Investigating soil properties along two regulated rivers in Texas

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CONTENTS

1 Introduction

Over half of the world's rivers are regulated by humans in some way. Many of these regulatory schemes are large operations, like dams and reservoirs, that drastically alter the natural water course and surrounding environment. Soil is the largest terrestrial sink of carbon on the planet, and for that reason, it is important that we understand how our human activities may affect soils around the globe. The interface between rivers and soils is a vital one; riparian zone processes play many roles, removing harmful materials, providing a sanctuary for plants and animals to thrive, and stabilizing carbon that percolates through the bank. This study looks at two large, regulated rivers in Texas: the Lower Colorado River below the Highland Lake System (outside of Austin), and the Red River below Lake Texoma (outside of Denison). Both of these study sites are located immediately below dams and are subject to large daily fluctuations in river stage. The primary goal of this analysis is to investigate and compare the health of the soils below these dams.

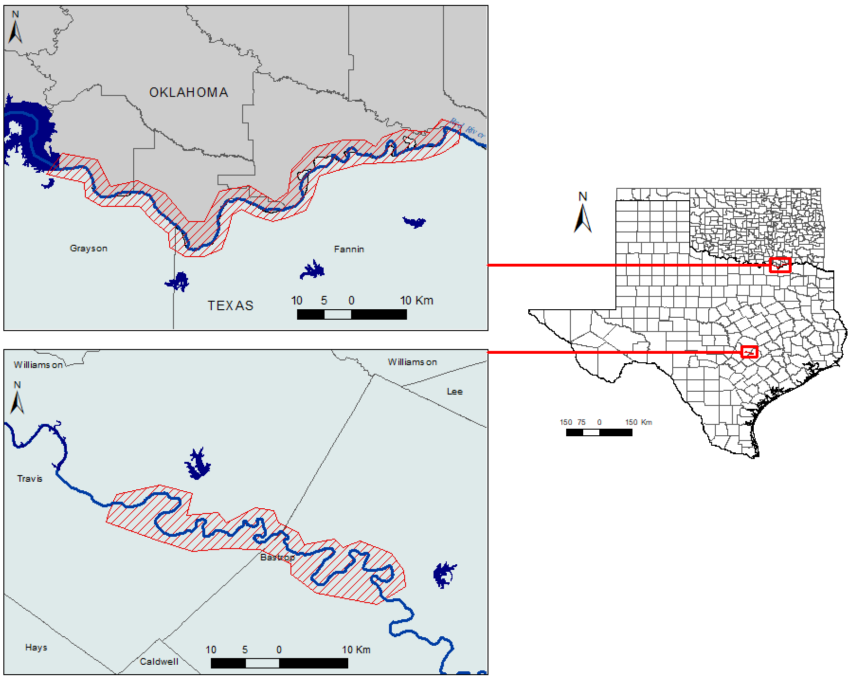
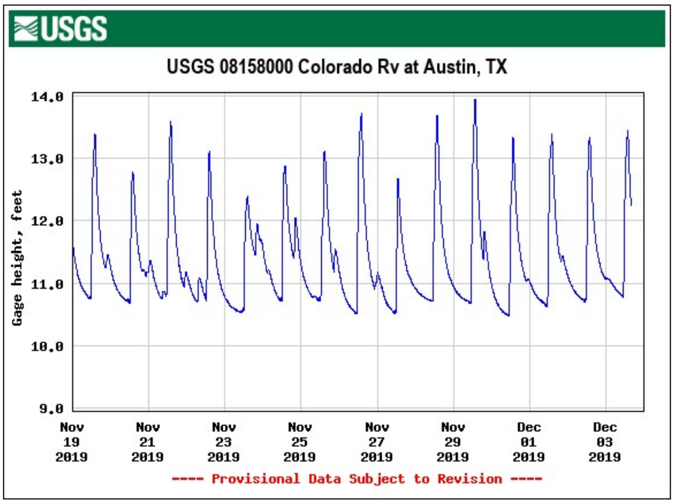


Figure 1.1: Two study areas near Austin and Denison, Texas.

Soil health is generally defined as "the continued capacity of soil to function as a vital living ecosystem that sustains plants, animals, and humans (NRCS)." One indicator of overall soil health is percent Soil Organic Matter (SOM). SOM includes the weight of decomposed plant, animal, and microbial residues exclusive of non-decomposed plant and animal residues. SOM is a good proxy for total organic carbon (TOC) in soil because there is an established



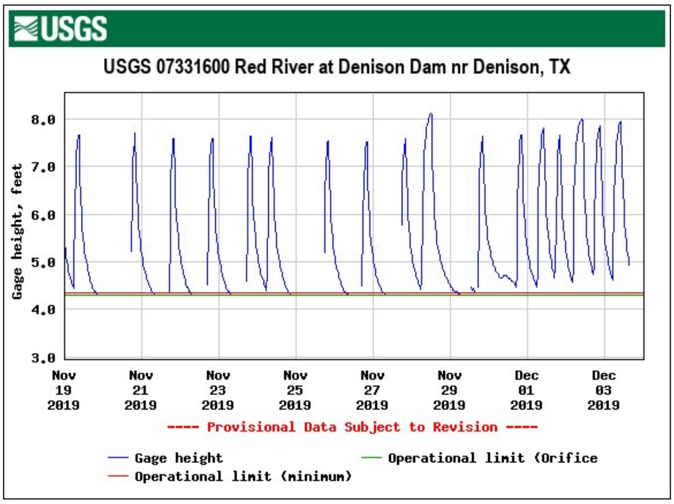


Figure 1.2: Hydropeaking in the Colorado and Red Rivers as a result of upstream dam operations. Graphs courtesy of USGS.

relationship between the two pools. Widespread TOC data is scarcely available, as it is time-consuming and laborious to acquire. SOM data, however, is widely available. For this study, we used a suite of soil health indicators- including SOM as a proxy for TOC- to analyze the areas directly under the dams. These areas would undergo the most intense hydropeaking as they would receive the largest volumes of water after a dam release. The hydropeaking phenomena could affect the stability of SOM in the soil by continually depleting organic material from the soil through changing the hyporheic flow patterns into the bank, by disrupting aggregate stability leading to less protected C, and by selecting for a microbial communities that may not cycle carbon and other nutrients as efficiently as others. To do this analysis, I followed the procedure described in Darwish and Fadel (2017) to calculate Total C Stock based on the following equation:

Eq. 1

$$OC\,Stock\,(ton) = \frac{[Soil\,Area\,(m^2)\ x\,Soil\,Depth\,(m)\ x\,Bulk\,Density\ x\,OC\,Content(\%)]}{100}$$

2 Methods

2.1 Data Collection and Pre-Processing

Data for this study was downloaded from the NRCS SSURGO database and from the Texas Water Development Board. The SSURGO data has to be located through the USDA Web Soil Survey (https://websoilsurvey.sc.egov.usda.gov/App/WebSoilSurvey.aspx). This tool requires the user to set an Area of Interest (AOI) no larger than 100,000 acres in size. Once the AOI is set, various data can be explored and compiled into a download package. Each package contains a shapefile of the AOI and the general soil map within the AOI. The other requested data are delivered as tabular data that are generally of poorer resolution than the shapefiles. The tabular data was first compiled into a single .csv file that could then be added to ArcMap. Once downloading data packages for both of the study areas, the requisite tabular data was compiled, and added to each map. Next, using the join tool, the tabular data was appended to the attribute table of the general soil map using the Map Unit Key (MUK). This produced four vector maps of each component in Eq. 1, and one map of percent clay content.

2.2 Raster Creation and Calculation

Next, each map needed to be converted into a raster dataset. To do this I used the polygon to raster tool in the conversion toolbox. I set the cell size to 20 and assigned values from the cell center (Figures 2.3 and 2.4). Next, I used the raster calculator to build Eq. 1 using the newly created rasters. The resulting raster shows SOM stock in tons across the AOI for both the LCR and the Red River (figures 2.5 and 2.6).

Next, I wanted to find SOM density for the two sites using the following equation:
Eq. 2

$$OC\,Density\,(ton\,ha^{-1}) = \frac{OC\,Stock\,(ton)}{Soil\,Area\,(ha)}$$

To do this I used the raster calculator to make new surface area rasters in hectares out of the square meter surface area rasters. The density rasters illustrate where and in which soil type along the rivers the most SOM has accumulated or been depleted from (figures 2.7 and 2.8).

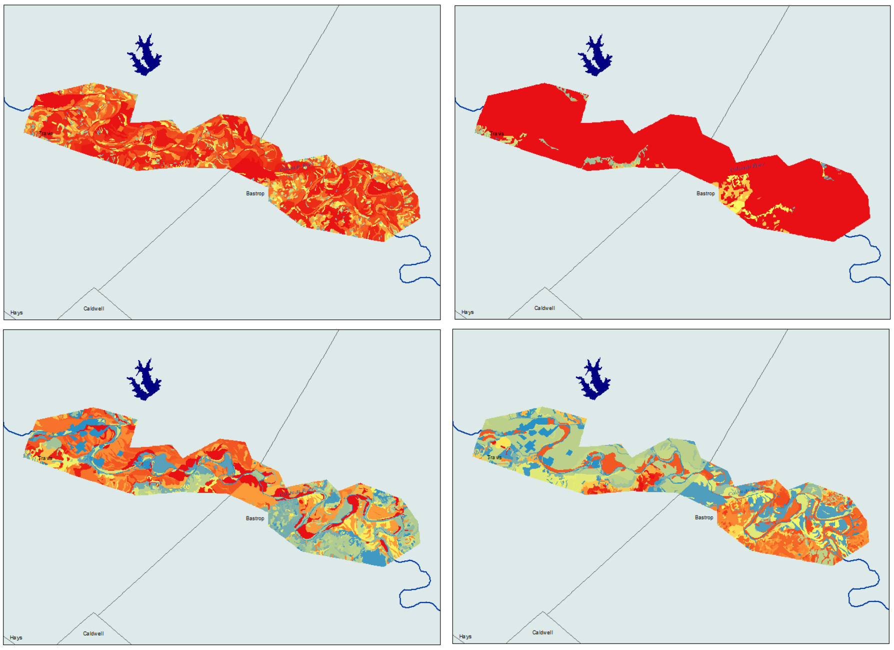


Figure 2.1: Four initial vector maps generated for the LCR from SSURGO data; clockwise from top left are soil unit surface area (m^2), soil depth (m), bulk density (1/3 bar), and SOM (%).

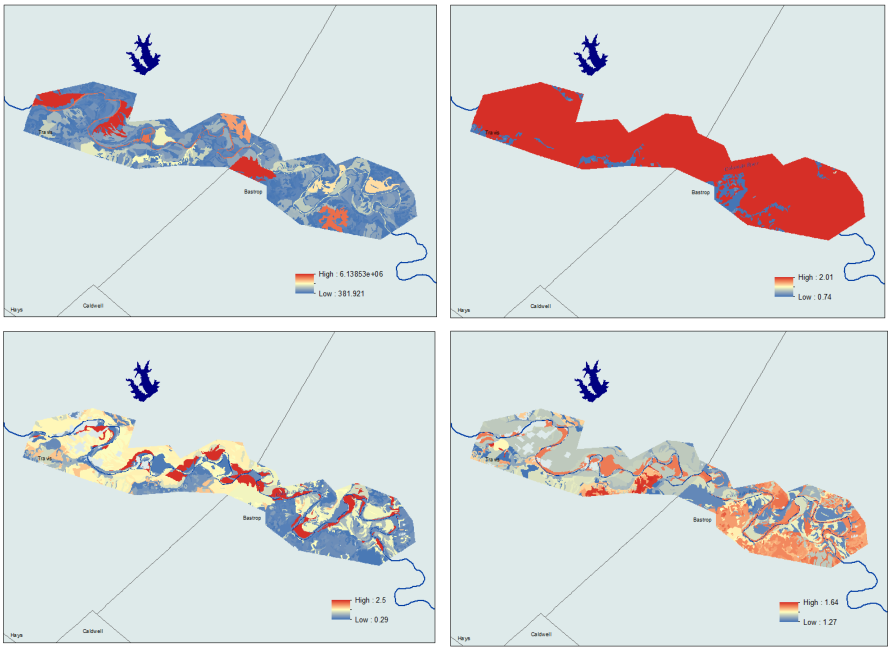


Figure 2.3: Four rasters generated for the LCR from SSURGO data; clockwise from top left are soil unit surface area (m^2), soil depth (m), bulk density (1/3 bar), and SOM (%).

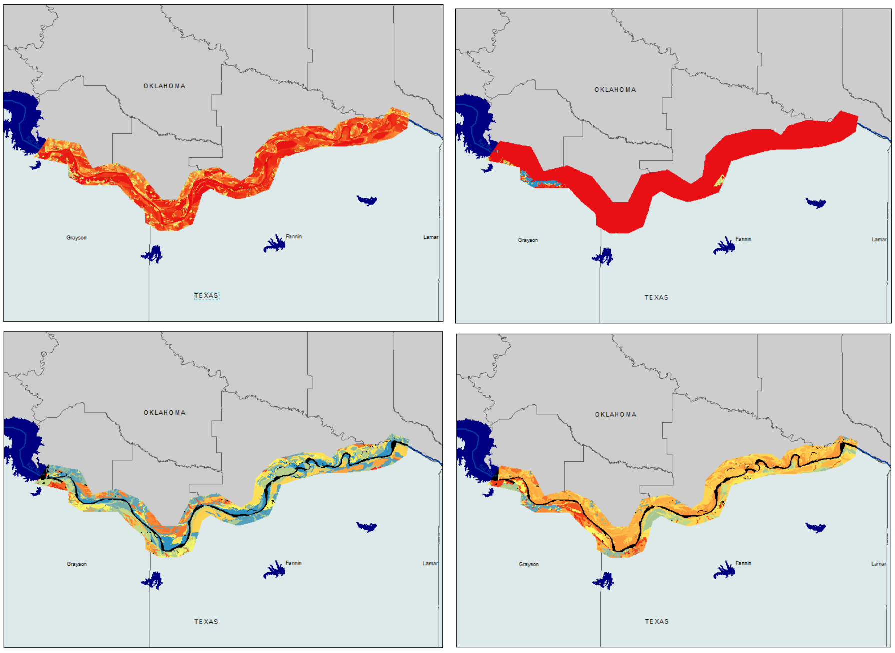


Figure 2.2: Four initial vector maps generated for the Red River from SSURGO data; clockwise from top left are soil unit surface area (m^2), soil depth (m), bulk density (1/3 bar), and SOM (%).

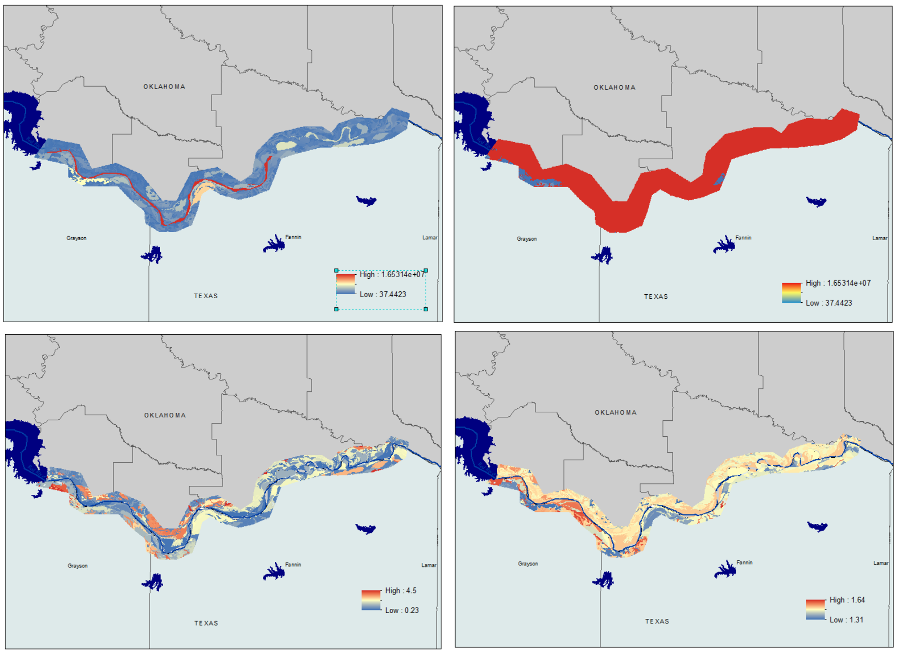


Figure 2.4: Four rasters generated for the Red River from SSURGO data; clockwise from top left are soil unit surface area (m^2), soil depth (m), bulk density (1/3 bar), and SOM (%).

Finally, I compared the SOM stock and density rasters to the percent clay content rasters by adding them in the raster calculator (figures 2.9 and 2.10). This should illustrate the areas where the highest SOM stock coincides with the highest clay content.

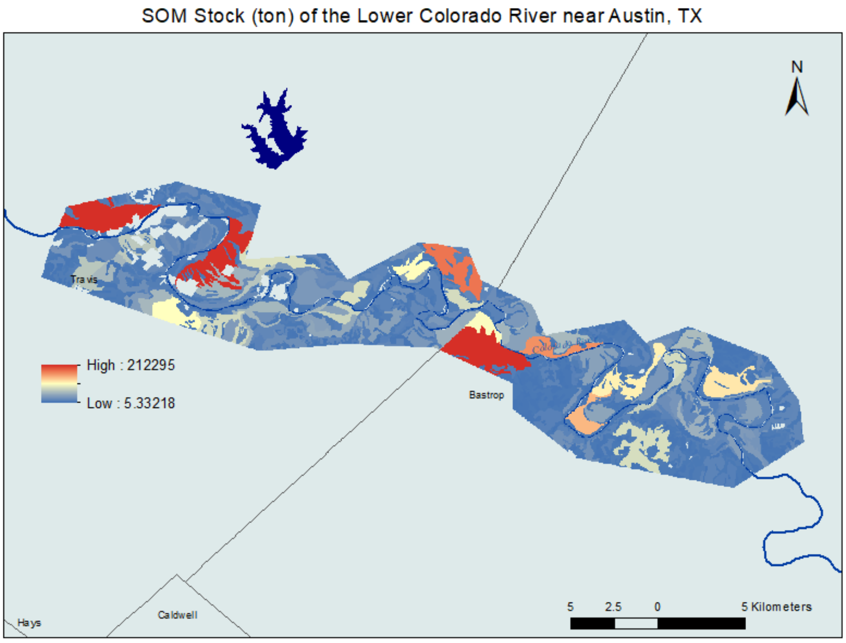


Figure 2.5: SOM stock (ton) along the LCR near Austin, Texas.

3 Discussion

The final SOM stock and SOM density maps exhibit different patterns between the two locales. The spatial variability of the SOM stock at both locations appears to be controlled more by river morphology than by distance from the dam, ie decreasing intensity of hydropeaking. It seems that at the LCR, there are relatively high stocks of SOM closer to the dam than away from it, suggesting perhaps an input of organic in that area. Along the Red River, the highest SOM stocks appear to be found in the most sinuous stretches of the river; if the water moves slower along these stretches, it would follow that erosion may be less of a factor and SOM could build up. When compared to the SOM density maps, however, new patterns emerge. Along the LCR the median SOM stock appears higher closer to the dam than further away from it, but highly dense pockets of SOM exist mostly along point bars. Because this area undergoes frequent, large floods, it makes sense that more organic material would accumulate further downstream as the river slows. SOM density along the Red River behaves in almost the opposite manner. Close to the dam, there are many pockets of highly dense SOM, whereas further downstream, the banks reflect a more average SOM density.

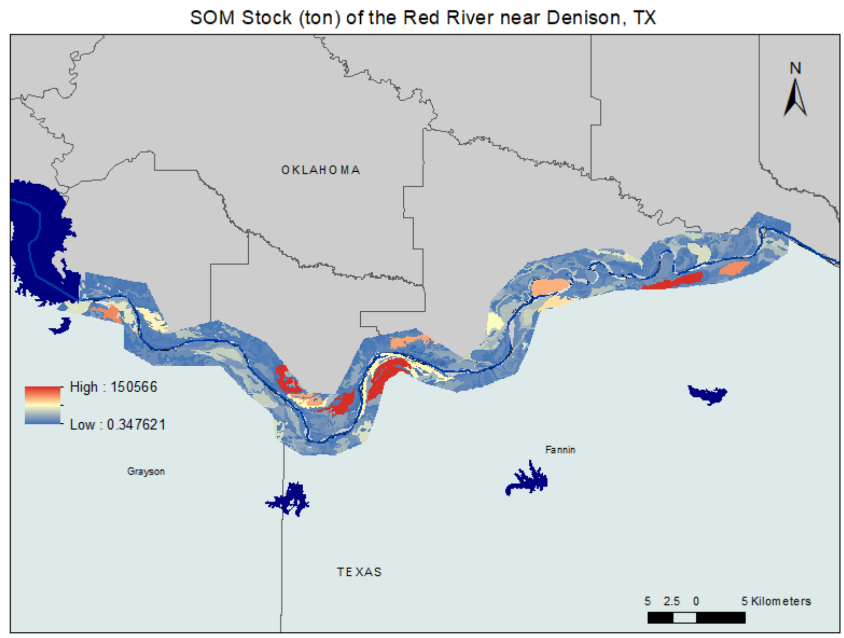


Figure 2.6: SOM stock (ton) along the Red River near Denison, Texas

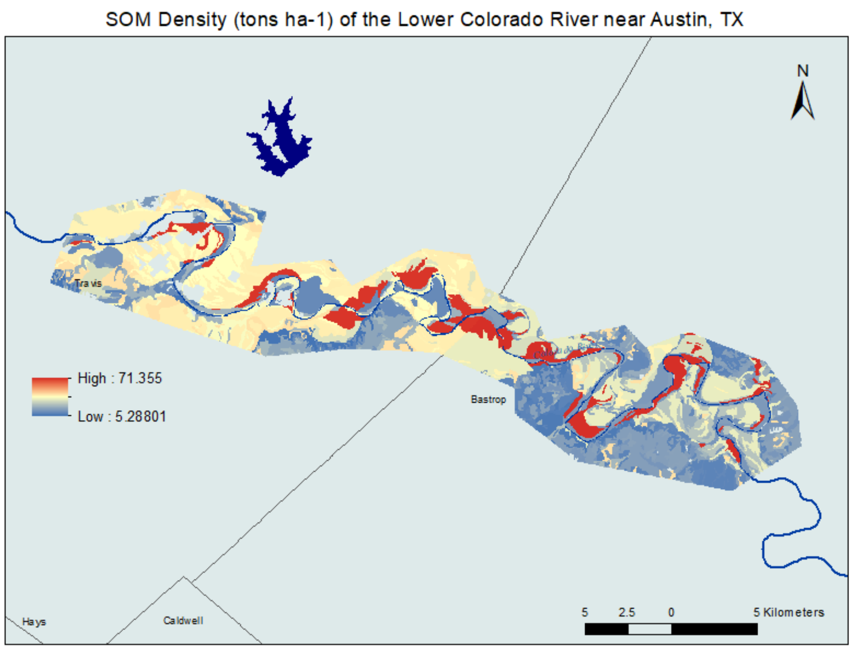


Figure 2.7: SOM density (ton ha^{-1}) along the LCR near Austin, Texas.

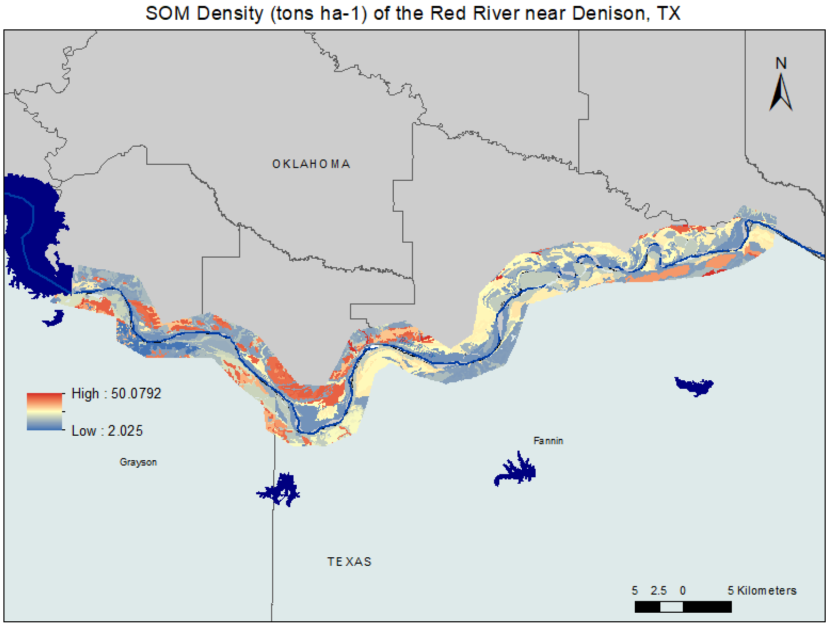


Figure 2.8: SOM density (ton ha^{-1}) along the Red River near Denison, Texas.

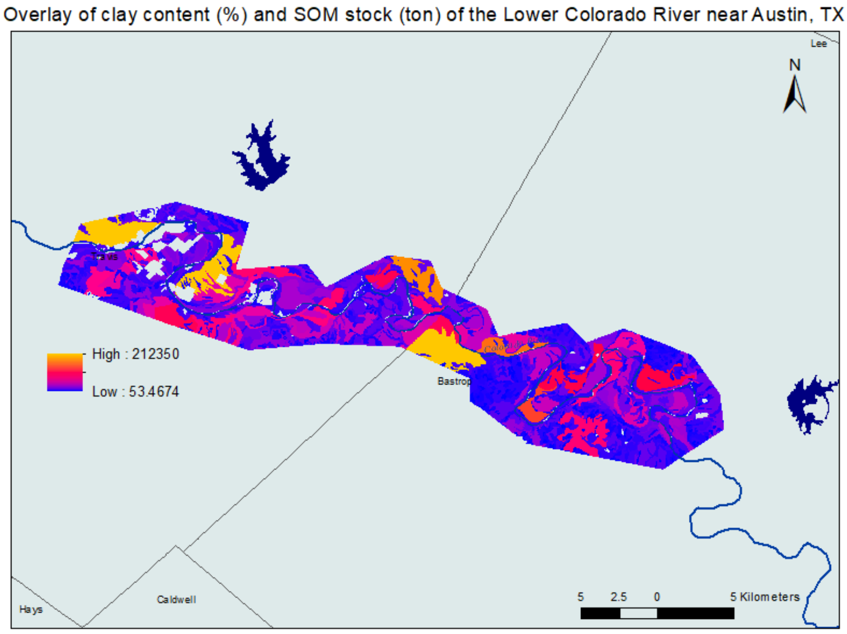


Figure 2.9: Clay content (%) and SOM stock (tons) along the LCR near Austin, Texas.

Overlay of clay content (%) and SOM stock (ton) of the Red River near Denison, TX

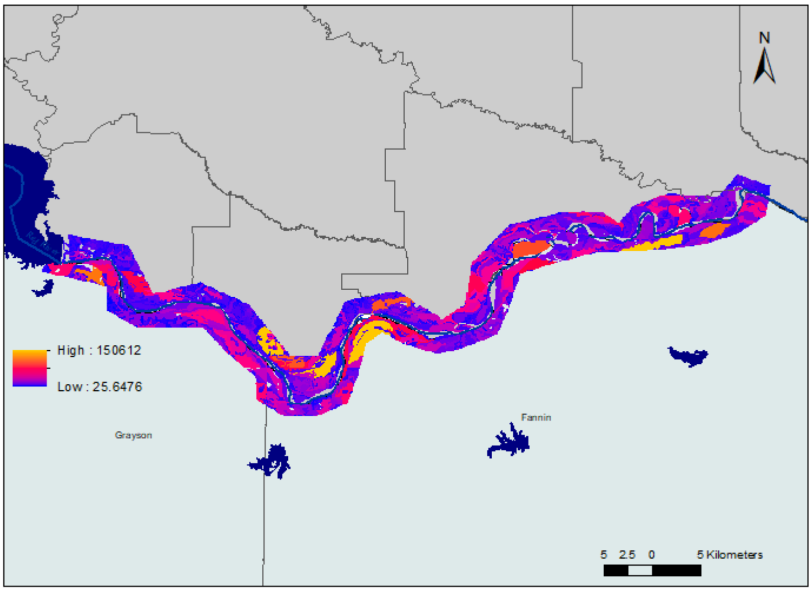


Figure 2.10: Clay content (%) and SOM stock (tons) along the Red River near Denison, Texas.

The maps of clay content and SOM stock reveal that clay content is highest upbank, away from the rivers, and there is little overlap between the highest instances of clay content with very high SOM stocks. This runs contrary to the assumption that areas with higher clay content would have higher SOM stocks due to the physical and chemical protections that clay minerals afford to carbon and organic material.

References

[1] Darwish, T. and Fadel, A. *Mapping of soil organic carbon stock in the Arab countries to mitigate land degradation.* Arabian Journal of Geosciences, 11(10):474, 2017.

[2] NRCS USDA Soils Division *Soil Health: Healthy Soil for Life* `https://www.nrcs.usda.gov/wps/portal/nrcs/main/soils/health/`