Elevated Nitrate Concentrations above the Southern High Plains Aquifer:

Determining areas for testing and remediation

Background Information

Nitrate (NO_3) concentrations within the High Plains (Ogallala) Aquifer (see Figure 1) system have increased alarmingly as the number of large farms and concentrated animal feeding operations (CAFOs) has increased since the 1950s agricultural boom. The constant addition of nitrogen from fertilizers and animal waste has elevated the nitrate levels of many rural areas above the Environmental Protection Agency's Maximum Contaminant Level (MCL) of 44 mg/L. Gurdak (2006) estimates that 21.1 percent of the land overlying the High Plains aquifer has relatively high (greater than 60 percent) predicted probability of reaching nitrate contamination greater than 4 mg/l.

Figure 1

Nitrate contamination it is the primary cause of infantile methemoglobinemia (Blue Baby Syndrome) and is a serious public health concern for the agricultural regions of the Midwestern United States. While public municipal drinking water is heavily regulated and tested to ensure contamination levels are below the MCL, private wells in rural, agricultural areas which are unregulated and closer to the source of contamination, experience elevated NO_3^- levels more frequently.

Data measuring contamination levels in wells since the 1950s agricultural shows a strong positive trend between nitrate concentrations and the percentage of land used for farming within the area overlying the aquifer boundary (Scanlon, Reedy et al., 2008). In fact, while the median Nitrate-Nitrogen (NO_3^-—N) concentration below natural ecosystems of the Southern High Plains was measured to be 7.2 mg/L, concentrations reached nearly ten times as much under irrigated agroecosystems at 71 mg/L (Scanlon, Gates et al., 2010). The nitrogen not consumed by plants is oxidized to form soluble nitrate, which if mobilized by increased rainfall or artificial recharge by irrigation, moves downward toward the underlying Ogallala Aquifer (Scanlon, Reedy et al., 2008).

While recharge rates tend to be low throughout the High Plains, much attention has concentrated on focused recharge within the approximately 25,000 playas of the High Plains. A recent literature review funded by the USGS and the Playa Lakes Joint Venture concluded that "recharge rates beneath playas are substantially (1 to 2 orders of magnitude higher) than recharge in interplaya settings" due to desiccation and root tubule cracks in the clay bed (Gurdak et al. 2009).

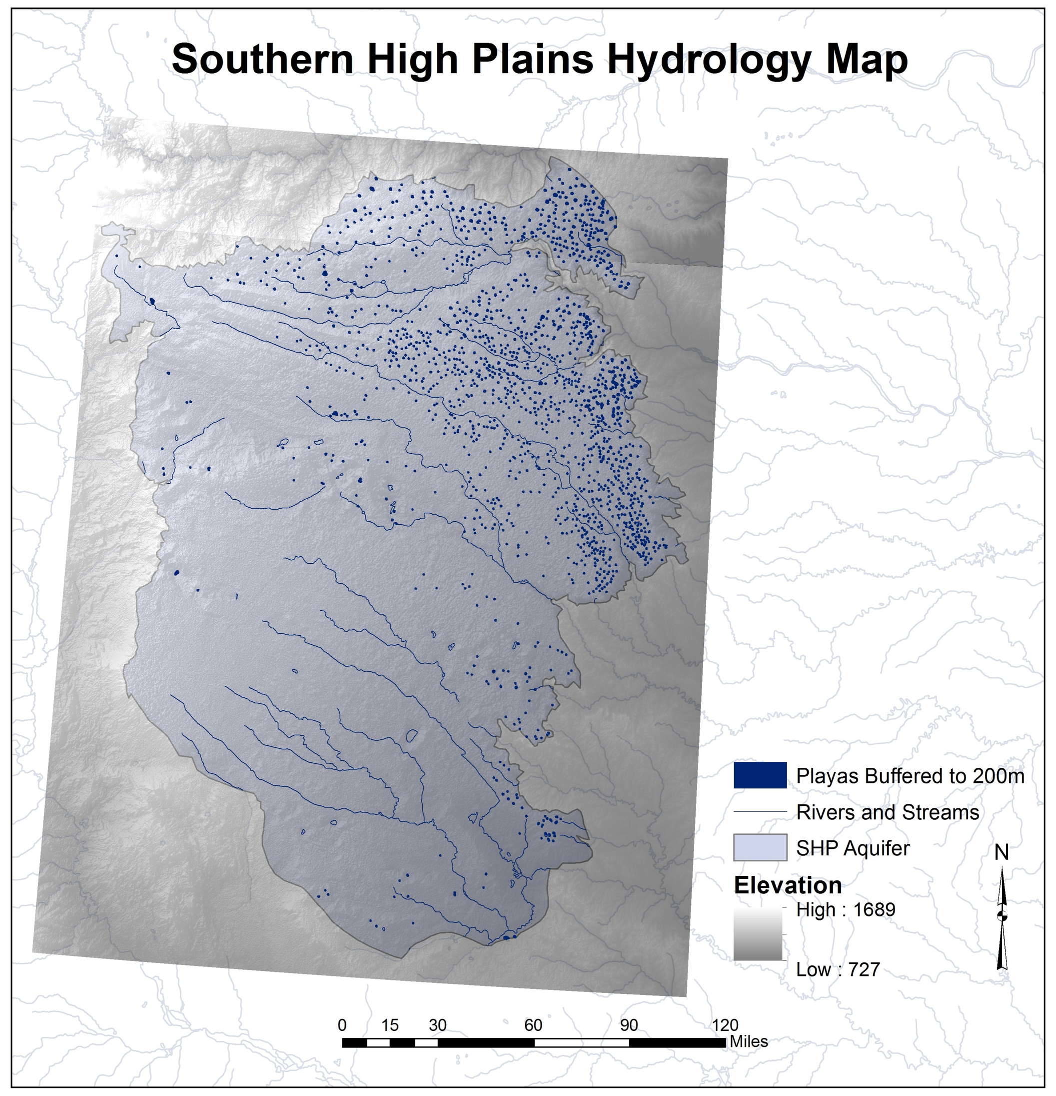
Groundwater quality will continue to decline in future years as high concentrations continue to move into deeper wells across the High Plains. Due to the variability in the hydrogeology and the vast geographic extent of the aquifer as well as the variability in pumping rates and nitrogen inputs, more detailed analyses of the aquifer boundary must be performed to obtain a more reasonable estimation of the increases in nitrate concentration over time and the areas of the High Plains that are currently in the greatest danger of high nitrate concentration.

Introduction

This project seeks to identify the areas of the Southern High Plains (SHP) Aquifer which are most critical for further evaluation, testing and remediation of NO_3^- concentration. The model will take in to account four major contributing criteria for evaluation:

- The magnitude of NO_3^- application will be included based on the percent of land treated with fertilizers and the number of cattle per square acre (see Figures 3 and 4 below)
- The presence of playas will be included in the model as concerning areas for evaluation due to their significant impact on regional groundwater recharge (see Figure 2 below)
- The impacts of mobilization of contaminants due to increased soil moisture (as well as increased probability of fertilization) by the percent of land that is irrigated, a satellite image of irrigated land area and the water level change in the aquifer since predevelopment (see Figure 5 below).
- Finally in order to account for the increased findings of elevated NO_3^- levels in rural wells and the regulation of water quality for municipal water supplies, the percentage of residents living in rural areas, the population per square area and a buffered shapefile of urban areas will also be included (see Figures 6 and 7 Below).

Figure 2



Methods

Information from the US Census Bureau and the USDA Agricultural Census for each category discussed in the introduction was joined to a map of the counties within the Southern High Plains Aquifer boundary and compared to other imported layers of playas, elevation data, and irrigation areas by satellite. These maps for comparison can be seen in the surrounding figures. Next, all relevant layers were converted to raster format and reclassified. Finally, a weighted overlay of each reclassified raster was performed. Weighting values for each layer can be seen in the table below.

Category	Criteria	Weight for Overlay(%)
Nitrogen Input	Cattle Per Acre	10
	Percent of Land Treated by Fertilizers	25
Natural Setting Impact	Buffered Playas (200 m buffer)	20
Irrigation Impact	Percent of Land Irrigated	13
	Irrigated Area (Satellite Raster)	12
	Water Level Change	5
Human Consideration for Drinking Water	Buffered Cities (3 km buffer)	5
	Population Per Square Mile	5
	Percent of Residents in Rural Settings	5

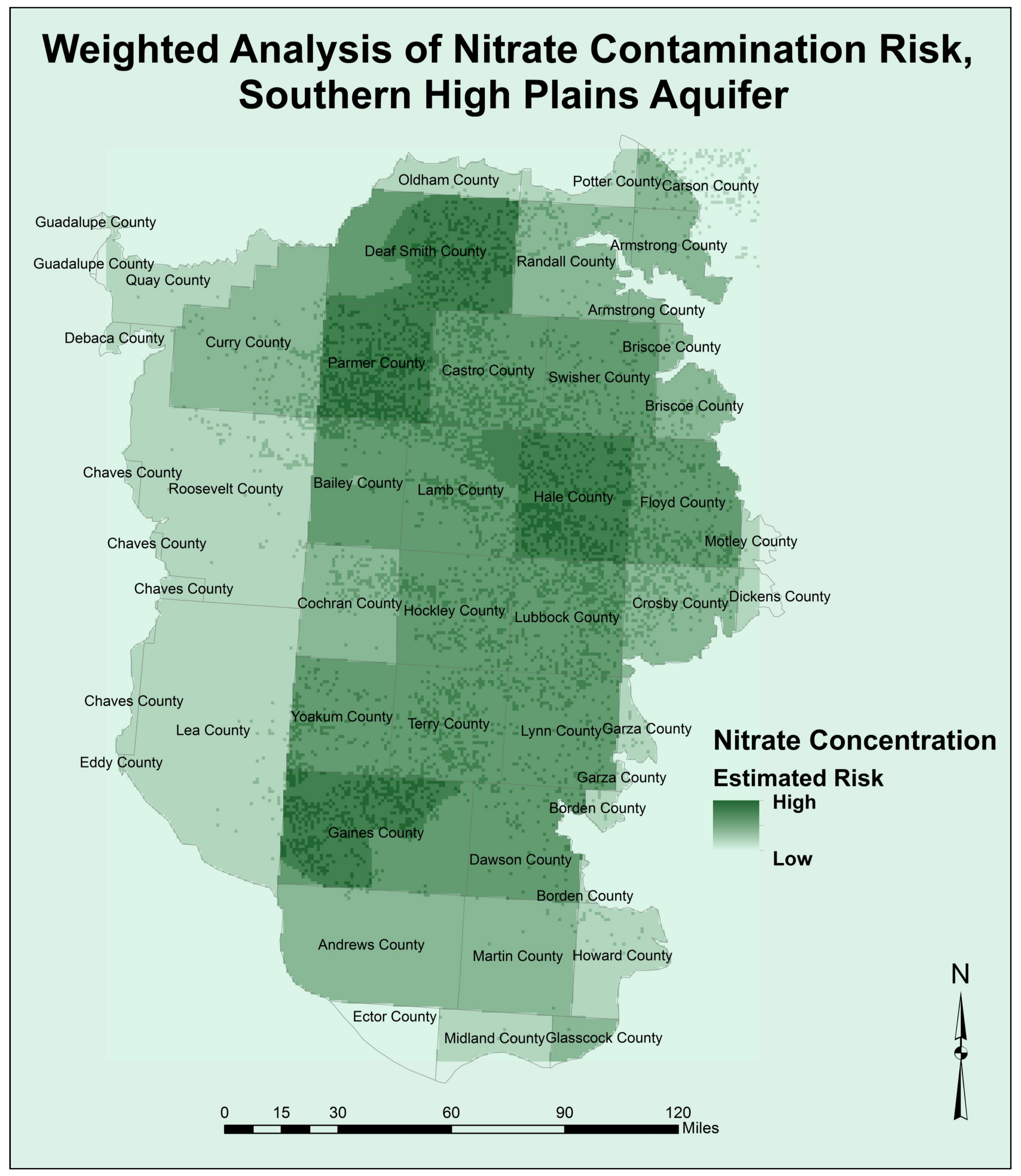
Results

The map generated from the weighted overlay can be seen in the figure at right. The result shows highest probable need for testing and remediation in Deaf Smith and Parmer Counties in the northern area of the aquifer boundary, Hale County in the center and Gaines County in the south. From the Southern Plains Hydrology figure it is clear that playa concentration is highest in the northern section of the boundary. Areas of high cattle production tend to be more concentrated in the north, while the percent of land used for farming seems to be more evenly distributed, with two higher areas in the north and south, mirroring the result of nitrate concentration.

Conclusions

The result of this spatial analysis can be used to address the concerning areas of elevated nitrate contamination in the SHP. The model can be used to consider the most critical areas for field testing of local wells. Once identified, the areas with highest concentrations can be remediated using conventional techniques such as ion exchange, biodenitrification, and reversed osmosis depending on the location and size of the contaminated site. In addition to the treatment of nitrate for public and private drinking water, more stringent state and national regulations of nitrogen use per acre must be established to limit the increases in nitrogen addition on farming lands. Models such as this may be used to help such a process.

While it is clear from this model which counties and even the areas within them to some extent are most necessary to test and remediate, the lack of high resolution data however, limited the result to this broad scope. A comprehensive map of measured nitrate concentrations in wells would be extremely beneficial to the success of this model. Additionally, higher resolution data for CAFOs and land used for agriculture rather than county based data would allow for a more accurate final weighted overlay.



Cartographer: John Gill - Spring 2012

Sources

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Figure 3

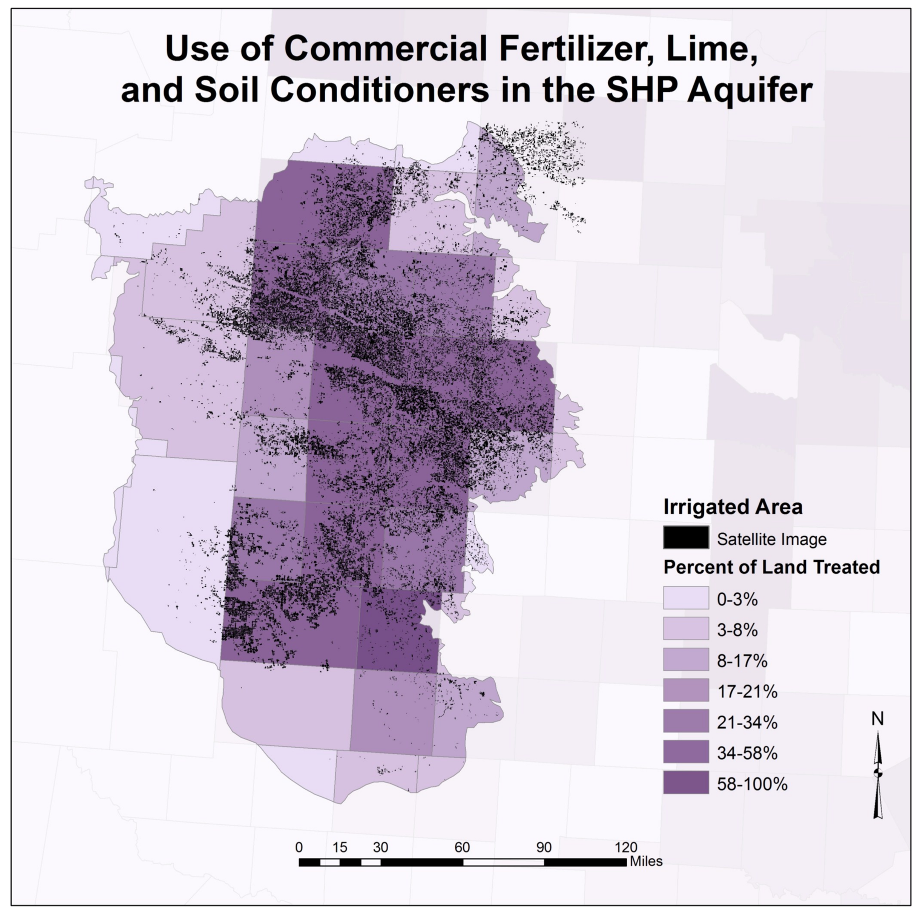

Figure 4

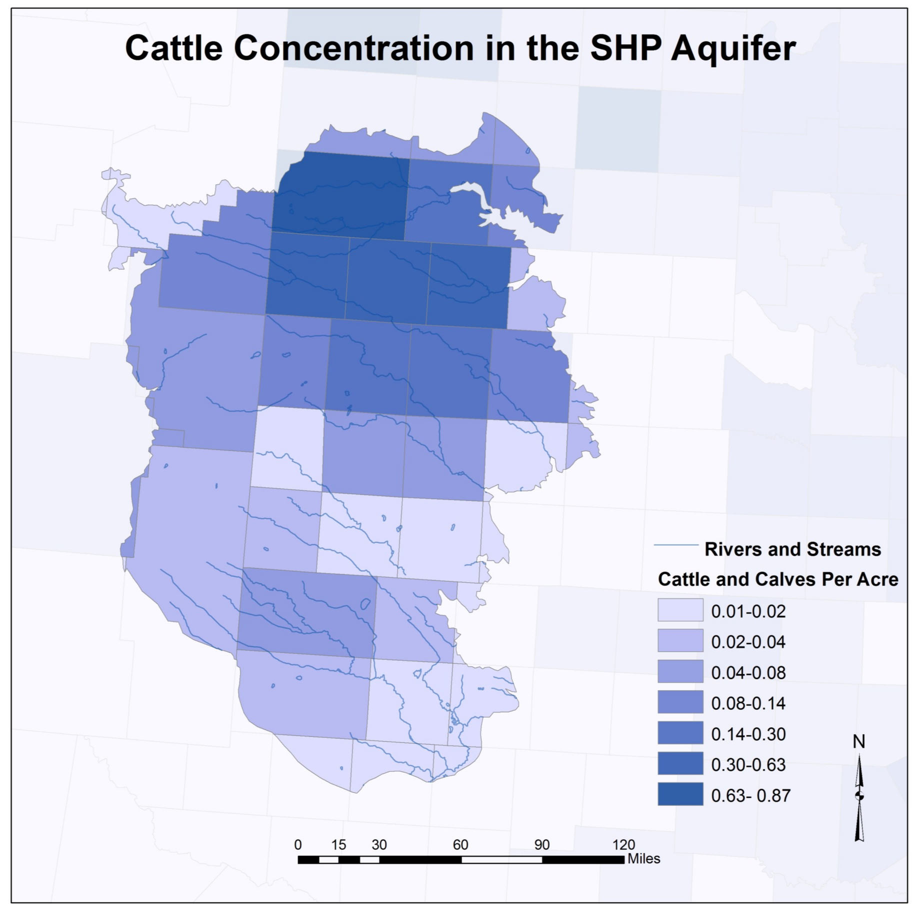

Figure 5

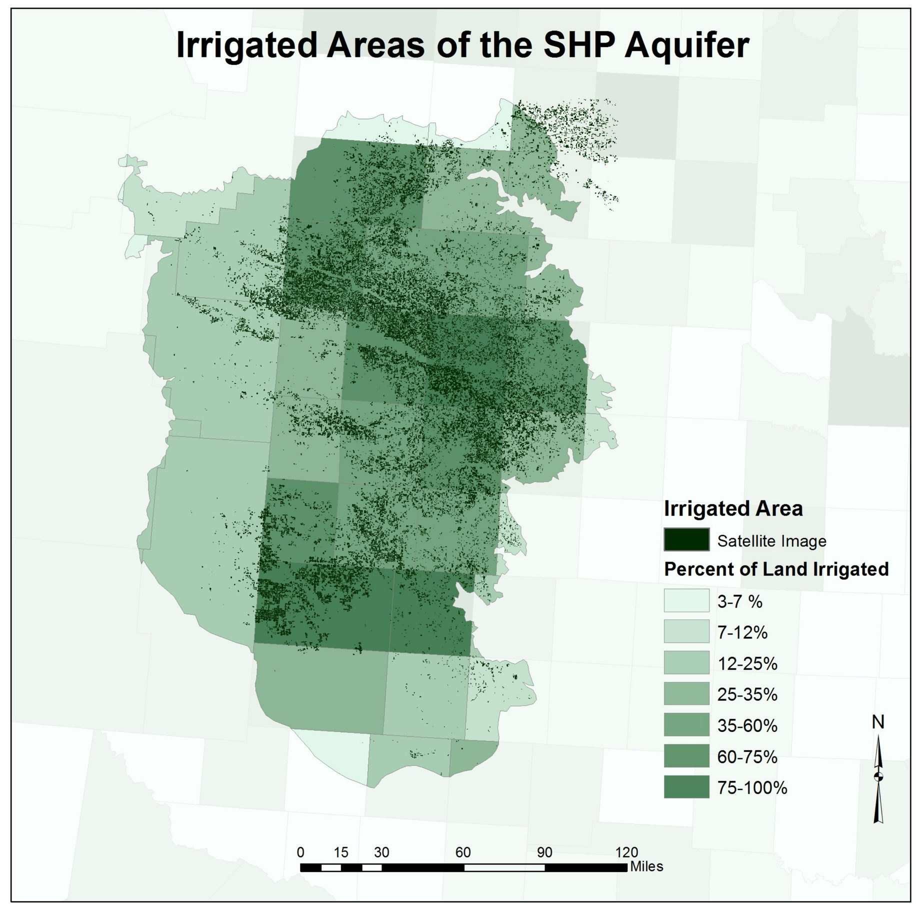

Figure 6

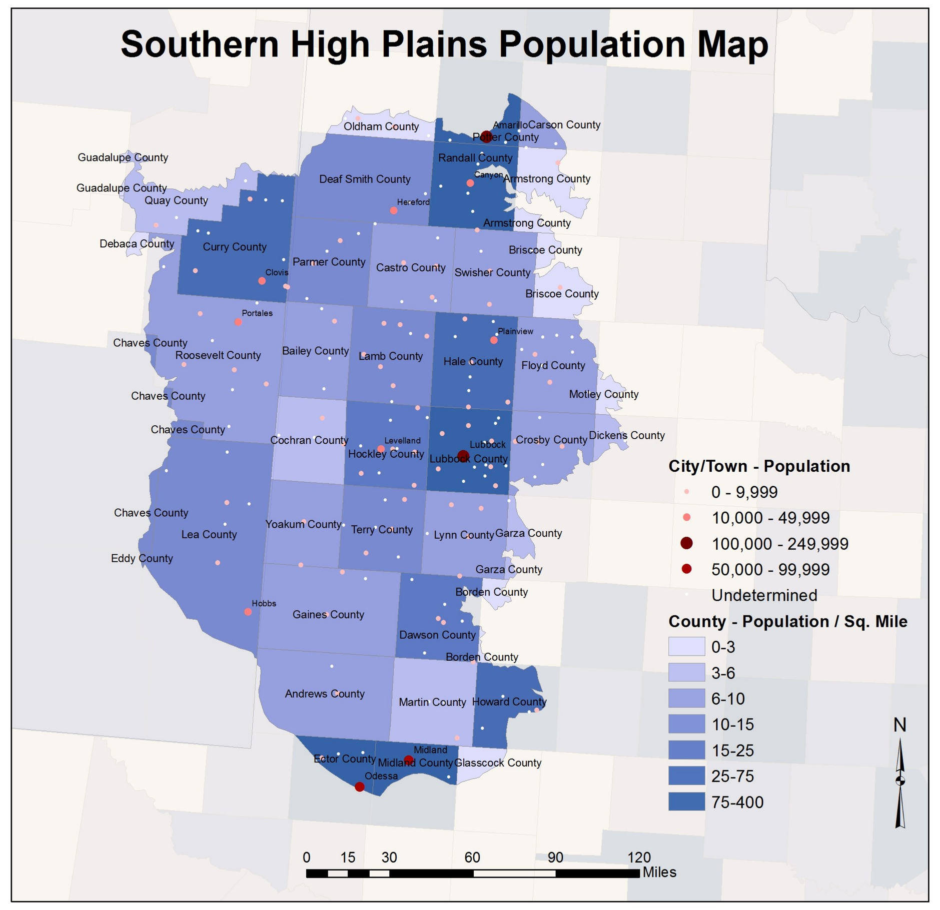

Figure 7