Depletion of the Southern High Plains Aquifer: Simulating the effects of irrigation water conservation practices

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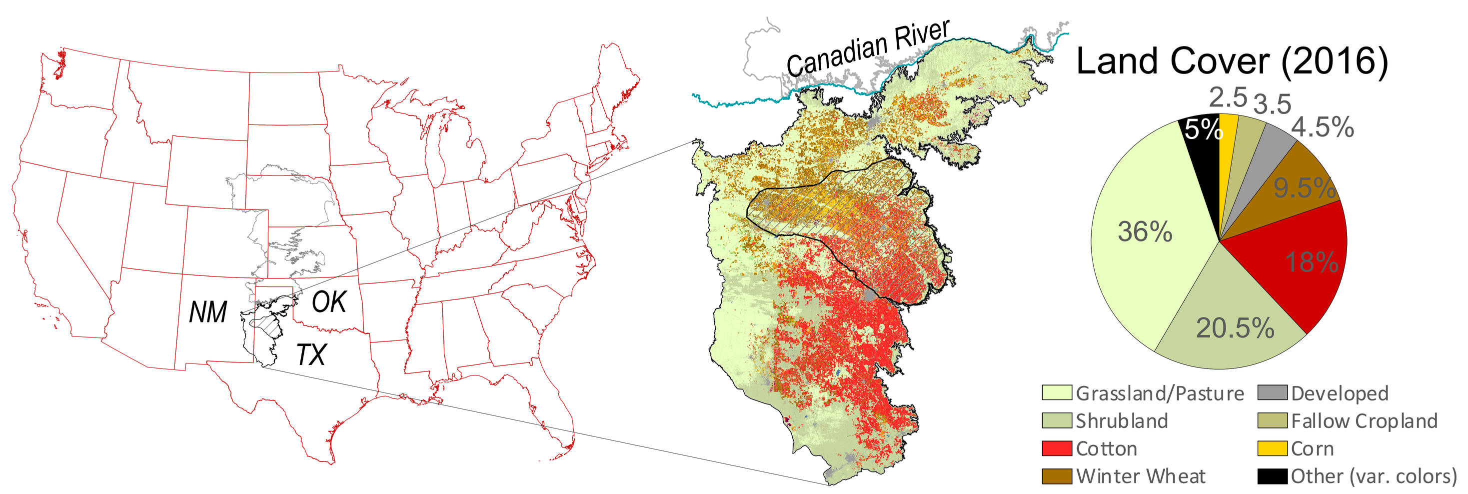
1 Rationale

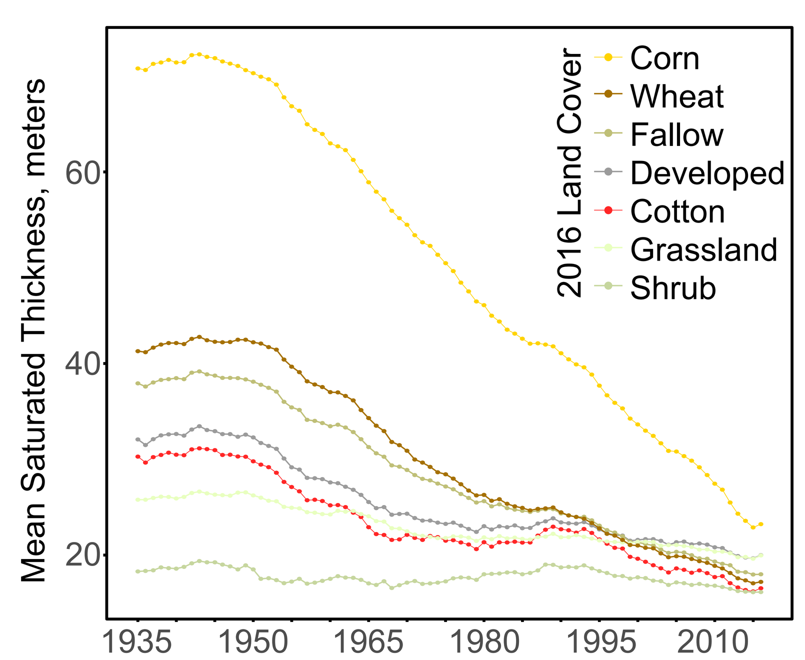
The Southern High Plains is a subregion of the High Plains Aquifer located in Texas and New Mexico. Crop irrigation, particularly for corn and cotton, is a regional anchor of the economy. About 95% of annual water use for the region is for irrigation. There are no perennial streams in this area, and the groundwater has declined substantially in the past several decades.

Water planning and conservation are essential to this region. Irrigation water can be conserved in two ways: by limiting the amount of water applied to a given field (referred to in economics as the intensive margin), or limiting the amount of irrigated land (similarly, the extensive margin).

This study focuses on the differences in the water table between water conservation through decreased application per acre versus decreased number of acres irrigated.



Groundwater in the Southern High Plains has been mined since the early 1900's. The low rate of recharge makes this an effectively unrenewable resource. What methods can help irrigators preserve water for the next generation?



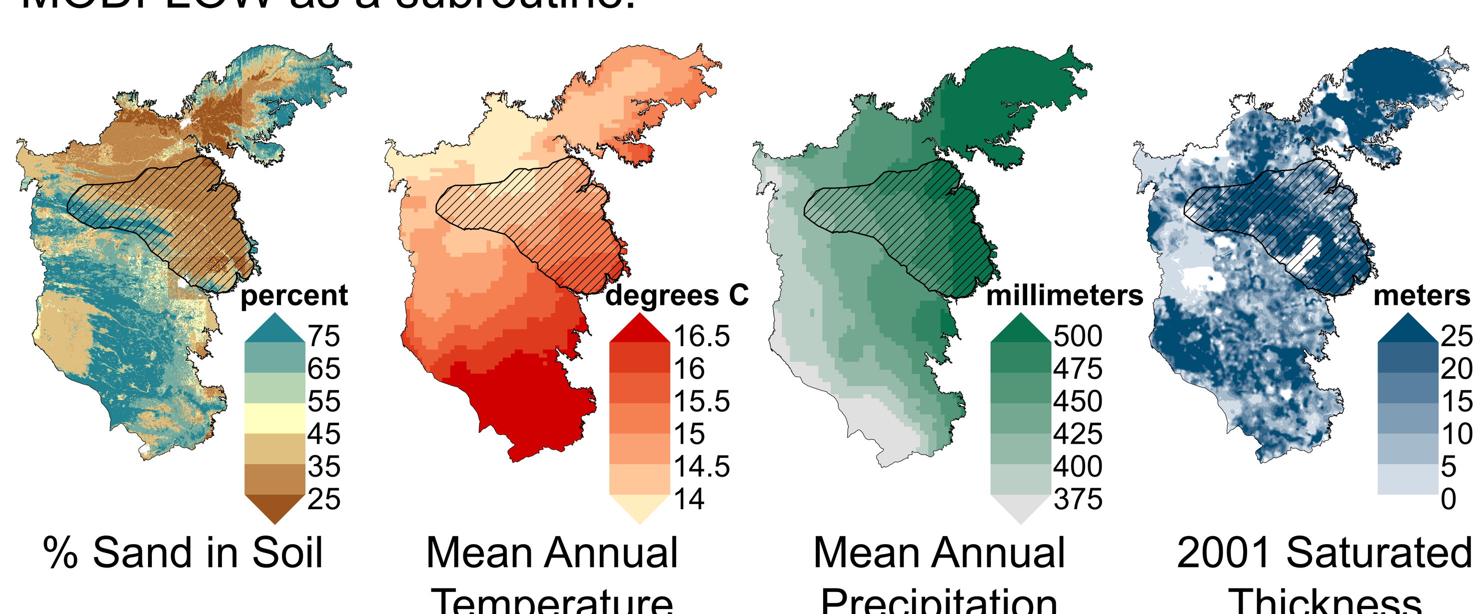
2 Methods

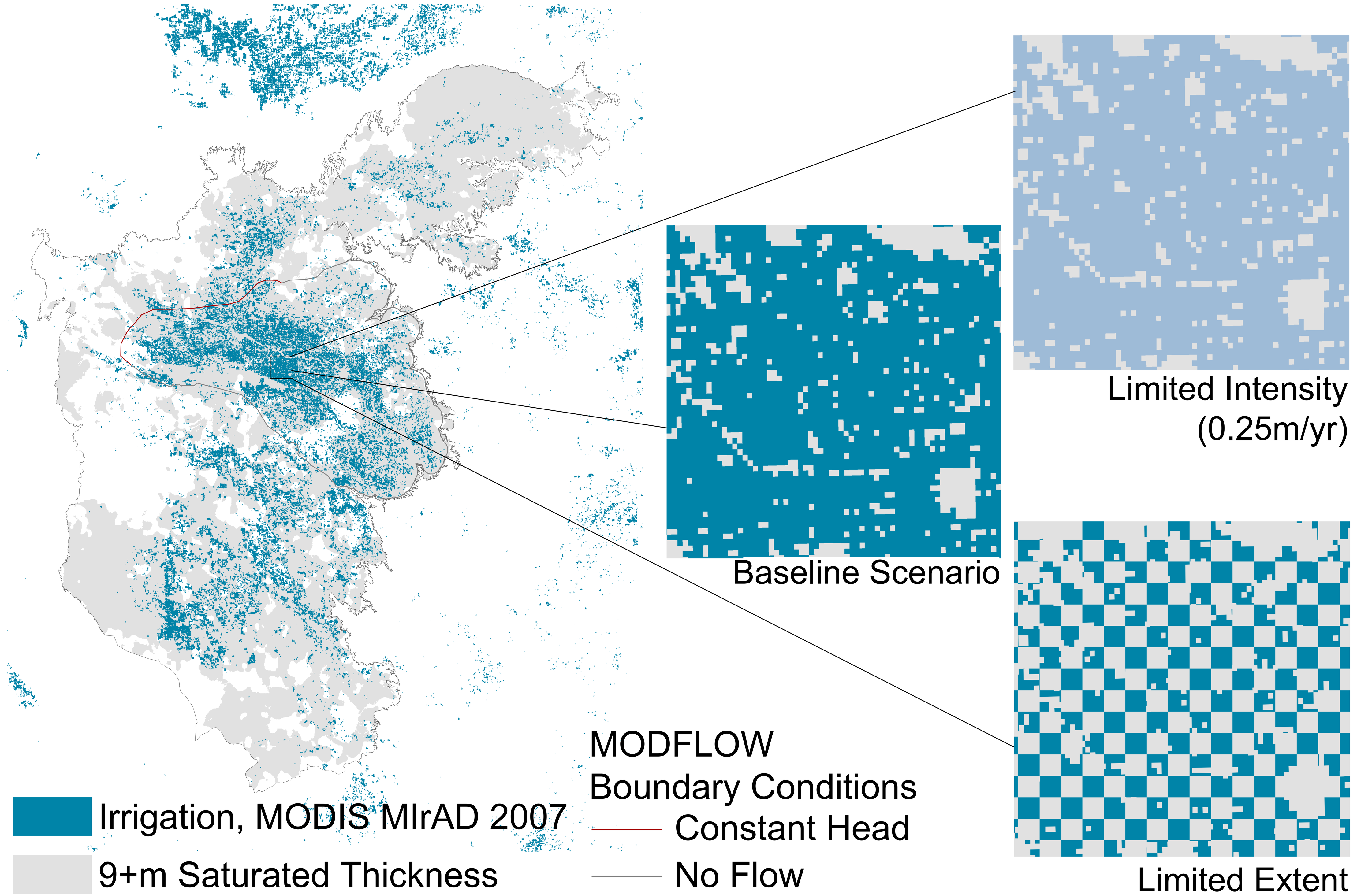
The purpose of this study was to determine whether there is a difference in the water table over time when water is conserved by limiting the intensity (depth) of irrigation water applied, as opposed to limiting the extent of irrigated land. In both of these cases, water is conserved, but each has a different effect on runoff, return flow, and crop water requirements. In order to investigate this question, a hydrologic model was developed for the study area for the years 2001-2014, using the Landscape Hydrolgoy Model (LHM). This time period was selected because all data for these years was available at the time of model construction. The MODFLOW model was run for a subset of the study area, since other parts of the Southern High Plains are not hydrologically well-connected to the main irrigated subregion.

LHM is a cell-based surface hydrology model that calculates components of the water cycle, including crop water requirements for irrigation. It calculates deep percolation and irrigation water applied, and passes these data files to the MODFLOW groundwater model in order to estimate change in water table elevation.

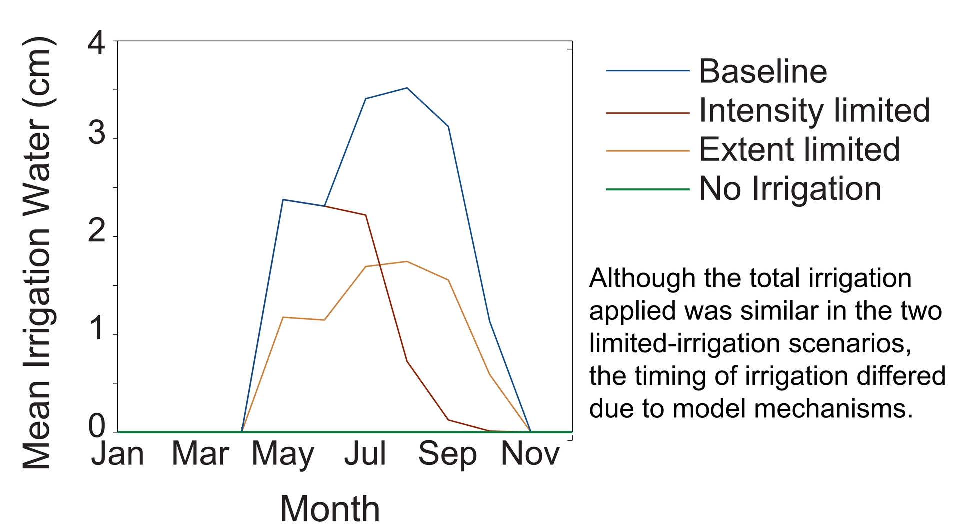
The model was run for the Southern High Plains with a 500-m cell size. Each model year takes between seven and eleven hours to run without a high-performance computing system.

The Landscape Hydrology Model (LHM) incorporates physical data such as soil properties, climate, elevation, and land cover. It runs MODFLOW as a subroutine.





3 Scenarios



Four scenarios were run:

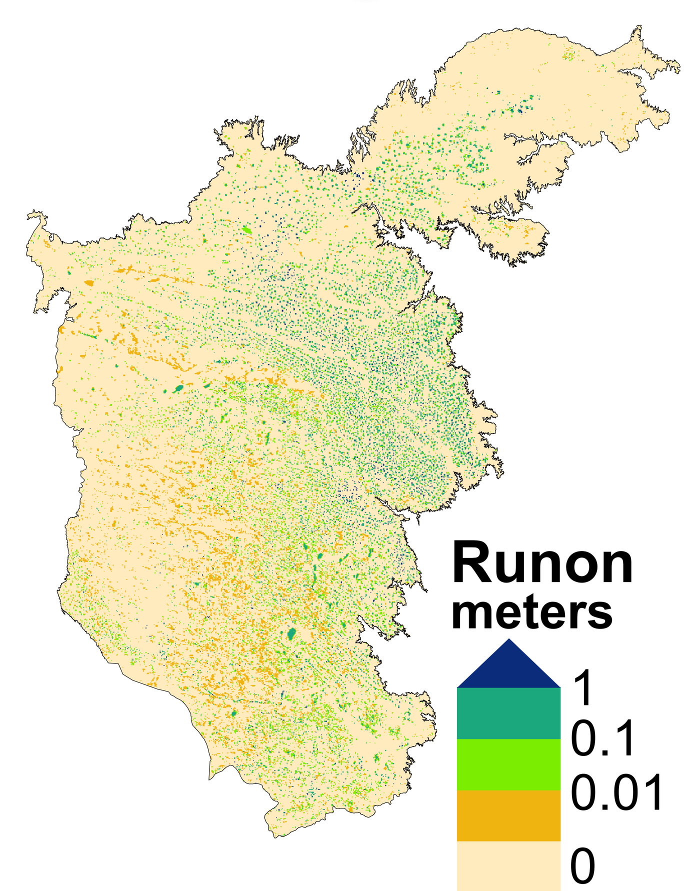
- Baseline scenario - full irrigation permitted, assuming an 800 gallon per minute (3 m³/day) well capacity
- Intensity limited - irrigation was cut off after reaching a 0.25m/yr allocation
- Extent limited - 50% of irrigated area was removed following a checkerboard pattern
- No irrigation

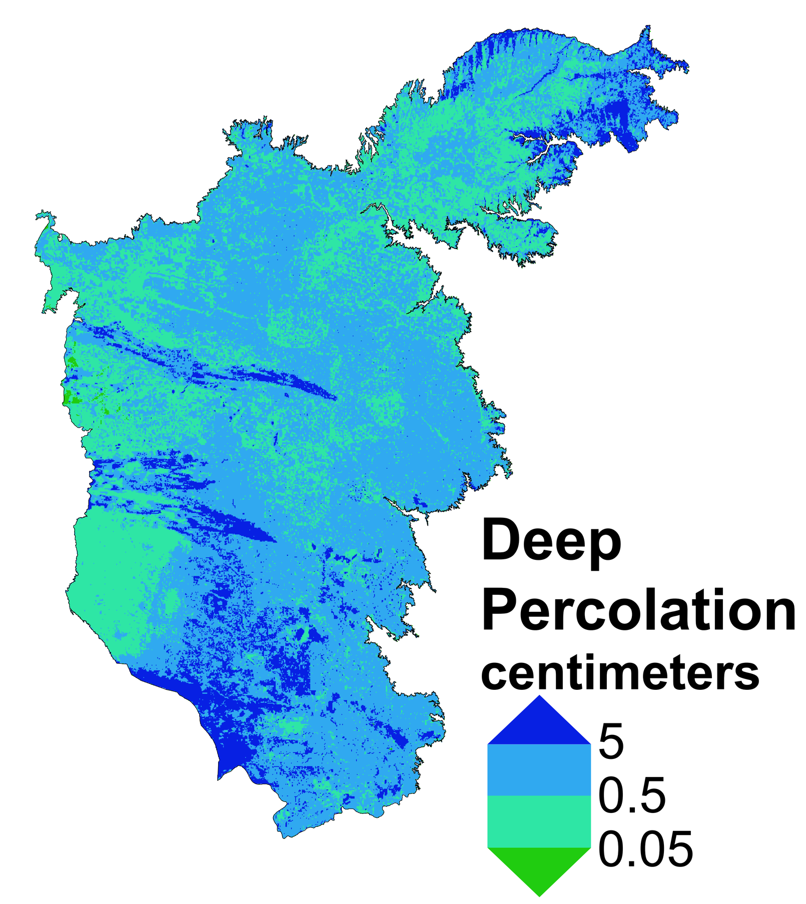
4 Results

LHM replicated the playa lake hydrology of the region, with most deep percolation occurring below local ephemeral drainage features visible in the runon map at right. More deep percolation also occurred in sandier soils.

If pumping had ceased in 2001, our 14-year simulations show that water levels in the Southern High Plains would have recovered by an average of 0.062 m/y, whereas with no pumping limits, the aquifer declined by about 0.46 m/y. This suggests that the aquifer has about a 7:1 ratio of depletion to recovery including return flow.

In the limited-irrigation scenarios, the amount of irrigable land continued to decline over time at a slower rate compared to the baseline scenario.



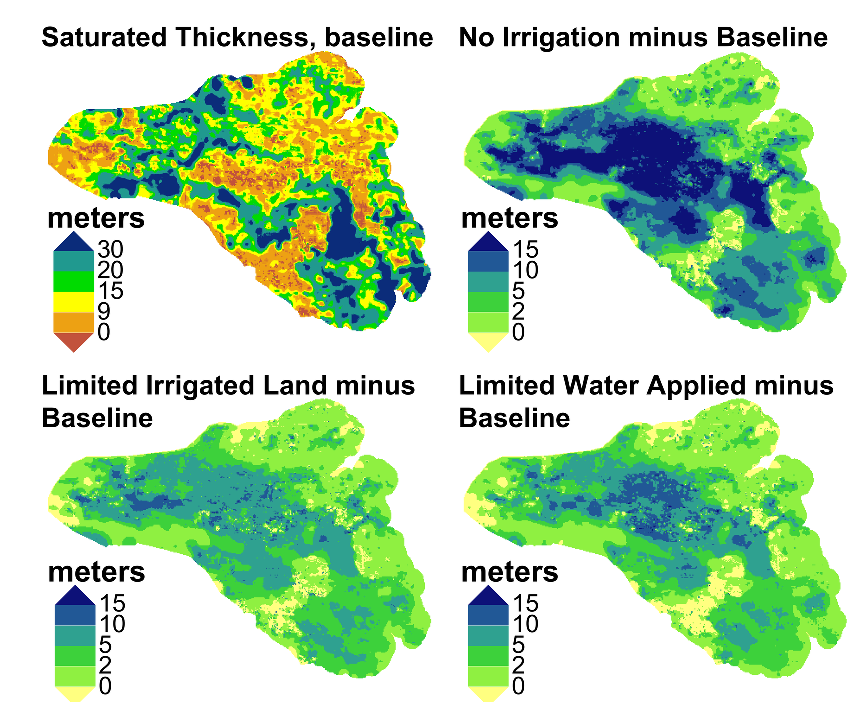


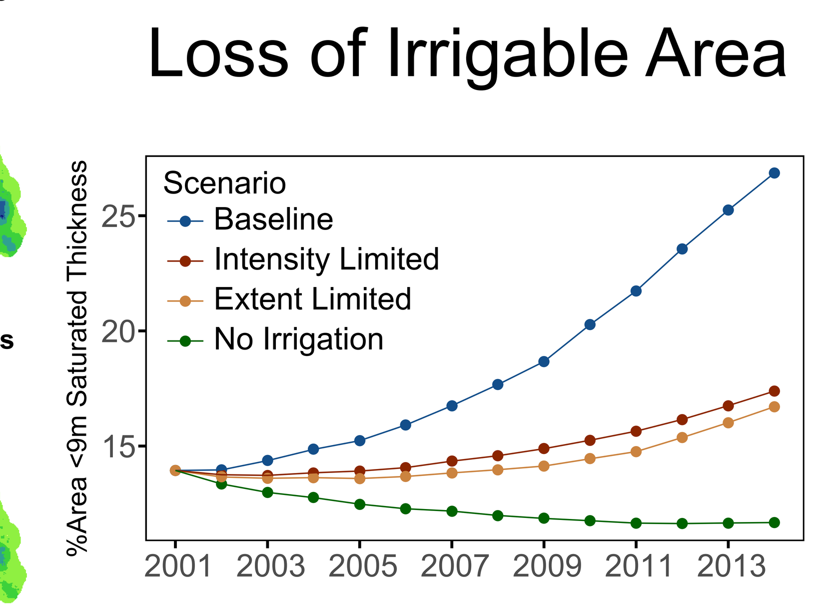
5 Discussion

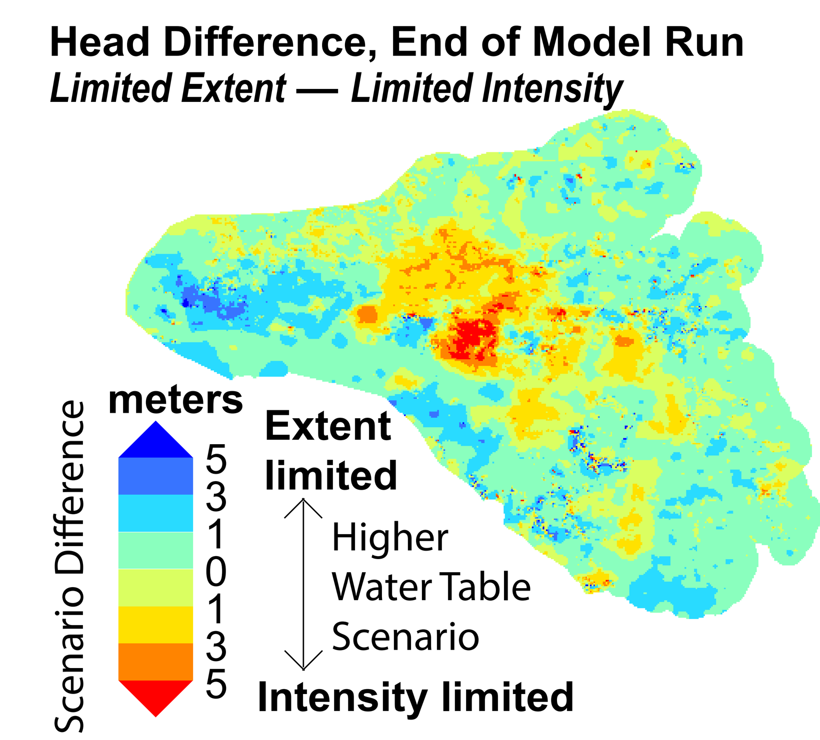
- A reduction in irrigated area was better in places where irrigated land was already fairly sparse. Limits to the extent of irrigated land improved the ability of remaining irrigated areas to adjust to drought.
- Limiting depth of irrigation water applied was favorable in areas where most of the land is under irrigation.

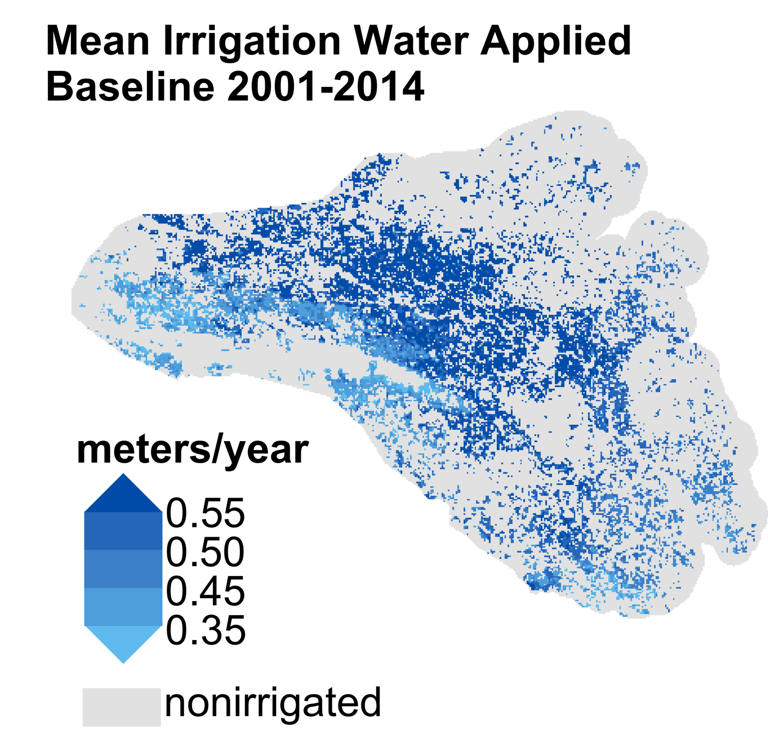
The limited irrigation scenarios mimic legal conservation initiatives that mandate minimum well spacing or encourage retirement of irrigated land (extent limitations) or water allocations (intensity limitations). However, these scenarios are not policy recommendations. Water use regulations in the High Plains are complex and politically challenging.

A 50% reduction in irrigation is too extreme for political reality, but is still insufficient to make groundwater in the Southern High Plains sustainable indefinitely.









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USDA NSF OgallalaWater.org Nebraska Water Center Daugherty Water for Food Global Institute MICHIGAN STATE UNIVERSITY