Sustainable Groundwater

1. Case Study A: *Sustainable Groundwater Management through Managed Aquifer Recharge (MAR): Site Selection, Characterization, and Monitoring.*
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Introduction

Changing global climate extremes, including some of the most severe droughts on record in California, spotlight the need to more precisely observe and allocate our water supply for agriculture, ecosystems, and growing population in semi-arid regions. The varied geography, hydroclimates, ecosystems, and system shocks that have occurred and are expected in California and Mexico provides compelling intersections of water resource availability and demand. The goal of this proposal is to collaboratively explore combinations of precision water monitoring and modeling strategies in support of integrating agriculture with managed aquifer recharge (AgMAR). In short, AgMAR has the potential to enable subsurface storage gains achieved during wet years to supplement irrigation needs in dry to normal years. As we complete our understanding of and gain the capacity to precisely monitor AgMAR processes and systems, growers and water resources manages will be more able to act decisively with respect to water allocations. We can imagine, for example, a cyber-physical system for observing and managing short-term (e.g. irrigation events) and long-term water operations on a farm (see figure below).

Objectives

- Developing and testing measurement and modeling strategies for assessing AgMAR potential on farmland, or marginal lands near farms, and identifying best practices.
- Identifying metrics for success in AgMAR and developing a pilot program for testing these metrics.
- Exploring the potential impact of widespread AgMAR implementation in vulnerable agricultural regions in California and Mexico, particularly in severely over-drafted groundwater basin.

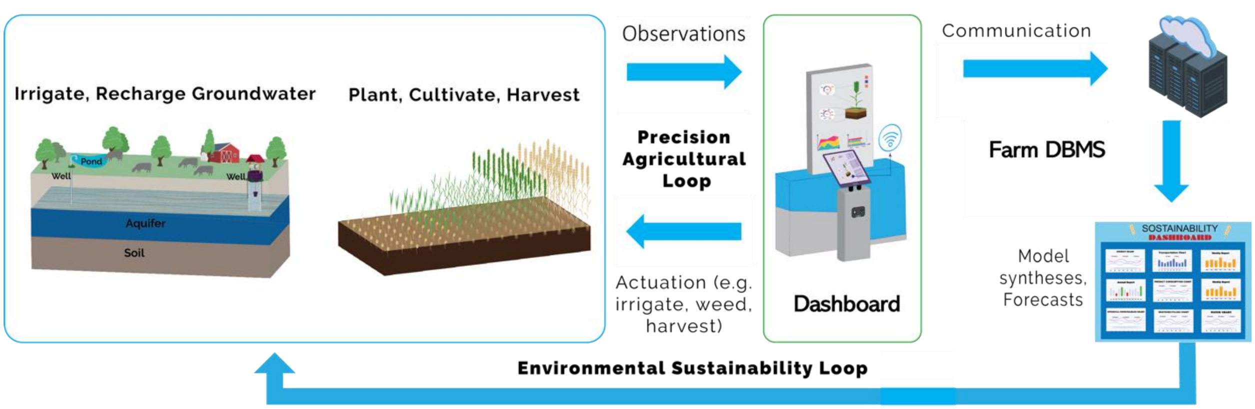

Figure A-3- Illustration of monitoring, modeling, and management technology for an agricultural managed aquifer recharge (AgMAR) system, showing optimization of short-term (irrigation event) and long-term (aquifer recharge event) operations.

Hypothesis/Expected Outcomes

- The proposed research will explore current approaches and develop new strategies for AgMAR monitoring and management in California and Mexico.

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2. Case Study B: *Aguascalientes Valley Aquifer in Aguascalientes, Mexico*
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Introduction

Administratively, Mexico's groundwater is divided between 653 aquifers, where 105 of them are overexploited (National Water Commission [CONAGUA], 2018). One of these is the Aguascalientes Valley aquifer (Figure), located in Aguascalientes State, which supplies as much as 94% of the state's total water demand (Hernández-Marín et al., 2018). This is due to the semi-arid climate that prevails in the region, resulting in few natural surface water bodies. The mean yearly rainfall in the area is 510 mm with a yearly potential evaporation of 2,010 mm. The average temperature falls between 18 and 22 °C, and summer rains are present during the months of May-October, with the greatest incidence of rainfall occurring in the months of July and August (CONAGUA, 2020).

Aguascalientes Valley is the location of the state's capital city (Aguascalientes City), as well as other important urban centers. The state has a population of close to 1.5 million inhabitants, with about 60% of this total living in the capital (INEGI, 2021), and 95% of its economic activities are carried out within the valley limits (Sainz-Santamaria & Martinez-Cruz, 2019).

The region in which the aquifer is located is defined by important regional geological structures. It is within the Aguascalientes Graben, flanked by normal faults that run north to south (CONAGUA, 2020). However, the stratigraphy of the graben is not well-defined, as it is described mostly by lithological correlations and few reliable dating analyses. The drilling logs that are available show that the aquifer is composed by a sequence of sediments of sand and gravel, with a few intercalations of silt and clay (Pacheco-Martínez et al., 2013). On the other hand, the Mexican Geological Service (SGM) defines the general geology of the area by a large mass of alluvial material, with conglomerates and tuffs making up the southernmost part of the aquifer (SGM, 2005).

The aquifer system itself is mainly unconfined (a water table type aquifer), but exhibits confined aquifer hydraulic behavior in a few locations (Hernández-Marín et al., 2018). It extends over an area of 3,129 km2. The aquifer flows from north to south (CONAGUA, 2020), with the piezometric levels from various years confirming this (CONAGUA, unpublished data, 2015). These levels have been declining quite significantly in the last couple of decades, primarily due to the excessive pumping needed to meet the growing demand for water resources for agriculture, municipal, and industrial consumption (Pacheco-Martínez et al., 2013). Data from 2020 show that in the region of the aquifer, there are 1,468 active wells, extracting an estimated volume of 348 million m^3/year. However, natural recharge happens only at a roughly 250 million m^3 a year, indicating a serious overdraft of almost 100 millions of m^3/year at the cost of the aquifer's non-renewable storage (CONAGUA, 2020).

The Aguascalientes Valley aquifer has been the subject of much research throughout the years, due to its importance as the primary water resource of the region. The current work is an attempt to mathematically model its behavior, using the MODFLOW code (Harbaugh, 2005). This model is being carried out on the ModelMuse program (Winston, 2022), which facilitates the use of ASCII raster files as input data. Having a mathematical model of this overdrafted aquifer will allow faster and more reliable analyses on the implementation of MAR to this study case.

Objectives

- Define groundwater modeling parameters using mathematical model configurations.
- Define input data referring to the natural and anthropogenic movements in the groundwater flows
- Finalize model calibration process to determine the hydraulic conductivities and specific storage to slow the simulated flows through the aquifer

Hypothesis/Expected Outcomes

- Calibrate the groundwater model for use of the case study.