APPLICATION OF REMOTE SENSING IN MONITORING FOREST COVER CHANGE AND CARBON DIOXIDE LEVELS AT KISATCHIE NATIONAL FOREST OF LOUISIANA

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ABSTRACT:

It is estimated that the globe's forest has shrunk by 3% since 1990, an area equivalence to the geographical boundaries of South Africa. The Kisatchie National Forest of Louisiana replicates plentiful climatic, physiographic and edaphic differences in the country and this forest faces a serious problem of degradation and disturbance of different nature. Remote sensing from satellites offers the best way to observe these changes over time. This study will employ Landsat-8 satellite imagery to analyze forest cover change in Kisatchie National Forest from 2010 to 2020. The objectives of the study are to (i) identify the trend, nature, and the magnitude of forest cover change, (ii) prepare image maps delineating forest cover change for the duration of the study (iii) establish the trend of CO_2 levels within Kisatchie environs. Results showed a gain of forest cover within the Kisatchie National Forest which correlated to the rate of CO_2 sequestration by sinks. NDVI of 2010 was 0.65 compared to 0.86 for 2020 indicating a gain of 32% of forest cover since 2010. This showed how effective Protected areas are in conserving forest cover and restricting land uses that may disturb forest structure.

INTRODUCTION

The Earth is submerged in 70% of water, with only 30% being made of land. 31% of this landmass is purported to be forested. Forests play important roles in the survival of living creatures within their domain. They serve as homes to different plant and animal species and are diverse in their composition ranging from boreal forests in the north to the tropics of Africa, from the Pine plantations of New Zealand, evergreen rainforests, coniferous of Europe, the mixed deciduous of the northeastern of the United States and anywhere in between. These forests provide various resources and some services whose true value may not even be quantifiable. From firewood for heat generation to timber for so many purposes, food, recreation and invaluable services like carbon storage and oxygen release which humans and a lot of other organisms employ for energy generation.(C, 2019) These services highlight the obligation we have as humans to protect our forests considering the rate at which they are been lost to settlement, deforestation and other disturbances.

High amounts of carbon dioxide in our atmosphere means a lot of heat would be trapped, resulting in warming, which leads to climate change. Forests act as sinks for the collection and storage of carbon dioxide. When forest covers are lost, we lose part of the absorptive capacity and the forest cover loss returns further carbon dioxide into the atmosphere as these trees are made of carbon. The use of remotely sensed imagery and geospatial technologies present us with the key to observing, mapping and monitoring changes that occur within our forest. (Congalton, 2021). This is important for monitoring biodiversity and ensuring sustainable conservation. This would help to quantify cover loss, observe activities that degrade forest, estimate carbon, calculate forest lost rates emissions and provide recommendations for safeguarding these dynamic systems.

LITERATURE REVIEW

In 2010, Louisiana had 4.54-million-hectare meters (Mha) of natural forest, extending over 52% of its land area. In 2020, it lost 35.4kha of natural forest, equivalent to 18.2 million metric tonnes (Mt) of CO_2 of emissions. Deforestation poses the primary threat that governs global environmental changes. Forest cover and forest cover change have grown in importance with the need to quantify global timber stocks, modeling of global biogeochemical cycles and climate variability and for the assessment of threats to biodiversity and ecological integrity. (Potapov et al., 2008) Land covering change is a process of altering the biophysical state of the surface of the Earth and the immediate subsurface of the earth. (Oduro et al., 2021). Forest cover change is a function of land use, a process that combines how the biophysical attributes of the land are been altered or manipulated and the underlying reasons for which necessitated the manipulation. Even though different agents have accounted for the disturbances of forest cover in recent times, it is evident that anthropogenic influences have the maximum share in forest cover manipulation. Balanced use of forests correlates strongly with the type of business activity and careful management of forest ecosystems. (Bartalev et al., 2014)

Due to the increasing populations worldwide and urbanization in developed and developing countries, there has been high demands for lands. Hence, the clearing of lands to provide more food and for building places of shelter, there is the rising need to establish Protected Areas. The establishment of Protected Areas is one of the means to conserve forest and its associated ecological benefits including biodiversity preservation, hydrological conservation and carbon sequestration. PAs also provide scenic and aesthetic surroundings for recreation and tourism. (Dadhwal et al., 2010) Most PAs are established before stem forest removal by limiting land uses that would result in change thereby restricting any form of extraction.

The establishment of Protected Areas has proven to be an effective way over time and this has accelerated the setting up of PAs around the world. Protected Plant Report (2016) estimates PAs around the world to be around 202,467 which is projected to cover an area of 19.8 million km^2. With Aichi Biodiversity target 11 which is to ensure that at least 17% of terrestrial and inland water areas are conserved, at least 10% of coastal and marine areas are conserved. Areas of particular importance for biodiversity and ecosystem services are conserved and equitably managed to ensure connectedness to large seascape and landscape PAs are bound to extend across the face of the globe.(Gu et al., 1998) It is however intriguing to know that degradations of various magnitudes have been found in and around PAs from different researches. studies have found that forest degradation occurs near or even inside some PAs. From 1982 to 2000, approximately 70% of the surrounding buffers of forest cover adjacent to PAs have suffered disturbances resulting in loss, while 25% of PAs experienced deforestation within. Deforestation near and inside PAs is considered as one of the main causes aggravating the ecological services of these biodiversity arks which decreases the Aichi Biodiversity target 11 to achieve connectedness. (Fagundes et al., 2018)

The Kyoto Protocol intends to reduce CO_2 emissions levels and to ensure that emission is balanced out sinks such as forest cover. Forest clearance contributes to 20% of total carbon emissions. (IPCC 2007) Reducing Forest loss is therefore important in reducing the magnitude of emissions and subsequent effects. With protection being partly geared to address this, it is important to understand the extent to which PAs are subject to land-use change and understand whether improving effectiveness in management structure would lead to emission reduction by controlling deforestation and degradation. (Conservancy & Areas, 2020). By establishing the trend of carbon emission with forest cover loss it becomes easy to empower management in a direction to reduce cover loss and to control emissions.

The use of remotely sensed imagery and other geospatial technologies holds the key to our effective mapping and monitoring of our forests. Satellite technology provides a synoptic of forests and prevailing conditions in real-time. Satellite imagery serves importance in forest mapping, monitoring and roles that ecosystems play in ensuring survival through the relationship between reflectance properties and structural composition. (Rajendra et al., 2017). Mapping (from the context of this work) is the process of representing nature and the classification allows the estimation of their true conditions.

VEGETATION INDICES (VIS)

Vegetation indices (VIs) are essential for vegetation cover classification captured from the radiometric biophysical derivation and vegetation structure. Vegetation indices contribute to land use planning and natural resources management and provide information to policymaking. (Nguyen Trong et al., 2020). VIs is widely employed in monitoring forest cover by employing reflectance values obtained from satellite data. Satellite images are needed to prepare maps of VIs using the GIS software. An advantage of using satellite images to monitor forest cover is it provides you with data from different dates and with the help of the VIs it becomes easy to compare changes for a period.

Normalized Difference Vegetation Index (NDVI)

Normalized Difference Vegetation Index (NDVI) is an index of fauna greenness or an indication of photosynthetic activity. Healthy vegetation (chlorophyll) reflects more near-infrared (NIR) and green light compared to other wavelengths. But it absorbs more red and blue light. This is why our eyes see vegetation as the color green. If you could see near-infrared, then it would be strong for vegetation too. Satellite sensors like Landsat and Sentinel-2 both have the necessary bands with NIR and red. It is an easily calculated satellite image-based proxy that serves the basic purpose of expressing vegetation productivity. It works by producing a simple numerical indicator that is related with Photosynthetic Active Radiation (PAR) and gives information on the capacity of leaves(greenness) helping to measure the vegetative cover of a location. (Demirel et al., 2010; Kunkel, 2011). The index employs a positive numerical value to express correlation with plant biomass, Leaf Area Index (LAI), vegetation cover and photosynthetic capacity. NDVI is computed by the formula;

$$\text{NDVI} = \frac{NIR-RED}{NIR+RED}$$

NIR- Near Infrared; RED- red bands where NIR represents the spectral reflectance in near-infrared band while RED represents the red band. NDVI values range from -1 to 1. Low values of NDVI correlate to barren surfaces of rock, soil, cloud, waterbody, snow cover, etc.

Table 1 NDVI value range and correlation

NDVI value range	**Correlation**
-1	Waterbody

0	Bare Soil, sand, rock, snow cover, cloud
0.2-0.3	Shrub and Grassland
0.3-0.5	Sparsely distributed forest
>0.5	A dense and healthy forest

Source: *www.researchgate.net*

NDVI is easy to implement and interpret but limited by the flaws of interference from non-vegetative factors like atmospheric conditions, (cloud, aerosols, water vapor) satellite geometry and calibration.

The objective of this research was therefore to observe the trend of forest cover lost at the Kisatchie National Forest for each decade from 2010 to 2020. This would help to develop image maps to observe land-use types, forest cover loss in the Protected area. The Carbon trends would help to evaluate if the dynamics of forest cover change within the catchment has any effect on emission levels.

METHODOLOGY

Study Area

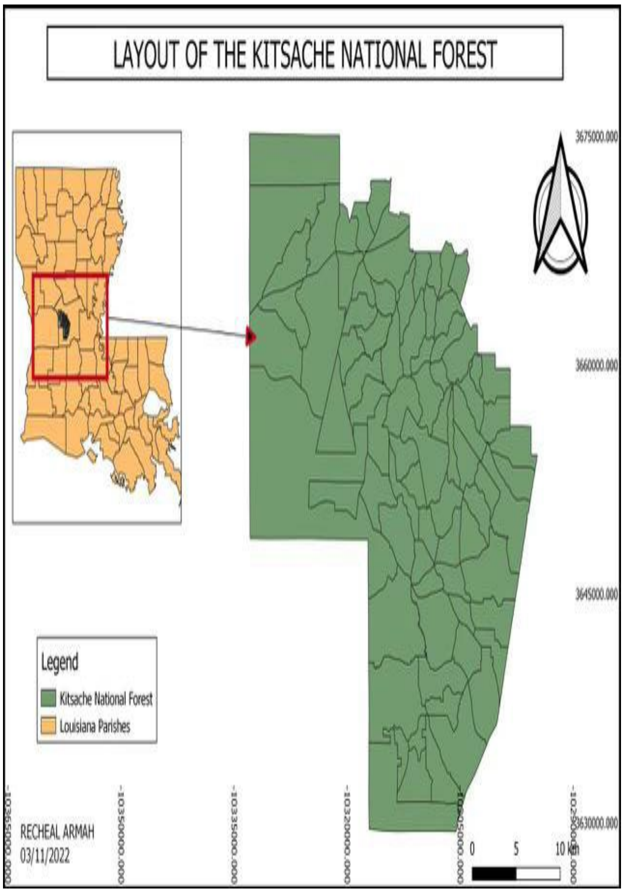


Fig 1: Map of study Kisatchie National Forest

The study area was selected in a strictly protected area named Kisatchie National Forest. It was established as a PA on the 10th of June 1930 and is the only forest cover found in Louisiana (Fig. 1) located in the forested piney hills and hardwood bottoms of seven central and northern parishes. It covers approximately, an area of 604,000 acres (2,440 km^2 of public land and with longleaf pine accounting for more than half the vegetation. It locates in 31^o 20' N to 12^o 00" N latitude and -92^o 24'W and 26^o 99" W longitude. It also serves as home to some of America's rare plants and animal species. The terrain across the forest is flat to gently rolling hills, with maximum elevations of approximately 400 feet MSL. The weather is temperate; summers are hot and humid and the winters are cool and mild with about 45 inches of rainfall annually.

Data Sources

Multitemporal clear, cloud-free Landsat images were downloaded for the area of study. The images were downloaded freely from QGIS version 3.22 using semi-automatic classification plug ins. The data for carbon emissions of the State of Louisiana was downloaded from the United States EPA Inventory of US's Green House Gas emissions and Sinks; an inventory site that seeks to establish a balance between carbon emissions and the sinks that exist for the absorption.

RESULTS AND DISCUSSIONS

NDVI

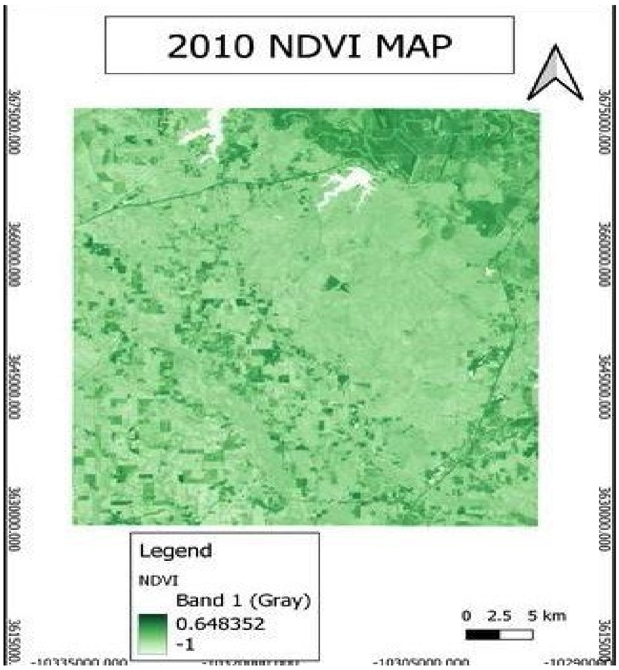


Fig 2: NDVI map of the study area (2010) (A)

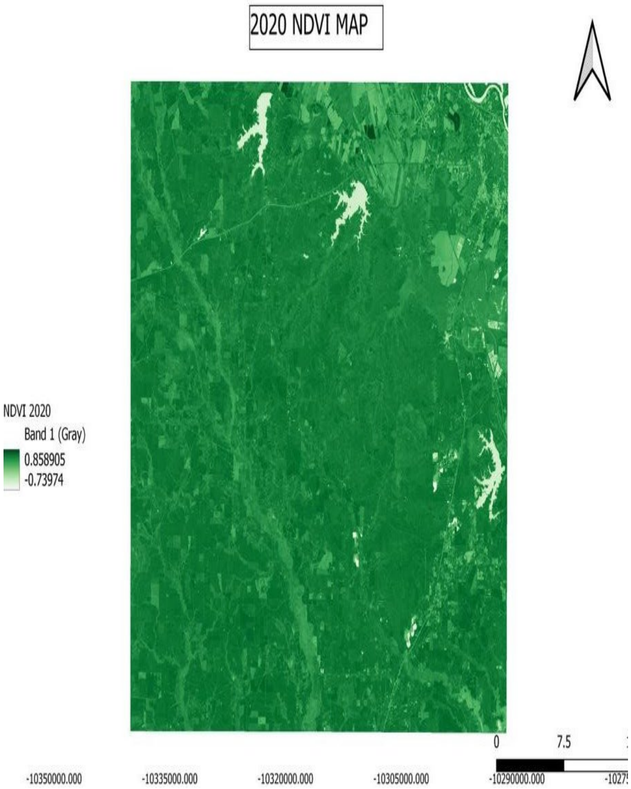
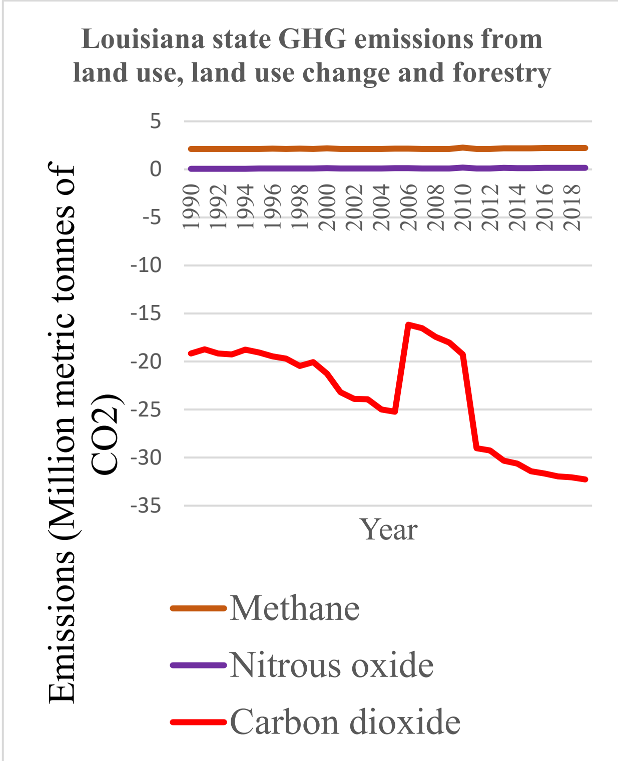


Fig 3: NDVI map of the study area (2020) (B)

NDVI value range	Year	Fig
-1 to 0.65	2010	A
-1 to 0.86	2020	B

The range of NDVI values in 2010 range from -1 to 0.65 and from -1 to 0.86 for 2020. High NDVI value correlates to high vegetation cover whilst low NDVI correlates to low vegetation density. Both NDVI maps indicate healthy vegetation within the Kisatchie forest (Table 1). The image values (Fig 2&3) indicate a positive change in forest cover change from 2010 to 2020. There has been an increase of 32% of forest cover since 2010 hence a gain of 2.1% each year.

Carbon emission



Carbon emissions from the US EPA Inventory of US's Green House Gas emissions and Sink (1990-2020) indicate that carbon sequestration in Louisiana has been high due to the increasing availability of sinks (wetlands, forest cover, water bodies, etc.). This has reduced the amount of carbon in the atmosphere. In 2010, 19.272 metric tonnes of CO_2 were sequestrated from the atmosphere by forests. In 2020, 32.267 metric tonnes of carbon were sequestrated by Louisiana's sinks. This upward trend of carbon removal from the atmosphere is an indication of gain in forest cover. Trees employ CO_2 photosynthesis thereby reducing the amount of carbon in the atmosphere, hence when there is forest cover gain, it is expected that atmospheric concentrations of carbon would reduce which correlates to the US EPA report. Kisatchie National Forest is influential in carbon sequestration within the region.

CONCLUSION

Forest degradation, has become a major concern around the world, especially in developing countries where the dependency on forests may be high. This study however ever provides data to back the effectiveness of protected area establishment. Though some available literature reports of forest loss even in protected areas, results of this research prove the importance of PAs in conserving biodiversity and limiting land uses within as forest cover was gained.

NDVI is a significant technique that can be easily employed in monitoring forest cover change, tree distribution across a landscape and land use monitoring. Results of NDVI indicated a gain of forest cover from 2010 to 2020 by 32%. This technique of NDVI could be useful in planning and policymaking.

Research must be conducted to find the extent of degradation surrounding the Kisatchie Forest as rapid degradations around the reserve would be detrimental. As the scope of this work only covered 2010 and 2020, more research must be done to examine the years between, to ascertain if this gain was gradual or only in 2020. This is since the impact of COVID-19 led to a temporal halt in a lot of sectors which could explain why forest cover was gained if the change was only reported in 2020.

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