Maximizing on-farm groundwater recharge with surface reservoir releases: a planning approach and case study in California, USA

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1) Background

Excessive groundwater extraction
↓
Geological disaster (groundwater level decrease)
↓
Sustainable resource management
↓
Managed Aquifer Recharge

Previous work:

Niswonger et al. (2017) examined potential benefits **from Agriculture MAR (Ag-MAR)** for a hypothetical groundwater sub-basin in the semi-arid western USA.

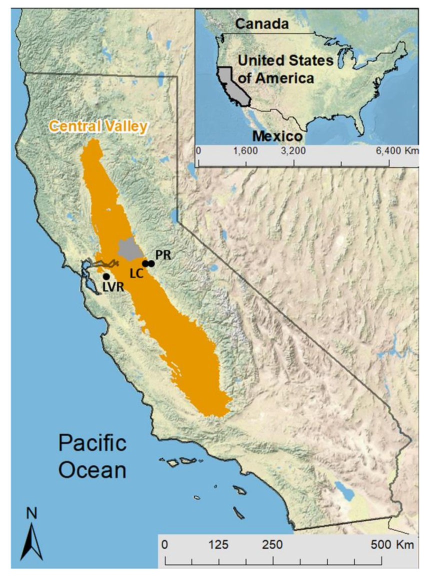
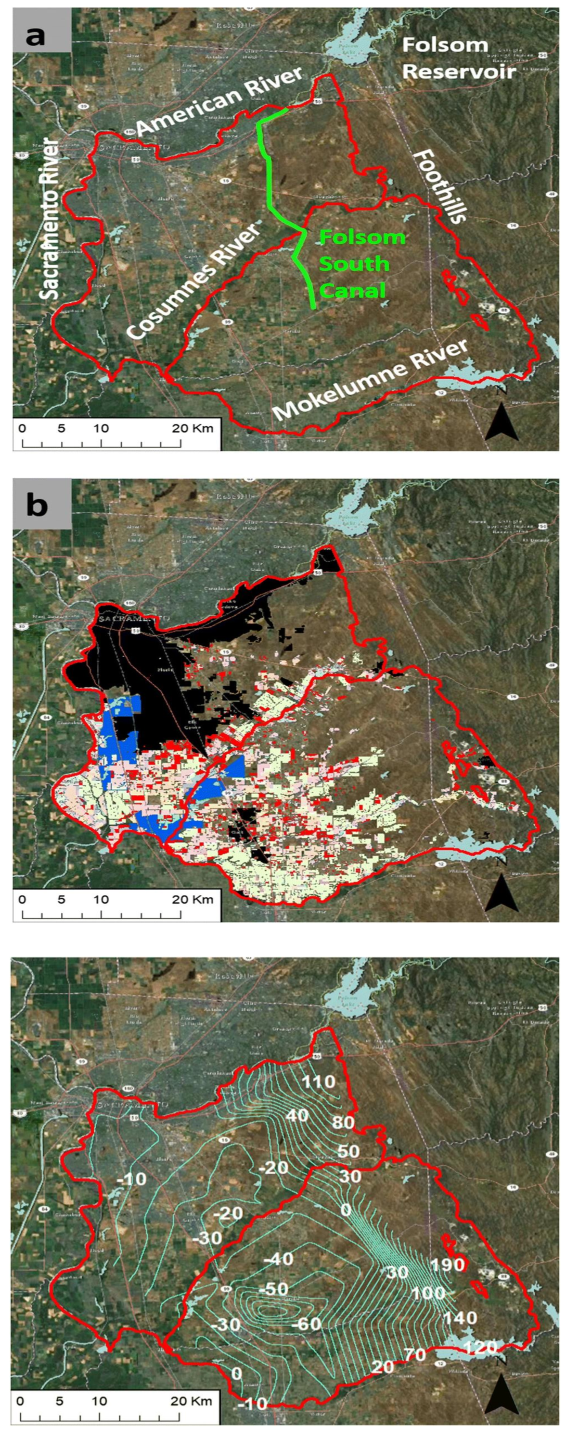


Fig1. Study area in USA.

This work addresses planning-level analysis of **Ag-MAR** expanding on previous work by including:
(1) Consideration of recharge water from reservoir reoperation,
(2) Evaluation of recharge water sourcing, cropland characteristics and groundwater hydrology for a **site-specific** setting
(3) Demonstrating a **hydro-economic** optimization approach that simulates separate decisions for land access and water delivery in the performance of Ag-MAR.

2) Study area



- The regional-scale analysis is conducted for a **semi-arid** part of California, USA. (Fig 1)
- **Scale: 525,000 arec** with urban, **agricultural (27%)**, wetland and undeveloped rangeland. **41% of agricultural** acreage planted **vineyards and orchards.**
- **90%** of total water supply in this area is from **Groundwater.**
- The spatial distribution of recent water levels indicates localized **depressions from extractions far exceeding** groundwater recharge.
- Groundwater levels have dropped as much as **20m** over the past several decades.
- Using of on-farm recharge alone could achieve a potentially significant amount of aquifer recharge using some of the 140,000 ac (57,000 ha) of croplands in the study area.

3) Methods of analysis

Identifying recharge application schedules

- Based on an Ag-MAR recharge program
- Using hydro-economic formulation, which develops from initial hydrological formulation.
- ***Hydro-economic formulation***: combining elements of recharge basin and groundwater hydraulics with economic considerations at a regional scale.
- Decomposing formulation into a two-part linear programming formulation and solving them by iteration.

Simulating recharge application and evaluating groundwater system

- Recharge volume schedules are calculated after solution of the linear programming model
- Evaluate changes in groundwater storage and stream flow relative to a base case of no recharge operations.

4) Results

Data development and preliminary analys

- Water available for recharge
- surface-water storage capacity
- infiltration rates
- Crop categories

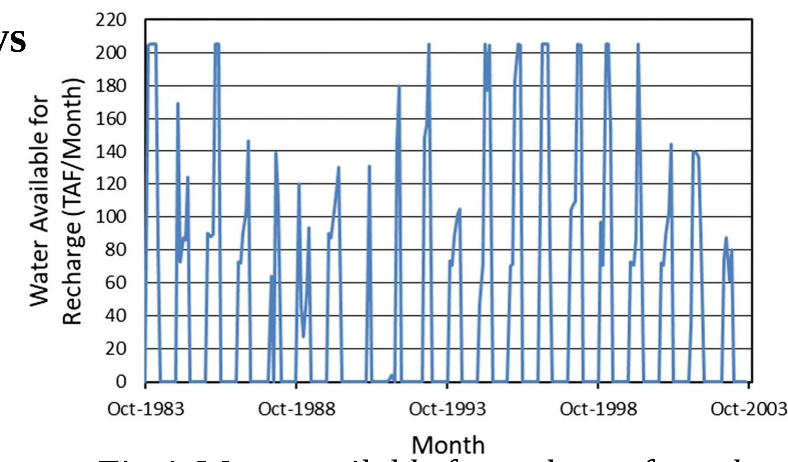
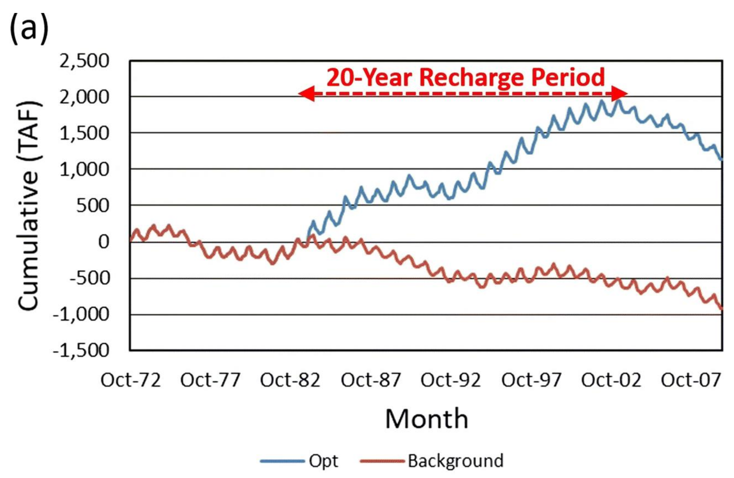


Fig 4. Water available for recharge from the reoperation of the reservoir

Potentially achievable recharge

The distribution of recharge volume

- Increased groundwater storage: 2419 TAF ,62%
- Discharge to surface water: 718 TAF, 18%
- Flow to other sub-basins: 764 TAF, 20%



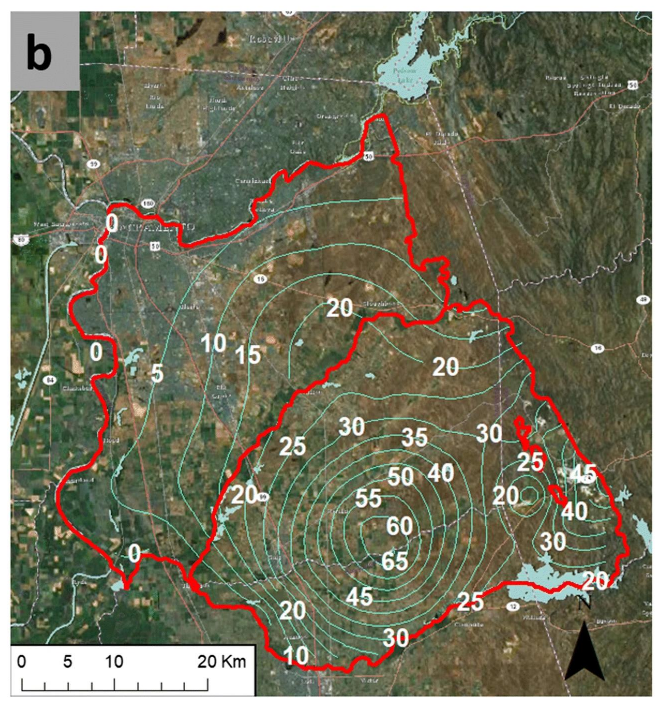


Fig5. The increase in groundwater storage (a) and spatial distribution of elevation (b) increases from recharge using all of the cropland (high level of funding)

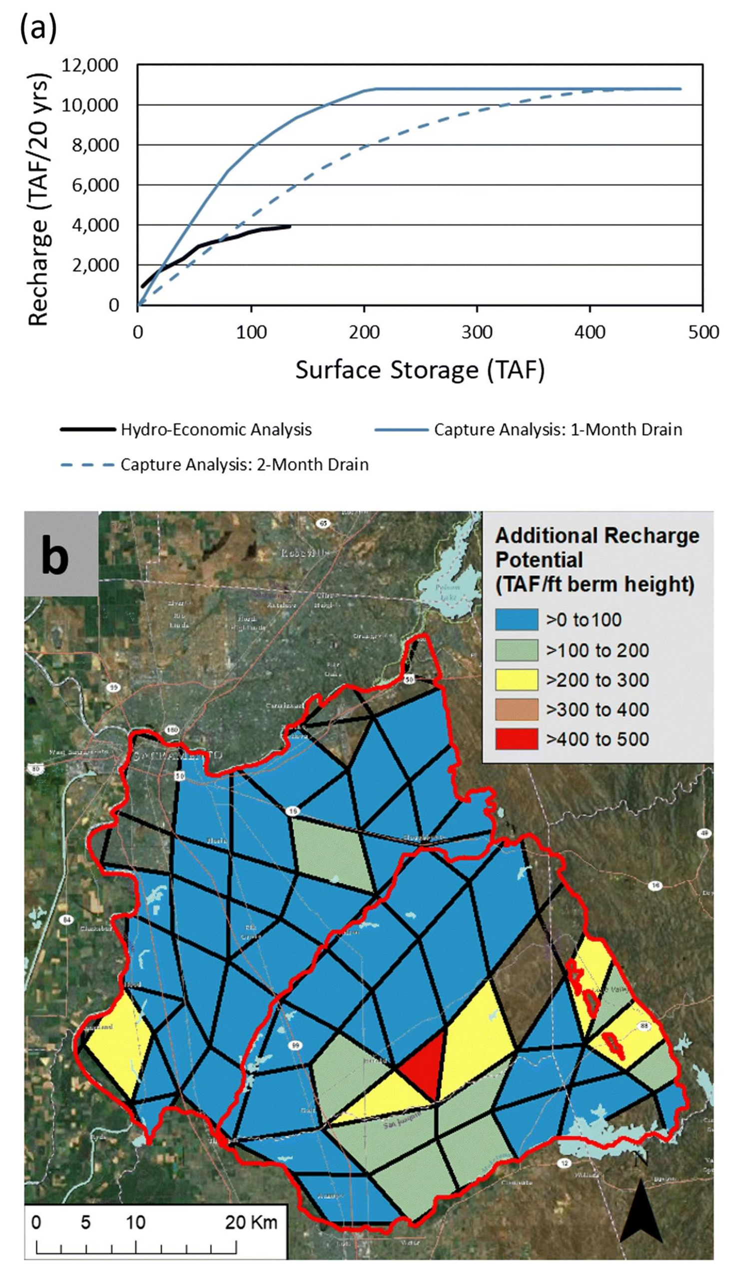


*Fig. 6 Effect of spatial variation in infiltration rate on recharge volume potential: a capture curves and b Lagrange multipliers (after changing **berm heights**)*

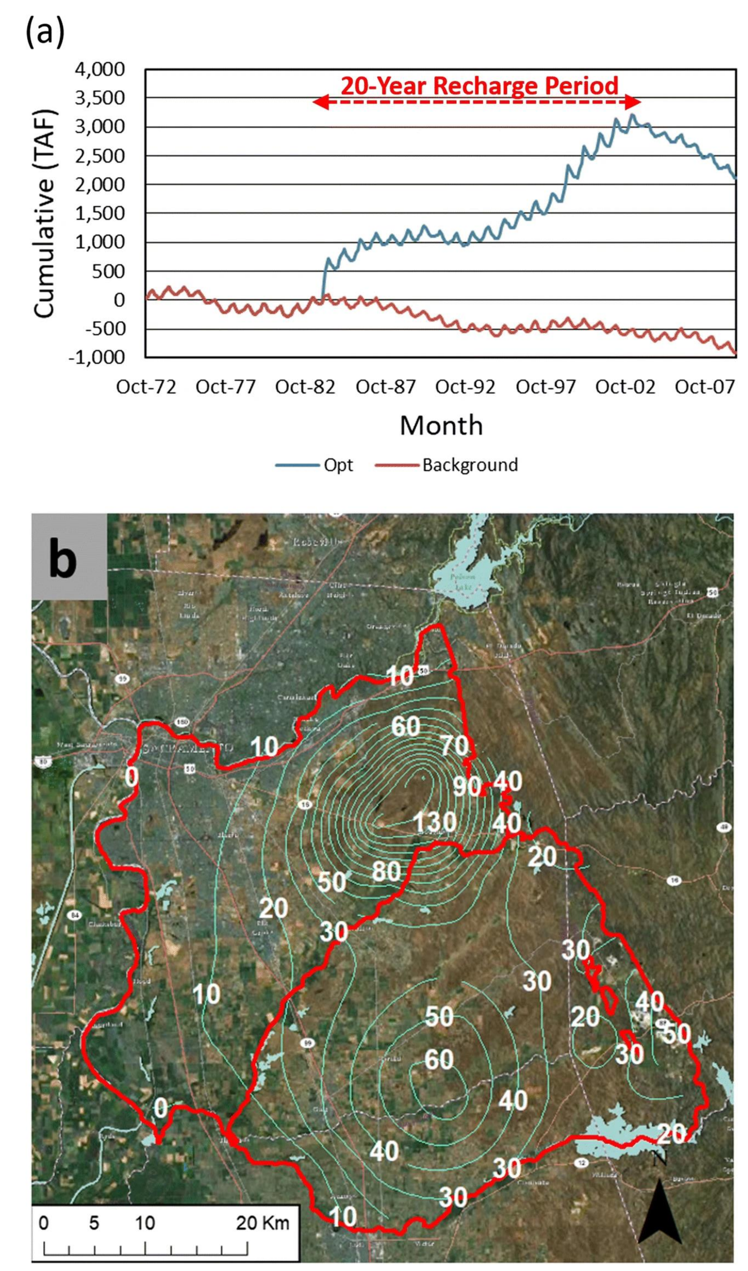


*Fig. 7 Increase in groundwater storage using all cropland and repurposed **gravel pits** in north: a storage accumulation over time and b spatial distribution of elevation increases.*

5) Conclusions and extensions

- Using all of the **134,000 ac** of cropland modeled in the study area would have allowed approximately **3900 TAF of recharge** over the 20-year period considered.
- **Limits** to recharge effectiveness are expected from
  (1) Temporal variability in recharge water availability
  (2) Variations in infiltration rate and few high-infiltration recharge sites
  (3) Recharged water escaping to surface water and adjacent sub-basins.
- These limitations might be **reduced** by
  (1)Raising berm heights on higher-infiltration-rate croplands
  (2) Creating dedicated recharge facilities over high-infiltration-rate sites.
- **Extensions** of the work could readily address related considerations such as
  (1) Financial considerations regarding investment and operations.
  (2) Measures to safeguard groundwater quality.
  (3) Support for base flow to the Cosumnes River.
  (4) Portfolios of recharge facility types and approaches.

Reference:
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