS

The impacts of climate change and human development on Arizona's grasslands are numerous. Hotter and drier conditions, altered variability in precipitation, unsustainable groundwater pumping, agriculture, and mining all contribute to the degradation of these areas and declines in recharge potential.

- Climate change may alter precipitation regimes year-round, with effects being felt most acutely in winter. Winter rain and snowfall have the greatest recharge potential due to lowered evaporation demand and plant water use. However, higher intensity precipitation events during the summer monsoons provide additional opportunities to collect or manage excess runoff for use in recharge.
- Human and climatic effects on evapotranspiration (ET) in grasslands can be difficult to quantify. While land management practices such as fire suppression or regenerative grazing may allow for increased vegetation, increased transpiration of plants, and decreased soil evaporation losses, the dominant control on total ET in southeastern Arizona's grasslands is the precipitation amount (Scott et al., 2019, 2021).
- Human activities such as irrigated agriculture, groundwater pumping, and road construction may deplete groundwater supplies and obstruct surface water flows, reducing water previously available to grasslands. These activities may reduce the ability of grasslands to persist or be restored.
- Mining has also had a significant impact on Arizona's Basin and Range semidesert grasslands. Dewatering of mining pits in these areas can reverse recharge flows and cause evaporation from the aquifer.

PARTNERSHIP OPPORTUNITIES

Fostering cross-sector partnerships with researchers, land management agencies, agricultural and conservation partners, and individual landowners may lead to innovative solutions and impactful outcomes in grasslands.

- Multi-benefit projects for grasslands engage both a broader array of partners and funding opportunities. For example, erosion control projects to reduce sedimentation can also enhance downstream recharge, if thoughtfully designed.
- Collaborating across ownership and management boundaries increases the likelihood of broader ecosystem benefits, such as aquifer recharge, at the landscape scale. Given the complexity of groundwater recharge processes, land use planning and management should also be approached from a landscape-level perspective.

RESEARCH NEEDS

Additional research is needed to fully characterize recharge opportunities in grasslands.

- Differences in grassland recharge processes between the three physiographic provinces of Arizona could be significant and depend on site-specific geology. A comparison of chloride accumulation rates in the unsaturated zones beneath grasslands could be useful in understanding how quickly water makes it to the aquifer under different geologic conditions.
- Increased continuous/automated groundwater monitoring in grasslands and rangelands could enhance our understanding of recharge and serve both regional and site-specific research needs.
- A more comprehensive understanding of how climate change may affect recharge mechanisms and flowpaths across Arizona's different grassland types could greatly benefit land managers. While a warming climate is generally expected to reduce recharge rates, an improved understanding of how the variability in large, infrequent precipitation events associated with the North American monsoon will affect recharge is needed. Due to generally deep vadose zones and long groundwater travel times under Arizona's grasslands, these longer-term climatic changes may have a greater impact on recharge rates than short-term land cover changes.
- Developing a more comprehensive toolkit that provides land and water management guidance for reducing erosion and enhancing infiltration across Arizona's different grasslands could contribute to increased adoption of these practices and ultimately, healthier grasslands.

CONCLUSION

Opportunities for enhancing recharge in Arizona's grasslands vary by physiographic province and depend on site-specific conditions. Land management strategies such as livestock grazing management, process-based interventions (e.g. large branch mulch and rock detention structures), and capture and retention of overland sheet flow may help mitigate grassland degradation and contribute to enhanced infiltration and recharge potential. Cross-sector partnerships are key to securing support and finding innovative and impactful recharge and environmental enhancement opportunities in grasslands. Finally, research needs such as increased groundwater monitoring, a more comprehensive understanding of the changing climatic impacts on grasslands in Arizona's different physiographic provinces, and the development of a comprehensive toolkit could assist land and water managers in their restoration and enhanced recharge efforts.

FOR MORE INFORMATION ON RECHARGE OPPORTUNITIES IN GRASSLANDS, PLEASE CONTACT:

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The Arizona Tri-University Recharge and Water Reliability (ATUR) project is a 3.5-year hydrologic science study investigating how and where water that would have otherwise evaporated can be captured and recharged to support Arizona's groundwater supplies now and in the future. This research is conducted by an interdisciplinary team of 30 researchers across the University of Arizona, Arizona State University, and Northern Arizona University at the request of the Arizona Department of Water Resources. Additional information on the ATUR project can be found at: ccass.arizona.edu/arizona-tri-university-recharge-and-water-reliability-project

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ACKNOWLEDGEMENTS

We would like to acknowledge the many experts that contributed to this assessment of the state of knowledge in grasslands hydrology, and the ATUR and TNC team members that hosted this insightful discussion.

Experts: Mark Apel, Cameron Becker, Julia Fonseca, Dave Goodrich, Ariel Leger, Mike Milczarek, Laura Norman, Russ Scott, Jackie Watkins, Stephen Williams

TNC: Kim Schonek, Bailey Winston, Gita Bodner

ATUR: Kathy Jacobs, Neha Gupta, Holly Richter, Jia Hu, Fern Bromley, Marlana Hinkley

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