University of Texas at Austin

Assessing Water Table Change and Land Use of Select Texas Counties Overlaying the Ogallala Aquifer for Focus Area Analysis

Emma Moffat
GEO327G GIS & GPS Applications in Earth Science
Dr. Mark Helper
December 6, 2021
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Background
Underlying the Great Plains in eight states, the Ogallala supports nearly one-fifth of the wheat, corn, cotton, and cattle produced in the United States. It has long been the main water supply for the High Plains’ population and is currently being used at an unsustainable rate. It has been used since the early 1900s but pumping exponentially grew when the Ogallala region became extensively irrigated after the Second World War. Throughout much of the aquifer, groundwater withdrawals exceed the amount of recharge, and water levels have declined consistently through time. With an aquifer so extensive, conservation efforts need to target areas of high priority to reduce overexploitation of the aquifer.

Problem
The goal of this study is to determine the overexploitation susceptibility of select counties located in the Texas Panhandle. This study includes 16 counties that account for about 90% of the total groundwater withdrawals from the Ogallala Aquifer in the Texas High Plains (TWDB, 2005). This assessment could be helpful identifying possible focus areas for aquifer conservation.

The susceptibility of overexploitation can be assessed by analyzing the water table change over the past several decades as well as the current land use of the area. These data are combined into a ranked map where areas containing high water demand crops and see large decreases in the water table are the most susceptible.

This analysis can be helpful in determining focus areas for conservation. Other studies that focus on water quality as well as recharge and discharge zones could also be helpful in identifying focus areas. Efforts like this will not only save the aquifer, but it will also help the people and businesses that depend on it.

Methods
This study required water table level data, land use data, and shapefiles of the study area and the Ogallala. After data preprocessing, a reclassified land use map and water table level maps for 1960 and 2020 were created. A water table change map was then created by map algebra from the water table level maps. The water table change map was reclassified into defined ranks and combined with the reclassified land use map by map algebra into one ranked map that shows susceptibility. Each of these steps are discussed in greater depth below.
Data Collection

Water Table Level Data:
https://www.twdb.texas.gov/groundwater/data/gwdbrpt.asp
   Source: Texas Water Development Board
   Type: .csv
   Used Data: Latitude, Longitude, Water Elevation

Land Use Data:
   Source: USDA
   Type: ADRG Image (.img)
   Projection: NAD 1983 Albers Conical Equal Area

Study Area Data:
https://gis-txdot.opendata.arcgis.com/search?collection=Dataset&tags=Boundaries
   Source: Texas Department of Transportation
   Type: Shapefile
   Projection: WGS84

Aquifer Data:
https://www.twdb.texas.gov/mapping/gisdata.asp
   Source: TWDB
   Type: Shapefile
   Projection: NAD 1983

Data Processing

Data Preprocessing
Before any data preprocessing, I defined a common coordinate system. The Texas counties shapefile was originally projected as WGS84 and was reprojected to NAD 1893 to match the other data being used. The coordinate system for the land use raster was also redefined from NAD 1983 Albers Conical Equal Area to NAD 1983.

Using the Texas counties shapefile (Figure 1), I selected the 18 counties that consist of my study area and created a new shapefile. I also loaded the aquifer shapefile (Figure 2) into ArcMap, selected only the Ogallala polygons, and created another new shapefile. I then clipped the Ogallala shapefile to the study area shapefile. The clipped Ogallala shapefile and the study area shapefiles were merged into one shapefile that shows the study area with Ogallala boundaries (Figure 3).
I also used Extract by Mask (spatial analyst) with the land use raster image and the clipped Ogallala shapefile to create a new land use raster of only the study area (Figure 4).
I obtained the water table level data from the Texas Water Development Board’s groundwater database. Under the “Water Levels by County” tab, I downloaded .csv files for the counties included in the study area.

Within each county excel spreadsheet, I selected the data from the years I am interested in (Figure 5) and pasted the data in respective spreadsheets. Since the Ogallala has been a widely used water source for over a century, I wanted to be able to assess the change in the water table throughout this wide stretch of time. I chose the dates 1960 and 2020 because these dates had consistent well data for all counties included in the study area. The 1960 well data spreadsheet and the 2020 well data spreadsheet were exported as .csv files and loaded onto ArcMap.

![Figure 5: Ogallala well data for Biscoe County. The data from 1960 and 2020 is copied and pasted into respective spreadsheets.](image)

Data Processing
I started the data processing by using the Reclassify tool to change the values of the land use raster into five different ranks (Map 1). I used the 2017 State Water Plan created by the Texas Water Development Board to help me define my rankings. The Plan states that irrigation and livestock consist of 76% of the aquifer water use and 19% of the aquifer water goes to municipal use. Therefore, the high-water demand crops were given a high rank, municipal areas were given a lower rank, and areas that use very little to no water were given the lowest rank (Table 1).

For this study, all reclassified factors are not weighted and considered equal.
Reclassified Land Usage Based on Water Demand in Select Texas Counties in 2020

Map 1: Reclassified land usage based on water demand
Table 1: Ranking used for reclassified land use

<table>
<thead>
<tr>
<th>Rank</th>
<th>Water usage</th>
<th>Examples</th>
</tr>
</thead>
<tbody>
<tr>
<td>5</td>
<td>High-water demand crops and most prevalent crops</td>
<td>Cotton, corn, pasture, peanuts, alfalfa</td>
</tr>
<tr>
<td>4</td>
<td>Other most prevalent crops that require less irrigation</td>
<td>Sorghum, wheat, triticale</td>
</tr>
<tr>
<td>3</td>
<td>Other crops present in area</td>
<td>Other fruits, vegetables, legumes grown in study area</td>
</tr>
<tr>
<td>2</td>
<td>Developed areas (municipal water use)</td>
<td>Developed cities</td>
</tr>
<tr>
<td>1</td>
<td>Land that uses very little/no water from aquifer</td>
<td>Shrubland, forests, idle cropland, barren land</td>
</tr>
</tbody>
</table>

To display the well data, I first loaded the 1960 and 2020 .csv files into ArcMap. I selected “Add XY Data” under the “Files” tab in the main menu. For each .csv file, I used “LongitudeDD” as the X field and “LatitudeDD” as the Y field (Figure 8). I then converted these data into shapefiles that contain these well measurements as points. Figure 6 and 7 shows all the well points for 1960 and 2020. The difference in the number of data points between the 1960 and the 2020 dataset is due to a significant increase in well measurements over the decades.
I then used the Spline (spatial analysis) tool to convert the shapefiles to rasters (Map 2, Map 3). I based the Z value field on the “WaterElevation” attribute and the output cell size on the reclassified land use raster (Figure 9). After the rasters were created, I clipped them to the clipped Ogallala shapefile and symbolized the data by breaking it up into nine manual variables 200 feet apart. The water tables range from 2300 to 4200 feet above sea level.

Figure 9: Spline dialogue box that converts the well data shapefiles to rasters
Map 2: 1960 water table calculation
Map 3: 2020 water table calculation
To visualize the water table level change over the past 60 years, I used the raster calculator (spatial analysis) tool. The calculation seen in Figure 10 was used to create Map 4. I symbolized it such that red represents in a water table decrease and blue represents a water table increase.

*Figure 10: Raster calculator dialogue box used to calculate water table change*
Map 4: Water Table Change from 1960 to 2020
I then used the Reclassify tool to reclassify the water table change raster into 5 different ranks of equal intervals to create Map 5.

Map 5: Reclassified Water Table Change
Finally, I used the raster calculator shown in Figure 11 to combine both reclassified maps to create the final map shown (Map 6).

*Figure 11: Raster calculator dialogue box used to calculate water table change*
Analysis of Exploitation Susceptibility of the Ogallala Aquifer in Select Texas Counties

Legend
- Ogallala
- County Boundaries

Susceptibility
- 2 (least)
- 3
- 4
- 5
- 6
- 7
- 8
- 9
- 10 (most)

Map 6: Exploitation Susceptibility Analysis Map
Conclusion
Map 1 shows that most of the study area is covered with high-water demand crops, except for the City of Lubbock and uninhabited land in the west. When both ranked rasters are combined into one map, we can see that the land to the west and the City of Lubbock is less susceptible to exploitation, but susceptibility increases outside the city where land is used for irrigation.

Based on the statistics of the raster from Map 4, the water table dropped by an average of 56.64 feet, which is roughly 11.33 inches a year. The Texas Water Development Board states that the average aquifer thickness under the Texas Panhandle is 95 feet, meaning that the aquifer will be dry in a century if current rates of pumping continue.

This analysis can be helpful in determining focus areas for conservation. Other studies that focus on water quality as well as recharge and discharge zones could also be helpful in identifying focus areas. Efforts like this will not only save the aquifer, but it will also help the people and businesses that depend on it.
References

