**NASA DEVELOP National Program**



Mobile County Health Department

*Fall 2015*

Coastal Texas Water Resources

Using NASA Earth Observations to Assess the Health of the Laguna Madre through Land Cover Mapping and Thermal Analysis

 **Technical Report**

Rough Draft – October 8, 2015

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# I. Abstract

[Placeholder - do not put anything here until the final draft submission. The abstract in the project summary is where the working draft of the abstract should “live”]

**Keywords**

Honey mesquite, taproot, normalized difference vegetation index, normalized difference infrared index, groundwater, lagoon, hydrogeology (would it be more effective to break up hydrogeology into hydrology and geology?)

# II. Introduction

*2.1. Background*

The Laguna Madre is one of only a few hypersaline estuaries in the world (Tunnel 2001). It is located within the Padre Island National Seashore on the Gulf Coast of Texas. As part of a National Park, the lagoon falls under federal land management. However, much of the nearby land is privately owned, complicating management of the Laguna Madre. As a result, the National Park Service currently only collects *in situ* data from limited locations to monitor different water properties of the Laguna Madre, such as temperature, pH, turbidity, and salinity.

Historical evidence suggests that while the lagoon is presently hypersaline, this was not always the case. It is hypothesized that the proliferation of honey mesquite (*Prosopis glandulosa*) trees in the surrounding area have resulted in decreased freshwater inflow to the lagoon due to the trees’ well-developed root systems capable of tapping into groundwater resources. However, the relationship between the salinity of the lagoon, honey mesquite trees, and groundwater resources, is not being systematically studied. As much of the area surrounding the lagoon is privately owned, remote sensing data is ideal to analyze the expansion of honey mesquite trees and their suspected effect on the Laguna Madre.

Therefore, the objective of this study was to use remote sensing technologies via NASA Earth observations to investigate the suspected positive correlation between the salinity of the Laguna Madre and the increase in honey mesquite trees. This was done in several ways. To start, honey mesquite tree expansion was analyzed from Landsat 5 (TM) and 8 (OLI) data through a time series of Land Use/Land Cover (LULC) maps as well as through the calculation of vegetation indices including the Normalized Difference Infrared Index (NDII) and the Normalized Difference Vegetation Index (NDVI). Maps predicting future mesquite tree coverage were also generated to understand possible tree expansion in order to forecast how future groundwater resources for the lagoon may be affected. Additionally, the areas of mesquite tree coverage identified by the LULC analysis were compared with soil and underlying geology data. This allowed the team to investigate the relationship between soil type and tree presence as well as proximity to aquifers, calcium carbonate layers, and other geologic features. The last portion of the project, in order to achieve the objective, was to identify potential areas where there was groundwater inflow into the lagoon. This was done by analyzing Landsat 5’s thermal band to locate anomalies in the surface temperature of the lagoon, as images were collected during seasons when there should be a distinct difference between groundwater and surface water temperatures.

*2.2. Study Area*

Broadly speaking, the study area of this project included the Laguna Madre within the Padre Island National Seashore located on the Gulf coast of Texas as well as some of the surrounding lands to the west of the lagoon. For this location, the study area was delineated by the latitude lines, 27.6° N and 26.2° N, for the northern and southern boundaries, respectively. The western boundary stretched past US Highway 77 while the eastern boundary extended into the Gulf of Mexico.

For thermal image analysis, this study area was focused on the Northern Laguna Madre where it is hypothesized groundwater inflow to the lagoon will be visible. For the LULC maps, the study area was focused on the landmass west of the Laguna Madre, extending eastward to Kingsville, TX and south to Edinburg, TX.

*2.3. Study Period*

The study period of the project spanned from 1984 to 2000. Land cover analyses and vegetation indices calculations were conducted incrementally during dry years as identified from precipitation data. Late summer months, August - October, from these dry years were targeted due to the greater spectral difference between honey mesquite trees and surrounding vegetation, mostly grasslands. This is because the honey mesquite has taproots that can access water, keeping leaves green, whereas the surrounding vegetation cannot and would display browning from significant water stress. Thermal data were downloaded for winter months, January – February, and late summer months, August – October. These months offered the greatest potential differences between the temperature of the lagoon and groundwater inflow. Years that had higher precipitation amounts during these months were specifically targeted due to a greater probability of seeing the groundwater recharge to the lagoon via thermal imagery.

*2.4. National Application Areas Addressed*

By using NASA Earth observations to gather remotely sensed data to address water quality availability and forecasting concerns, this project addressed the Water Resources and Ecological Forecasting national application areas. Landsat was used to identify groundwater inflow into the lagoon through thermal analyses as well as examine the current and predicted changes in honey mesquite tree extent. In doing so, this project seeks to determine the relationship between these environmental factors and the health of the Laguna Madre.

*2.5. Project Partners*

This project partnered with the National Park Service (NPS) to address concerns over the rising salinity of the Laguna Madre. Historically, it is thought that the lagoon had lower salinity concentrations rather than the constant hypersaline concentrations of today. This is a concern to the NPS as the lagoon creates a diverse ecosystem that provides habitat to various flora and fauna, including threatened species such as the kemp’s ridley (*Lepidochelys kempii*) sea turtle (Tunnel 2001). While the unique ecosystem of the lagoon is threatened by the increasing salinity, it remains unclear what effect various environmental factors are having. By analyzing mesquite tree expansion and thermal anomalies, the relationship between these factors will be better understood and will aid the NPS in future land management decisions concerning the Laguna Madre. Furthermore, several scripts and a methodology will be provided to the NPS in order to allow them to continuously monitor the health of the Laguna Madre using NASA Earth observations with essentially no prior background necessary.

# III. Methodology

This study utilizes a novel methodology in order to attempt to identify the driving ecological factors that are causing the hypersaline conditions within the Laguna Madre. The steps necessary to do this include (1) data acquisition and preprocessing (2) script development and (3) statistical analyses. All Landsat data were downloaded from the USGS Landsatlook Viewer for path 26, rows 41 and 42.

*3.1. Data acquisition and preprocessing*

*3.1.1. Precipitation data*

Collecting precipitation data was critical for all parts of this project; it is a major driver that changes the hydraulic gradient—directing groundwater flow into the Laguna Madre—provides ancillary data for analysis when compared to indices such as NDVI and NDII, as well as used to target specific wet or dry years for image collection and analysis. For this project, both remotely sensed and *in situ* data was utilized. The Parameter-elevation Regressions on Independent Slopes Model (PRISM) was used to collect daily, monthly, and annual averages for the study region from 1984 - 2000. PRISM also provided a very high spatial resolution of 4 km. *In situ* data allowed for validation of the remotely sensed data and was collected from the Kingsville, TX and Corpus Christi, TX weather stations for the same time period. Using these datasets allowed the following years to be targeted: above average precipitation, or wet years, were 1985, 1986, 1991, 1993, and 1997, whereas below average precipitation, or dry years, were 1984, 1988, 1989, 1990, 1996, and 2000. Targeting these years for further analyses maximized the ability to highlight any anomalies, if present.

*3.1.2. Thermal Imagery*

As the study period was between 1984-2000, only Landsat 5 Thematic Mapper (TM) was required. From this sensor, band 6, the thermal infrared wavelength, was utilized for analysis. The purpose of this thermal analysis was to see differences between the fresh groundwater and hypersaline water of the lagoon. Particular months, in both the late summer, August to October, and winter, January and February, within the particular wet years, previously outlined, increased assurance in two categories: that the difference in temperatures within groundwater and lagoon water was maximized, making it easier to view differences via thermal imagery, and that these years had seen the greatest precipitation, maximizing the potential amount of groundwater inflow into the lagoon. Furthermore, as saltwater has a higher density than freshwater, the freshwater should rise to the surface of the lagoon and a distinction should be noticeable in thermal signatures. If a groundwater inflow hotspot is located, this will greatly aid the NPS in further data collection as well as begin to confirm their hypothesis that groundwater inflow has been decreasing into the lagoon.

*3.1.3. Normalized Difference Vegetation Index (NDVI)*

The NDVI was calculated from Landsat 5 (TM) data. This index highlights the photosynthetic capability of plants and can be helpful for land classification maps, which was a particular need for this project.

*3.1.4. Land classification*

A time series of land use/land classification (LULC) maps was generated using Landsat 5 (TM) and Landsat 8 (OLI). TM data was collected for 1984-2000 whereas OLI data was collected for 2015. A time series of maps were created using NDVI as well as the image processing software ERDAS IMAGINE. The categories for land classification were as following: pasture/ grassland, urban, cropland/ bare soil, wetland, honey mesquite, sand, and water. This delineated the extent for the honey mesquite and how it has changed over time. Once these maps were created, they were used as inputs in Clark Lab’s TerrSet Land Change Modeler in order to predict the future extent of the honey mesquite.

*3.1.5. Normalized Difference Infrared Index (NDII)*

The NDII was calculated from Landsat 5 (TM) data. This index highlights changes in water content in vegetation, helpful in detecting water stress. Higher indices values denote higher water content. This was particularly useful when comparing the monthly precipitation averages to the honey mesquite extent derived from the land classification map.

*3.1.6. Geology data*

To refine the study area, an underlying geology shapefile provided by the USGS was used. Data from this shapefile contained attributes such as areas where calcium carbonate was present, which honey mesquite taproots cannot penetrate. Furthermore, the Texas Water Development Board provided data on maps where fresh and saltwater aquifers were located. The LULC was overlaid on top of these layers to compare how different vegetation types correlate with the underlying geology and to understand their proximity and ease of access to varying aquifers.

*3.1.7. Soil data*

The USDA National Resource Conservation Service (NRCS) provided soil data. This was compared to the LULC maps to find any correlations between the honey mesquite and soil types.

*3.2. Script Development*

*3.2.1. Python ForLoop for historical thermal data*

Several scripts are being developed in order to increase efficiency of data preprocessing. This helps the team but it will also be given to the project partner to allow them to conduct separate analyses with very little background knowledge for images that we did not analyze. These scripts will be for Landsat satellites 4, 5, and 7, as they all have only one infrared band. All the project partner will have to do is download the satellite image with associated metadata and run the scripts. The following processes will occur. Digital numbers will be converted to radiance, which will then be converted to Celsius temperatures and then outputted into a new folder. At this point, the images can be uploaded into a GIS or image processing software to easily analyze.

*3.2.2. Python ForLoop for present thermal data*

This script will be used for Landsat 8 (OLI) data as it has two infrared bands.

*3.3. Statistical Analyses*

*3.3.1. R*

*3.3.2. Excel*

# IV. Results & Discussion

Insert images, graphs, maps, charts, etc. here. Choose the most important results to highlight here. No word cap, but two to six pages is a good range.

Things to discuss:

* Analysis of Results: What can you tell from your graphs, images, etc? What does this mean for your project?
* Errors & Uncertainty: What factors could you not account for, what things didn’t work out like you expected they would, etc.
* Future Work: If this project was to be selected for another term, what would be the focus? What other areas would be of interest?

# V. Conclusions

Final conclusions. Word count: 200-600 (~a page).

# VI. Acknowledgments

The team would like to thank the following people for their help in the completion of this project: mentor Bernard Eichold, M.D., Dr. PH (Mobile County Health Department), the team’s Science Advisors Joe Spruce (NASA Stennis Space Center) and James “Doc” Smoot (NASA Stennis Space Center), the DEVELOP National Program’s National Science Advisor Dr. Kenton Ross (NASA Langley Research Center), as well as the team’s project partner and end-user, Joe Meiman (National Park Service).

Any opinions, findings, and conclusions or recommendations expressed in this material are those of the authors and do not necessarily reflect the views of the National Aeronautics and Space Administration.

This material is based upon work supported by NASA through contract NNL11AA00B and cooperative agreement NNX14AB60A.

# VII. References

Tunnel, John. 2001. “Protect the Laguna Madre.” *Corpus Christi Caller Times*. http://www.nps.gov/pais/learn/nature/laguna.htm. (October 7, 2015).

# VIII. Content Innovation

1. AudioSlides
2. Featured Author Videos
3. Featured Multimedia for this Article (video and podcast options)

# IV. Appendices

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