Studying the Potential Impact of Groundwater Depletion on Surface Vegetation in the Mississippi Delta Using Remote Sensing

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ABSTRACT:
The fertile soils of the Mississippi Delta physiographic province allow for the region to be a large producer of cotton, soy, rice, and other crops for commercial use. However, the extensive use of groundwater for irrigation raised concerns about the possible depletion of groundwater in this region. Therefore, it is important to understand the potential impact of groundwater depletion on surface vegetation in the Mississippi Delta region. The Gravity Recovery and Climate Experiment (GRACE) satellite data provides the opportunity to monitor the changes in the groundwater surface through recording gravity fluctuations over the entire planet, with data released every month. Pairing information provided by GRACE with the Moderate Resolution Imaging Spectroradiometer (MODIS) Normalized Difference Vegetation Index (NDVI) data, it is possible to see if there is a correlation between the changes in the groundwater levels over a period from 2011 to 2020, and the overall vegetative health of the region. This paper presents the obtained preliminary results of this study.

INTRODUCTION

The fertile soils of the Mississippi Delta physiographic province allow for the region to be a large producer of cotton, soy, rice, and other crops for commercial use. However, the extensive use of groundwater for irrigation raised concerns about the possible depletion of groundwater in this region. Therefore, it is important to understand the potential impact of groundwater depletion on surface vegetation in the Mississippi Delta region. The Gravity Recovery and Climate Experiment (GRACE) satellite data provides the opportunity to monitor the changes in the groundwater surface through recording gravity fluctuations over the entire planet, with data released every month. Pairing information provided by GRACE with the Moderate Resolution Imaging Spectroradiometer (MODIS) Normalized Difference Vegetation Index (NDVI) data, it is possible to see if there is a correlation between the changes in the groundwater levels over a period from 2011 to 2020, and the overall vegetative health of the region. This research is a continuation of GRACE research that was performed in the Mississippi Delta by Hossain (2014).

Gravity Recovery and Climate Experiment (GRACE)

GRACE and GRACE Follow On (FO) are a pair of satellites in low earth orbit that measure changes in gravity over the surface of the earth. The pair of satellites measures these fluctuations by monitoring the distance between the two satellites as they orbit in near polar orbit. The first of the two satellites will be “pulled” toward a larger mass and increase the distance between it and the tailing satellite. As the tailing satellite approaches the same mass, it will also be pulled toward the mass and bridge the distance between the two satellites. These changes in the distance between the satellites is measured by a precise k/ka-band ranging assembly, that can detect a change in distance of 1 micron (NASA, 2018).

The pair of satellites are used to measure the fluctuation in Ground Water Height (GWH) over the respective area when compared to an average of the GWH over previous measurements (Anapalli, 2022). This approach allows the observer to detect fluctuations in the GWH over the same month, which outside of some potential outliers, should have similar weather and natural processed occurring during that month over time.

Moderate Resolution Imaging Spectroradiometer (MODIS)

MODIS NDVI is readily available for download from NASA and the USGS. Due to the demand and many applications of NDVI imagery, these agencies have provided files where the calculations have already been performed, and the imagery is ready for observation or application upon receiving the file. NDVI pixel values range from -1 to 1, and the higher the value is to the higher the chance of vegetation being present. NDVI pixel values that are closer to 1 are often thought of being representative of healthier vegetation, being that they are absorbing more of the red of the electromagnetic spectrum and reflecting more of the Near Infrared of the spectrum.

Methods

GRACE global data was obtained for the period of 2011 to 2020 and processed in ArcMap 10.8.1. Each set of data was clipped to a smaller area that was comprised of Mississippi, Arkansas, and Louisiana. A shapefile of the Mississippi Delta physiographic region was acquired from the Mississippi Department of Environmental Quality and placed over the processed imagery (Figure 1). Due to the large size of the GRACE pixels, 12,100 km², any pixels that were in contact with the delta boundary were captured and included in the sample size. This application led to a total of eight GRACE pixels that were either located in or tangential to the Mississippi
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**Results and Analysis**

The eight points for each month of GRACE and MODIS NDVI values were averaged and plotted on a line graph by sensor from 2011 to 2020. The GRACE points averaged line graph exhibited an upward trend from 2011 to 2020 (Figure 3) with an increased variation between the local maximum and minimum of the line graph from October 2018 to September 2020. The averaged graphed MODIS data showed a downward trend in the NDVI values and a slightly increased variation of local maximum and local minimum of the line graph from October 2018 to September 2020 (Figure 4).

**Conclusions and Discussions**

The information that was provided by the graphical analysis of the GRACE and GRACE-FO was unexpected and led to more questions. It should be noted that from 2011 to 2018, the initial GRACE mission was reaching the end of its operations, and although there is accurate data available for every year of that range, it was not available for every month due to technical problems and the age of the satellite. GRACE-FO has been functioning properly since the beginning of its mission in 2018 and is regularly providing monthly data. Although there are gaps in several years of the initial GRACE mission’s data, we were still able to plot and observe seasonal trends from 2011 to 2020 using both GRACE and GRACE-FO data.

The MODIS NDVI data showed a downward trend from 2011 to 2020 which would be expected with the increased amount of extreme weather conditions that have been present not only in the Mississippi Delta, but in the Southern United States as a whole.

The upward trend in GWH observed from the GRACE satellite missions may be due to the eight points that were averaged together for each month. This approach is a good indicator of the GWH of the Mississippi Delta and the surrounding area but may not the most accurate method for analysis of what is taking place within the boundaries of the delta itself. The initial method of including pixels that were tangential to the boundary of the delta was due to large resolution of GRACE and to start with a more conservative approach. The upward trend in the GWH may also be a result of the increased amount of precipitation in the Mississippi Delta region, and the proximal tributaries of the Mississippi River. Mississippi experienced its record precipitation each year from 2016 to 2020, and several states in the immediate area experienced higher levels of precipitation in their respective river valleys during the same period.

For future research, GRACE and MODIS NDVI data will be attained from 2002 to 2011 and the same eight points will be extracted via the same methods and compared to the present set of information. This will also allow for analysis of the GWH and NDVI values and to deduce if there are trends or changes at different temporal ranges.

In addition to the data from 2002 to 2011, GRACE-FO and MODIS data will be gathered for the remainder of 2020 to December of 2021 to have data for a total of approximately 19 years. Pixels will be extracted from both the MODIS and GRACE – FO by the same methods as the previous sets, but solely within the confines of the Mississippi Delta Physiographic boundary to attain a more precise understanding of the variation of GWH and NDVI in that region. This will lead to a lower number of pixels for processing, but they all will be representative of the characteristics of the Mississippi Delta Boundary.

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**References**


Figure 1. Processed MODIS NDVI data for the state of Mississippi and the Mississippi Delta Physiographic region.

Figure 2. Processed GRACE data for the United States (Left), and Processed GRACE and MODIS data for the Mississippi Delta Physiographic region and surrounding states (Right).
Figure 3. Line graph of average of eight GRACE pixels/point values within and tangential to the Mississippi Delta Physiographic region from 2011 to 2020.

Figure 4. Line graph of average of the eight MODIS point values that were within 0.5° of each GRACE point in and tangential to the Mississippi Delta from 2011 to 2020.