ASSESSMENT OF WETLAND DYNAMICS AND LOSS IN TERREBONNE PARISH USING REMOTE SENSING.

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ABSTRACT

The coast of Louisiana is a major zone of the Gulf of Mexico and an ecologically critical area for both carbon sequestration and habitation of diverse ecosystems. The ten major marine sectors each have annual GDPs of tens of billions of dollars annually. In 2019 alone, these sectors provided 2.4 million high-paying jobs, 397 billion in goods and services and another estimated 667.5 billion in sales. Aside these obvious benefits that coastal wetlands provide, they also help to reduce inland flooding and coastal erosion. According to the National Oceanic and Atmospheric Administration (NOAA), about 32% of Louisiana alone is made up of wetlands. The U.S. Geological Survey estimates that Louisiana has been losing wetlands since the late 1930's and that the current rate of loss will result in total wetland loss in another two hundred years. Satellite data were obtained from Landsat 8 satellite imaging. The data was trained and processed using QGIS free software to produce maps. The maps were then analyzed and interpreted. The results of this study affirmed a gradual decline in wetland area with a major increase in vegetation cover in Dulac, supporting some findings by the USGS in 2017 which classified Louisiana's current rate of as low compared to the 1930's and 1970's. However, wetland dynamics is a complex series of events that occur over time and requires constant tracking and monitoring to provide evidence-based practical and applicable results that will suit the ever-emerging dynamics of management, policymaking, restoration, and management of wetlands themselves.

INTRODUCTION

1.1 Overview of wetlands

Wetlands can be defined as any moist aquatic or terrestrial systems or lands that support some form of hydrophyte life temporarily or permanently and are periodically flooded because their water tables are close to the soil surface. Wetlands occur in several states across the United States but vary in sizes and shapes due to the differences in climate, vegetation, soil, and hydrologic conditions. In 1979, wetlands were grouped in five (5) using based the service's classification system. Wetlands can therefore be classified based on at least one of the following three attributes: land that at least enables the survival of hydrophytes all year round or at certain times of the year, substrate that has predominantly undrained hydric soil or non-soil substrate that is saturated by surface water at certain times during a growing season of each year, these surface waters are mostly not deep waters (Cowardin *et al.*, 1979). Marine Wetlands generally consists of deep-water habitats open oceans and its associated coastline. Estuarine Wetlands are found along the U.S coastline (coastal wetlands) and are associated with salt and brackish tidal waters or estuaries, mangroves, and swamps.

Riverine Wetlands are limited to deep-water habitats in freshwater rivers and stream channels. Lacustrine Wetlands are also deep-water dominated but includes standing water bodies like lakes and reservoirs. Palustrine Wetlands occur in the interior of the country and are largely made up of freshwater wetlands, although in-land salt and brackish marshes exist in arid and semi-arid regions.

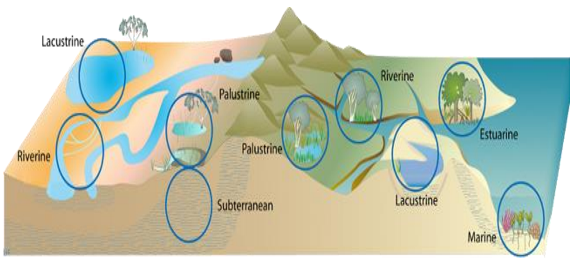

Fig.1 Graphic representation of wetland classes.

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1.2 Estimation of Wetland Cover and Extent

Topography and hydrologic conditions influence the expanse and size of wetlands. Most wetlands occur in low-topographic conditions or "landscape sinks," where ground or surface water collects. Others occur on hills or slopes where groundwater emerges as springs or seeps, or they depend solely on rainfall as a water source. On the global scale and regionally, wetlands cover a tiny fraction of the earth's surface. The area is about 5.3 million km^2 according to Matthews & Fung. However, the Ramsar Convention estimate is higher at 7.48–7.78 million km^2, excluding salt marshes, coastal flats, sea-grass meadows, and other habitats that they do not consider wetlands. Finlayson *et al.* acknowledge that estimates are not dependable and that the "tentative minimum" could be as high as 12.8 million km^2. Finlayson *et al.* based their estimates of global wetland area on results from three international projects; two of these were international workshops organized in 1998 by Wetlands International and the third was the Ramsar "Global Review of Wetland Resources and Priorities for Wetland Inventory" (GRoWI). GRoWI analyzed 188 sources of national wetland inventory data and forty-five international, continental, and global inventories, which included books, published papers, unpublished reports, conference proceedings, doctoral theses, papers, electronic databases, and information available on the World Wide Web. Of the 188 sources of national-level inventories, Finlayson et al. reported that only 18% could be considered comprehensive, 74% were partial inventories that considered either wetlands of international importance only or specific types of wetlands only, and 7% of 206 countries had what Finlayson et al. consider adequate wetland. Minimum estimates of global wetland area by region, as summarized by Finlayson *et. al.*, 1999)

Region Area (million square kilometers) Africa 1.21–1.24, Asia 2.04, Eastern Europe 2.29, Western Europe 0.29, Neotropics 4.15, North America 2.42, Oceania 0.36, Total 12.76–12.79 inventories. Using the 12.8 million km^2 as a base, less than 10% of this area has been designated as wetlands of international significance (Ramsar, 2002).

1.3 Wetland Dynamics and Loss

1.3.1 Pest Invasion as a driver of wetland dynamics

Wetlands are landscape sinks where nutrients are augmented by runoff or enriched groundwater, allowing invasive species to establish, spread, and displace native species (Zedler and Kercher, 2004). Native sedge meadows, for example, support more than 60 species but lesser than 15 when invaded by Phalaris *arundinacea* (Kercher *et al., 2004*). In a recent survey of about 80 Great Lakes coastal wetlands, C.B. Frieswyk, C. Johnston, and J.B. Zedler, found invasive cattails to be the most common dominant, and native plant species richness was decidedly lower as a result. According to this, "dominant" is the species judged to have the greatest influence on the community based on cover and associated species (C.B. Frieswyk, C. Johnston, and J.B. Zedler). In contrast, native plant dominants had many co-occurring species. The mechanism whereby invasive plants suppress other species include dense rhizomes and roots that leave little space for neighbors (as in T. x glauca), strong competition for nutrients (Perry *et. al.*, 2004), and tall dense canopies that usurp light (as in P. *arundinacea*) (Herr-Turoff 2005). Canopies that usurp light for longer periods of time have definite advantages over native species with more shorter canopies. A good example is P. arundinacea initiates growth far earlier than native Wisconsin vegetation and continues growth well into November, when natives have gone dormant. Allelopathic species may also be involved in the suppression of native species, but evidence is limited (Erwin *et al.*, 2003). Across the diverse dimensions of cultures, attitudes about exotic species differ immensely, most times in the negative sense. However, in a recent article from China (Zhang *et. al.*, 2004) enthusiastically rave about the virtues of Spartina alterniflora, which was deliberately transported and introduced from the U.S. Atlantic Coast to the eastern China coast. Out 954 km, currently 410km of coastline in Jiangsu Province have been taken over S. alterniflora providing protection to the coastal shores, and 137 km^2 of former mudflats have also developed into salt marsh after just 20 years. The progressive expansion of this plant suggests a bright future for the China's coastal wetlands in terms of restoration and shoreline protection. The same species however when transported and introduced to the Pacific Coast of Washington, Oregon, and northern California are considered ecologically damaging to shorebirds, oyster fisheries, and native ecosystems in the Pacific Northwest.

1.3.2 Anthropogenic Factors as a driver of Wetland loss

Half of global wetland area is believed to have been lost in recent years. The world's wetlands and rivers have felt the pressure and strain of human impacts. In Asia alone, agriculture and dam construction are the primary causes of wetland loss of about five thousand km^2 every year (McAllister *et. al.*, 2001). Ladhar (2002) said that the primary reasons associated with wetland loss have been drainage, decreased inflows, siltation, and encroachment. Dudgeon (2003) also observed the results of habitat loss to be very poorly documented for most countries across Asia. Data from a century ago only provides correct maps for few nations hence making estimates of historic wetland areas crude. Hence only a few nations have concise maps from a century ago. One estimate is that 50% of the worldwide wetland place has been misplaced due to human activities (IUCN, 1996). Much of this loss happened in the northern nations for the first half of the 20th century but growing conversions of wetlands to surrogate land uses have elevated wetland loss in tropical and subtropical regions since the 1950s (Moser et. al 1996) with drainage for agriculture being the number one motive for wetland loss to date. As of 1985, 26% of the worldwide wetland loss was attributed to agriculture

Given data on more recent declines in area and changes in type, the U.S is not meeting its policy goal of no net loss. The goal of no net loss in acreage and function was developed by a National Wetlands Policy Forum convened by the Conservation Foundation (Conservation Foundation 1988) and subsequently established as national policy by Presidents G.H.W. Bush, W. Clinton, and G.W. Bush.

1.3.3 Climate change as a driver of Wetland loss

Climate change has long been associated with a lot of changes in the Earth's atmospheric and geographical features. Global warming is of specific concern to coastal wetlands because sea levels are rising (eliminating wetlands along the ocean edge) and because human populations are expanding (filling wetlands on the upland side). Globally, 21% of the human population lives within 30 km of the coast, and coastal populations are increasing at twice the average rate (Nicholls et. al., 1999). Development is already eliminating coastal wetlands at a rate of 1% per year. Nicholls et al. 1999 predict that a global sea-level rise of 20 cm by the 2080s would result in substantial damage, while a 1-m rise would eliminate 46% of the world's coastal wetlands. In addition, coastal wetlands would experience increased flooding. Their model indicates geographically different impacts, with wetland loss most extensive along the Mediterranean, Baltic, and Atlantic coasts, plus the Caribbean islands and coastal flooding greatest for wetlands in the southern Mediterranean, Africa, and South and Southeast Asia. Their prediction that small islands of the Caribbean, Indian Ocean, and the Pacific Ocean would receive the largest impacts of flooding was illustrated tragically by the 2004 tsunami that devastated small islands and coastal areas in Indonesia and Sri Lanka. Drainage is the main cause of wetland loss in agricultural regions. The example of Hula Valley in Israel shows how drainage leads to a chain reaction of impacts. There, some 45–85 km2 of shallow lake and papyrus swamps were drained, and 119 species of plants and animals were lost (Hambright and Zohary, 1999). As the soils dried, peat decomposed, and some became like powder, forming dust storms with local winds.

Decomposition and wind erosion caused the ground surface to subside about 10 cm per year. Chemical changes were also documented. Sulfur and nitrates were released during decomposition; these were leached into the Jordan River and transported to Lake Kinneret. Gypsum (calcium sulfate) formed in the Jordan River, and sulfate was later released to Lake Kinneret, where drinking water supplies were contaminated (Hambright and Zohary, 1999). Russi et al. 2013 reported that the world lost half of its wetlands in the twentieth century alone. According to the US Geological survey, Louisiana's 3 million acres of wetlands are lost at the rate of about seventy-five square kilometers annually, but minimizing these losses is a challenge that continues to be difficult and costly. Scientific projections predict that at the present rate of loss, Louisiana would have lost all its wetlands in another two hundred years. Several processes are a core part of Louisiana's wetland changes and loss. These processes may be geologic, human-induced, and climate-related. Although wetlands have long been identified as areas of concern by conservation experts, partly due to the recognition of the massive benefits that can be derived from maintaining wetlands and the impacts that habitat loss has on both landscape and biodiversity functions, but there is still a lot that is not known about them because they are constantly changing.

Although wetlands have since been given the attention they deserve, tracking wetland dynamics and loss over time provides evidence-based results that may be used for restoration, management strategies, mitigation and policy-making decisions geared towards conservation wetlands. This study seeks to provide an in-depth assessment of the wetland loss and changes of Terrebonne Parish in Louisiana over a 10-year period using Landsat 8 satellite images acquired from USGS Earth Explorer. The results of this study may be applied to various aspects of wetland restoration and conservation. The main objective of the study was to therefore assess wetland cover changes over the past ten years using Landsat 8 satellite images to produce evidence-based maps that may be applied in various aspects of management, policymaking, and management of wetlands.

2.1 Study Area

Terrebonne Parish is a parish located in the southern part of the state of Louisiana.

Terrebonne is derived from two French words, Terre and bonne which means good land. At the 2010 census, the population was 111,860, and 110,461 in 2019. In 2020, its population declined to 109,580. The parish seat is Houma. The parish was founded in 1822. Terrebonne Parish is part of the Houma-Thibodaux metropolitan statistical area. Census designated places in the parish include Chauvin, Dulac, Gray, Montegut and Schriever.

The area for the study was Dulac in Terrebonne Parish. Dulac is also an area within the Houma-Bayou-Cane-Thibodaux Metropolitan Statistical area. Using Landsat 8 satellite images, data was obtained using USGS Earth Explorer. The data was trained under supervised classification to extract features of relevance to the study. The results of the training of data produced four (4) classes. These classes were water, wetland, vegetation and built up. Each of the four classes were then assigned a false color composite to make identification easy and faster. The primary tool that was used for processing was QGIS software which resulted in the production of four maps. The NDVI maps were used to indicate areas with areas of high and low vegetation covers.

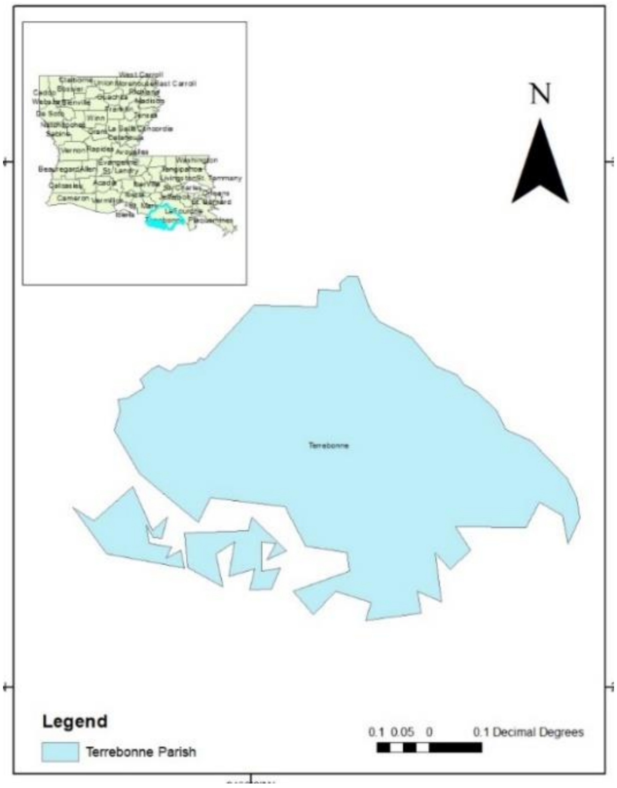
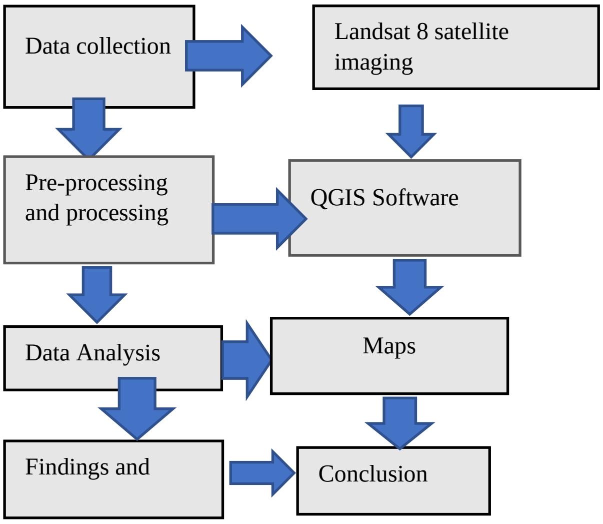


Fig.2 A map of Terrebonne Parish indicating the study area

2.1.1 Research frameworks



RESULTS AND DISCUSSION

The first classification map for 2014 showed that the area was largely comprised of wetlands. An estimated 60% of Dulac was covered by wetlands, 20% by vegetation, 15% by water and 5% by built ups as of 2014.There were few built up in Dulac, and these are mostly close to wetland and vegetated areas. The map shows that the area was still relatively intact in terms of wetland cover.

The second classification map showed that as of 2021, Dulac has seen a reduction in the area and number of wetlands. There is an increase in the area that is now covered by water and vegetation. About 40% of Dulac is estimated to be currently covered by wetlands, 25% by vegetation, 25% by water and 10% by built ups.

The maximum likelihood maps when compared shows there are more areas covered by vegetation (indicated by the red color) in the first map (2014) in comparison to the second map. This indicates that there was increase in the vegetation cover of Dulac in 2021 as compared to 2014. This result is affirmed by the NDVI maps which showed an index of 0.755 for 2014 and 0.795 for 2021. A greater NDVI indicates a higher vegetation cover hence 0.795 (2021) which is greater than 0.755 (2014) supports the result that the area has seen an increment in vegetation. The increase in vegetation may be attributed to introduction of new plant and algal species by ocean currents. Aquatic plants play crucial roles by actively regulating carbon. New remote-sensing technology promises to improve mapping, particularly for developing countries, where inventories are poorly developed, and wetlands have suffered the greatest losses in area since the 1950s (ICUN, 1996). Since the 1990s, satellite data have been increasingly used to map and document changes in wetland cover.

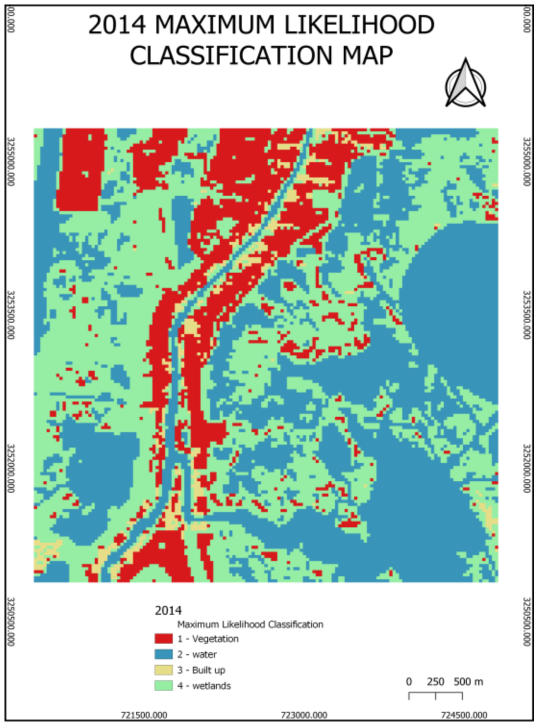


Fig.3 A 2014 map showing land use classes for Dulac

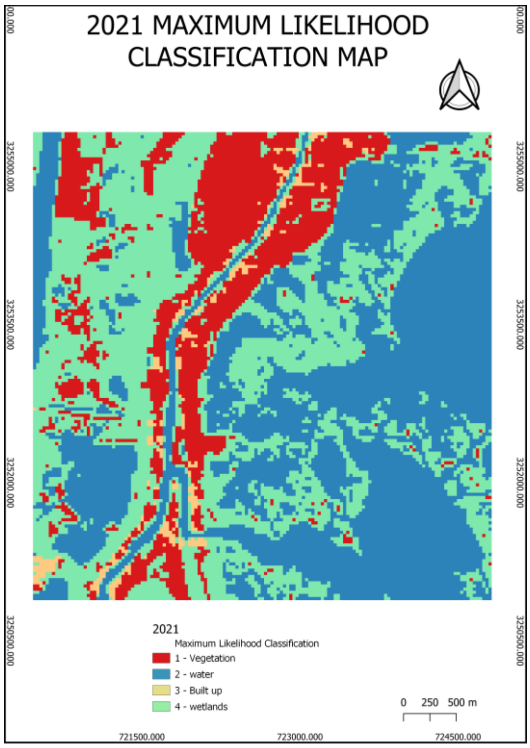


Fig.4 A 2021 map showing current land use classes for Dulac.

In 2021, the area also saw a slight increase in the number of built ups. The map shows that the area is losing wetlands at a relatively slow rate, and this is supported by findings by USGS, 2017. Between 2014-2021, the area has lost about 23% of its wetlands mainly due to coastal erosion. This can be attributed to sea level rise over the past few years. Louisiana has not been hit by any major subsequent hurricanes after Hurricane Katrina in 2005 and this is primarily believed to account for the decline in the wetland loss rate (USGS, 2017)

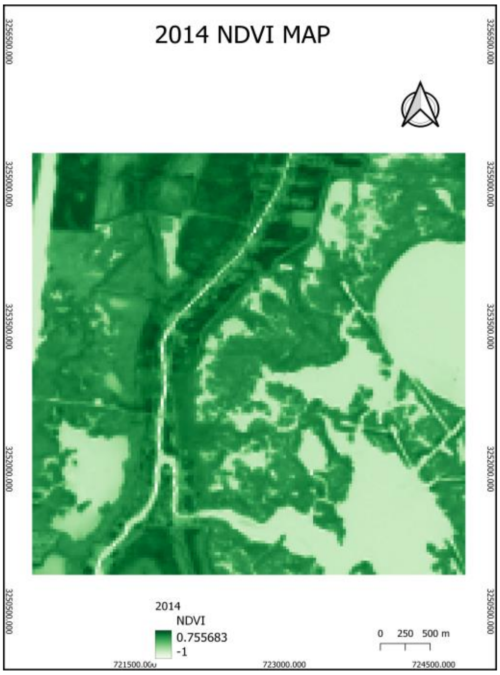


Fig.5 A 2014 map indicating the areas that were covered by vegetation at the time

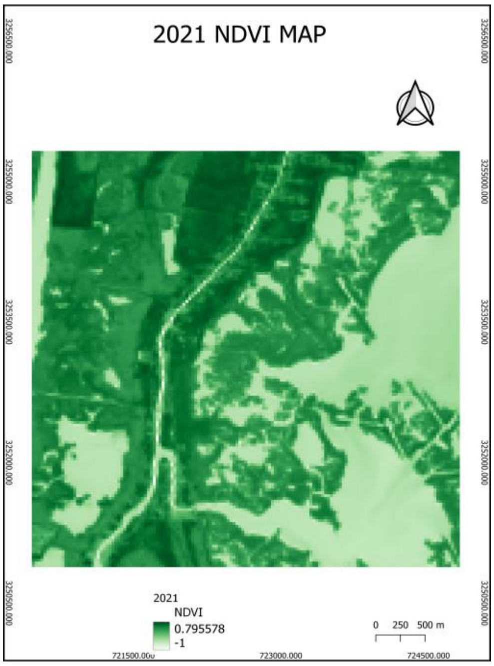


Fig.4 A 2021 map indicating the subtle increase in vegetation cover

3. CONCLUSION

There is more to be done to reduce wetland loss rates, restoration efforts should be focused on coastal wetlands that are at higher risk of loss annually. Although there is positive feedback from the results, there is still a need for further research. Further analysis can focus on determining whether the increase in vegetation is not primarily due to algal bloom. At the global scale, inventories of wetland areas by type are needed at 5-to-10-year intervals, using classification systems and methods that are congruent across nations. Currently, concise records on wetlands in Asia, Africa, Japan, Europe, the Pacific Islands, Australia, and South America (especially tropical and inland wetlands) are incomplete. Tropical Asia is specifically in need of records on its aquatic biodiversity. Even Great Britain with its massive history of research, lacks entire inventories of its coastal wetlands. Once similar and complete records and stock statistics are made available, quantification of losses and regional traits will be more efficient and dependable so that quotes of degradation and restoration may be well assessed so that wetlands emerge as the sole focus of regulation regimes.

GAPS FOR FUTURE RESEARCH

Comparative geospatial analysis of coastal land loss may be conducted to provide a better understanding of the most current prevalent causes of wetland loss and their implications for policymaking

A case study on the impact of wetland loss on coastal sediment transport may also be carried out for land management and restoration purposes

A comparative NDCI index study may be carried out to determine the distribution of vegetation and algal bloom in Dulac.

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