USING REMOTE SENSING TO DETECT FOREST COVER CHANGE IN SAM HOUSTON NATIONAL FOREST, TEXAS

Recheal Naa Dedei Armah[a] *, Z.H. Ning[a], M. Anokye[a], Y.A. Twumasi[a], C.Y, Apraku[a], D.B. Frimpong[a], A. B. Asare-Ansah[a], P.M. Loh[a], F. Owusu[a]

a Southern University A&M College, Baton Rouge, LA, Department of Urban Forestry and Natural Resources- (recheal.armah, yaw.twumasi, zhu.ning, caroline.apraku, matilda.anokye, diana.frimpong, abena.asare-ansah, priscilla.loh, faustina.owusu)@sus.edu

KEYWORDS: Remote sensing, Forest cover, Vegetation Indices, Hansen Global Forest Cover Data Set, I-Tree

ABSTRACT

The Sam Houston National Forest is a large, forested area in Texas that has experienced significant land-use changes over the past few decades. The study area replicates plentiful climatic, physiographic, and edaphic differences in the country and this forest faces a serious problem of degradation and disturbance of different nature. In this study, we utilized remote sensing technology specifically Landsat 4 ETM and Landsat 8 from USGS Earth Explorer with spatial resolution 30 m, to analyze forest cover change in Sam Houston National Forest from 2001 to 2020. We also employed the Hansen Global Forest Cover Data from the Google Earth Engine Catalogue to assess the forest cover loss and gain within the study period. Also, the i-Tree software was used to estimate carbon sequestration in the forest and assess the potential benefits of forest management practices. Results of the study showed that the Sam Houston National Forest has experienced a net loss of forest cover over the past few decades, primarily due to agricultural expansion and urbanization. However, the forest has also shown signs of regrowth and recovery in certain areas, highlighting the potential for effective forest management practices to promote carbon sequestration and conservation. Overall, our study highlights the importance of remote sensing technology for understanding forest cover change and its implications for carbon sequestration and climate change mitigation.

1.0 INTRODUCTION

Monitoring changes in forest cover is critical for assessing the health and sustainability of forest ecosystems, as well as the services they provide, such as watershed protection, climate change mitigation, and soil erosion prevention (Tsai et al, 2019). In recent years, remote sensing has emerged as a powerful tool for detecting and monitoring forest cover change over large areas. (Gross et al., 2009). The release of the Landsat archive by the United States Geological Survey, which contains more than 2 million satellite images of the Earth's surface dating back to 1972, has changed the standards for the availability of Earth observation data and contributed to the rise of forests as the present-day most popular large-area monitoring target. (Lui et al., 2015). In this study, we used remote sensing techniques to detect forest cover change in the Sam Houston National Forest in Texas.

The Sam Houston National Forest is a large, forested area in Texas that has experienced significant land-use changes over the past few decades. The study area replicates plentiful climatic, physiographic, and edaphic differences in the country. The forest also provides important ecological services such as carbon sequestration, biodiversity conservation and water regulation. However, the forest is facing various threats, including deforestation, wildfire, and land-use change. Therefore, it is crucial to monitor forest cover change in this region to support sustainable forest management practices and conservation efforts.

2.0 LITERATURE REVIEW

The USDA Forest Service oversees managing the 163, 037-acre Sam Houston National Forest (SHNF), which is in southeast Texas between Huntsville, Conroe, Cleveland, and Richards. In addition to being a significant supplier of timber, recreation, and other ecosystem services, the forest provides a vital habitat for a variety of wildlife species (USDA Forest Service, 2021). Deforestation, land use change, and wildfires are a few of the dangers the forest faces, and through time they have significantly altered the forest's land cover (Rudolph et al., 991).

Land covering change is a procedure that modifies the biophysical state of the Earth's surface and its immediate subsurface (Armah et al., 2022). Forest cover change is a result of land use, a process that includes how the biophysical characteristics of the land are altered or managed with the underlying reasons that made the manipulation necessary.

Even though a variety of factors have been implicated in recent forest cover disruptions, anthropogenic factors account for most of this manipulation. (Armah et al., 2022). In the SHNF, human activities such as timber harvesting, urbanization, and oil and gas extraction have contributed to land cover change (Anderson et al., 2002). The forest has also experienced natural disturbances such as wildfires and insect outbreaks, which have caused significant changes to the forest's land cover (USDA, 2021). Several studies have used remote sensing techniques to examine land cover change in forest areas. Many researchers have made use of the efficiency of satellite-derived data in developing land use/cover maps and identifying changes in the terrain over time (Alrababah et al., 2006). The global multispectral remote sensing tools Landsat measures the quantity of energy reflected and emitted by a variety of terrestrial objects, including vegetation, water, rocks, and structures, across several electromagnetic spectrum bands. The Landsat data's extensive area and consistent coverage are two of its most notable features. Scientific researchers now have access to useful imagery from Landsat that may be used for monitoring surface hydrology, agricultural activity, and vegetation cover conditions on land (Alrababah et al., 2006). The Hansen global forest change dataset is a time-series analysis of high (30m) spatial resolution Landsat (Remotely Sensed) pictures designed to record the amount and change of the world's forests between 2000 and 2012. (Hansen et al. 2013). According to Hansen, et al. (2013), "a stand-replacement disturbance or the complete removal of tree cover canopy at the Landsat pixel scale" is what they refer to as forest loss in their study. The creation of a tree canopy from a non-forest state, or the reversal of loss, was described as "forest gain." The Hansen global forest change dataset offers a clear, open, and consistent framework for quantifying important aspects of changing forest cover. These features of the dataset have encouraged scientific community investigation into studies connected to forest cover.

3.0 METHODOLOGY

3.1 Study Area

The Sam Houston National Forest, one of Texas' four national forests, is 50 miles north of Houston. Between Huntsville, Conroe, Cleveland, and Richards, Texas. The forest is interspersed with.

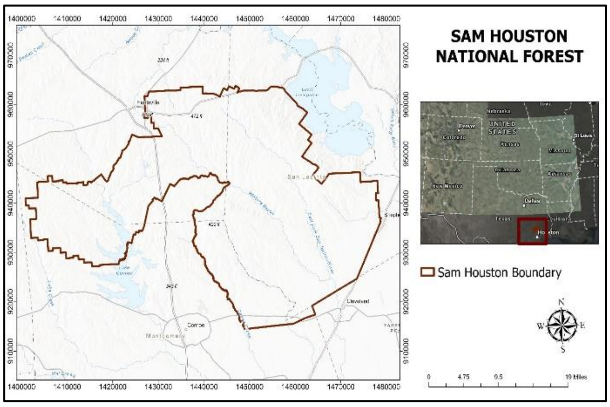

Figure 1. Sam Houston National Forest

privately held timber properties and small farms in Montgomery, Walker, and San Jacinto counties. It covers an area of 163,037 acres (about the area of Austin, Texas). The forest may be found at the coordinates 30.5413344°N, -95.3504978°W. It is home to various species of plants, animals, and birds, many of which are unique to the region. The forest's diverse habitats, including pine-hardwood forests, bottomland hardwoods, and wetlands, provide a unique opportunity for researchers to study various ecosystems and their functioning.

3.2 Vegetation Indices

Vegetation indices (VI's) are crucial for the classification of the vegetation cover derived from the radiometric biophysical derivation and the vegetation structure. The management of natural resources and the planning of land use are both aided by vegetation indices, which also give information for policymaking. (Armah et al., 2022). VIs is commonly used to monitor forest cover by using reflectance values derived from satellite data. Satellite pictures are required to create VI maps using GIS software. One advantage of utilizing satellite photos to monitor forest cover is that it offers data from many dates, making it possible to compare changes over time.

The Normalized Difference Vegetation Index (NDVI) is an indicator of photosynthetic activity or an index of fauna greenness. When compared to other wavelengths, healthy vegetation (chlorophyll) reflects more near-infrared (NIR) and green light. It does, however, absorb more red and blue light. This is why vegetation seems green to human sight. It would be strong for vegetation if you could see near-infrared. Satellite sensors such as Landsat and Sentinel-2 have the required NIR and red bands. It is a simple satellite image-based proxy that serves the primary aim of expressing vegetation productivity. It operates by generating a simple numerical indicator that is related to Photosynthetic Active Radiation (PAR) and provides information on the capacity of leaves (greenness), assisting in the measurement of a location's vegetative cover. (Demirel et al., 2010). The indicator uses a positive numerical value to express association with plant biomass, Leaf Area indicator (LAI), vegetation cover, and photosynthetic capacity. NDVI is computed by the formular.

$$\text{NDVI} = \frac{NIR-RED}{NIR+RED} \qquad (1)$$

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. The shortcomings of interference from non-vegetative elements including atmospheric conditions, (cloud, aerosols, water vapor), satellite geometry and calibration, make NDVI difficult to use and comprehend.

The objective of this study was to identify the trend of declining forest cover in the Sam Houston National Forest over the course of each decade, from 2000 to 2021. This would make it easier to create picture maps that show different types of land use and forest cover decline in the Protected area.

3.3 i-TREE

i-Tree is a suite of tools and applications that were developed by the United States Forest Service to help urban foresters, arborists, and other stakeholders to assess and manage urban forests. The i-Tree tools are designed to provide information on the structure, function, and value of urban forests, including information on ecosystem services, carbon sequestration, and air pollution removal (McPherson et al., 2012). These tools, which were initially released in 2006 and were created to function in the US, are now used by both professional and non-professional users in more than 130 different nations, including universities, regular people, schools, land managers, and foresters. (Nowak et al., 2018).

The vision of i-Tree is to promote forest and human health using simple technology that engages people all around the world in improving forest management and resilience. To achieve this objective, i-Tree continues to build tools that will allow anyone to readily assess:

- Local forest conditions
- Ecosystem services and values derived from forests.
- Local risks to forest and human health
- How changes in forest structure will lead to changes and tradeoffs among ecosystem services and values
- Best locations, tree species and planting rates to optimize ecosystem services and values through time and across space to enhance human health and well-being (Nowak et al., 2018)

In this paper, the I-Tree was used to was used to estimate carbon sequestration in the forest and assess the potential benefits of forest management practices.

3.4 Data Sources

Landsat 4 and 8 were used to assess the forest cover change over the study period. The images were assessed through the Landsat Collection in the Google Earth Engine Data Catalogue. The Google Earth Engine (GEE) is a cloud computing platform designed to store and process huge data sets (at petabyte-scale) for analysis and ultimate decision making (Mutanga & Kumar, 2019). These two satellite sensors have a 30 m spatial resolution with a temporal resolution of 16 days. Landsat 4 was used to assess the period between 2001 to 2012 and Landsat 8 covered the years 2013 to 2021. This was because of the early launch date of Landsat 4 to supplement the years that Landsat 8 did not cover. The Hansen et al. (2013) Global Forest Change dataset in Earth Engine represents forest change, at 30 meters resolution, globally, between 2000 and 2014. This dataset was employed to look at the forest cover loss and gain in the study area.

4.0 RESULTS AND DISCUSSIONS

4.1 Forest Cover

The NDVI was used to map the forest areas showing different levels of vegetation. The areas with the deeper shade of green shows dense vegetation cover whereas, the areas with the light shade of green show sparse vegetation. Some areas on the map had white and gray patches. These areas are non-vegetative areas and could be bare lands, waterbodies, or impervious surfaces.

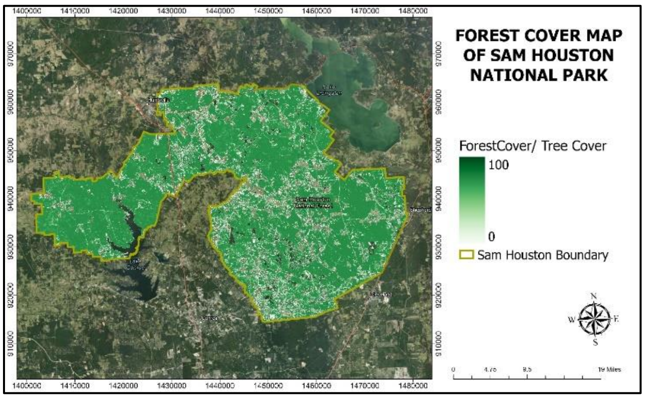

Figure 2. Forest Cover Map of Sam Houston

4.2. Forest cover loss

The map below shows the forest cover loss from 2000 to 2021. This result was obtained using the Hansen Global Forest Cover Change Data Set to show the areas that had lost cover in the forest. Forest loss was defined as a stand-replacement disturbance or the complete removal of tree cover canopy at the Landsat pixel scale (Hansen et al., 2013). The orange patches on the map to the left shows areas that had lost cover only. The map on the right was obtained by overlaying the forest cover loss layer on the forest cover layer. The final map of the forest covers loss shows areas with dense vegetation, non-vegetative areas, sparse vegetation, and areas that loss forest cover within that period. Areas with the shade of green shows vegetative areas whereas the areas with the orange patches are areas that experienced loss.

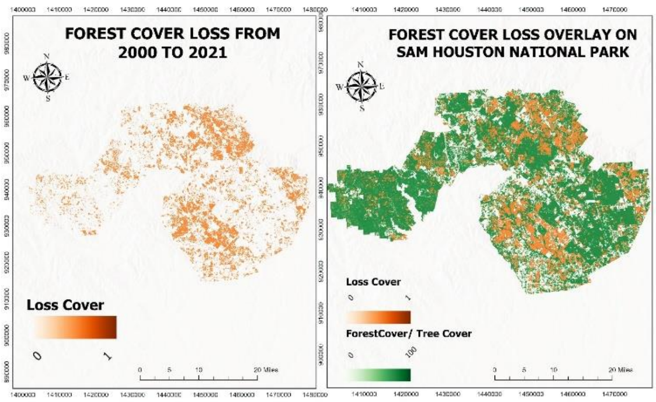

Figure 3. Forest Cover Loss Map of Sam Houston

4.3. Forest cover gain

The map below shows the forest cover loss from 2000 to 2021. This result was obtained using the Hansen Global Forest Cover Change Data Set to show the areas that had lost cover in the forest. The purple patches on the map to the left show areas that had gained cover only. The map on the right was obtained by overlaying the forest cover gain layer on the forest cover layer. The final map of the forest covers gain shows areas with dense vegetation, non-vegetative areas, sparse vegetation, and areas that gained forest cover within that period. Areas with the shade of green shows vegetative areas whereas the areas with the purple patches are areas that experienced gain.

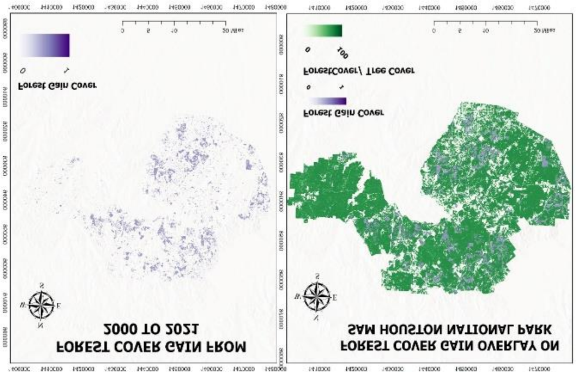

Figure 4. Forest Cover Gain Map of Sam Houston

4.4 Recovering areas.

Superimposing Hansen derived forest loss and gain shows areas that have lost forest cover and have over the years regained. These areas may have been taunted with urbanization projects, deforestation, and inadvertent wildfires; however, reforestation and tree care and management activities may have helped these areas to regain their vegetation cover. Figure 5. shows recovering areas that have lost and gained forest cover over the study period.

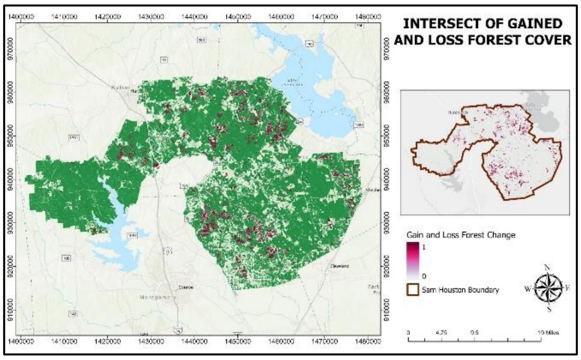

Figure 5. Forest Cover Loss and Gain Map of Sam Houston

4.5 Spatio-temporal Forest Cover Change

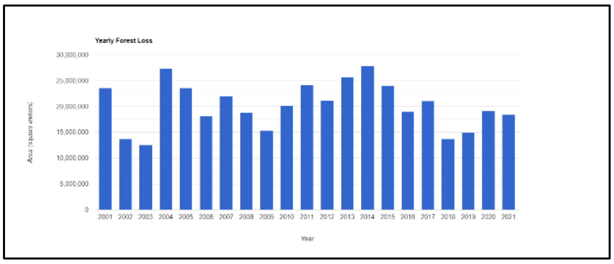

Figure 6. Forest Cover Change trend between 2001 to 2021

The graph above shows the graphical representation of the Spatio-temporal changes in the forest cover over the study period. It can clearly be seen that the area coverage (square meters) has seen changes over the study period. The years 2002 and 2003 saw massive forest cover loss which was not captured in literature to confirm the reason for the loss. However, the Sam Houston National Forest has seen urban developments for recreational activities over the years. There could have also been other environmental stressors that could have caused this loss such as forest wildfire, droughts, etc.

4.6 iTree - Canopy Survey

The iTree – canopy tool was used to classify Sam Houston Forest National Park using random sampling of aerial imagery. By uploading the shapefile of the study area, the i-Tree Canopy randomly generates sample points and zooms to each one so you can choose from your pre-defined list of cover types for that spot. With i-Tree Canopy, you review Google Maps aerial photography at random points to conduct a cover assessment within a defined project area.

A total of 500 points were surveyed as the more points you complete, the better your cover estimate for your study area. By estimating tree cover, tree benefits can also be estimated. From this classification of points, a statistical estimate of the amount or percent cover in each cover class can be calculated along with an estimate of uncertainty of the estimate (standard error (SE)). A total of seven glasses were generated for this iTree project as shown in Figure 7. Table 1 below shows the areas covered by each of these classes with Tree/Shrub covering the largest area, followed by Grass/ Herbaceous (*I-Tree Canopy*, n.d.).

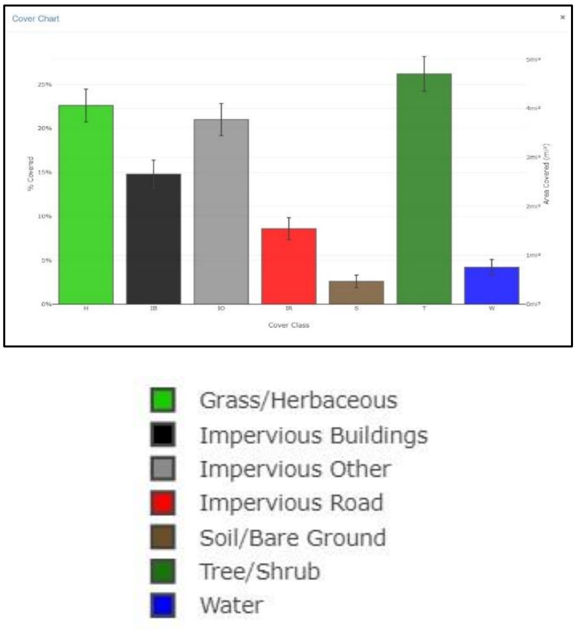

Figure 7. iTree Land Cover Classes of the Sam Houston National Forest

Table 1. Land Cover Classes showing the Standard error and area covered at Sam Houston National Forest

Abbr.	Cover Class	Points	% Cover ± SE	Area (mi²) ± SE
H	Grass/Herbaceous	113		4.06 ± 0.34
IB	Impervious Buildings	74	14.80 ± 1.59	2.66 ± 0.29
IO	Impervious Other	105	21.00 ± 1.82	3.78 ± 0.33
IR	Impervious Road	43	8.60 ± 1.25	1.55 ± 0.23
S	Soil/Bare Ground	13	2.60 ± 0.71	0.47 ± 0.13
T	Tree/Shrub		26.20 ± 1.97	4.71 ± 0.35
W	Water	21	4.20 ± 0.90	0.76 ± 0.16
Total		131 500	100	22.60[illegible]

An analysis of the tree cover using the iTree canopy survey can be used to estimate the various benefits attributed to trees across the Sam Houston National Park by assessing their role in easing air pollution, stormwater management, and carbon absorption. The percentage of tree cover is used to provide amounts and monetary value of Carbon Monoxide removed annually, Nitrogen Dioxide removed annually, Ozone removed annually, PM10* Particulate Matter greater than 2.5 microns and less than 10 microns removed annually, PM2.5 Particulate Matter less than 2.5 microns removed annually, Sulfur Dioxide removed annually, Carbon Dioxide sequestered annually in trees, Carbon Dioxide stored in trees (*I-Tree Canopy*, n.d.).

Table 2. Carbon and CO_2 estimates stored and sequestered by trees respectively at Sam Houston

Carbon	Carbon (kT)	±SE	CO_2 Equiv. (kT)	±SE	Value (USD)	±SE
Sequestered annually in trees	3.21	±0.24	11.79	±0.88	$548,166	±41,144
Stored in trees	103.35	±7.76	378.94	±28.44	$17,625,735	±1,322,939

The currency is in USD and rounded. The amount of carbon dioxide sequestered is based on 0.682 kT of Carbon, or 2.502 kT of CO_2, per mi²/yr and rounded. The amount of carbon stored is based on 21.940 kT of Carbon, or 80.446 kT of CO_2, per mi² and rounded. (English units: kT = kilotons (1,000 tons), mi² = square miles) (I-Tree Canopy, n.d.).

Table 3. Tree Benefits Estimate of Air Pollution removed annually at Sam Houston National Forest

Abbr.	Pollutant (removed anaually)	Amount (T)	±SE	Value (USD)	±SE
CO	Carbon Monoxide	3.28	±0.25	$2,042	±153
NO2	Nitrogen Dioxide	8.12	±0.61	$1,956	±147
O3	Ozone	57.37	±4.31	$77,040	±5,782
SO2	Sulfur Dioxide	1.54	±0.12	$120	±9
PM2.5	Particulate Matter < 2.5 microns	2.85	±0.21	$156,116	±11,718
PM10*	Particulate Matter > 2.5 microns and < 10 microns	7.97	±0.60	$26,901	±2,019
Total		**81.12**	**±6.09**	**$264,175**	**±19,828**

6.0 CONCLUSION

The Sam Houston National Forest has experienced a significant land use change over the years. This study, however, 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 some areas experienced. 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 vegetative and non-vegetative areas. The Hansens Global Change Data set was employed to show areas that gained and areas that lost cover. This could be useful in planning and policy making as well as implementation of management strategies. The I-Tree was used to estimate the benefits of the Forest. Research must be conducted in this area to provide evidence or literature to support future findings.

7.0 ACKNOWLEDGEMENTS

The authors would like to acknowledge the USDA National Institute of Food and Agriculture (NIFA) McIntire Stennis Forestry Research Program funded project with award number NI22MSCFRXXXG077. We would also like to thank the American Society for Photogrammetry and Remote Sensing (ASPRS) Foundation for providing a grant to present this paper at the summer 2023 ASPRS International Technical Virtual Symposium

8.0 REFERENCES

Alrababah, M. A., & Alhamad, M. N. (2006). Land use/cover classification of arid and semi-arid Mediterranean landscapes using Landsat ETM. *International journal of remote sensing*, *27*(13), 2703-2718.

Anderson, S. P., Corsi, R., Banks, J., Kinney, K., & Sarwar, M. G. (2002). Non-Point Source Ammonia Emissions in Texas: Estimation Methods, Pitfalls, Corrections, and Comparisons.

Armah, R. N. D., Twumasi, Y. A., Ning, Z. H., Apraku, C. Y., Anokye, M., Frimpong, D. B., ... & Owusu, F. (2022). Application of Remote Sensing in Monitoring Forest Cover Change and Carbon Dioxide Levels at Kisatchie National Forest of Louisiana. *The International Archives of Photogrammetry, Remote Sensing and Spatial Information Sciences*, *46*, 27-32.

Demirel, H., Ozcinar, C., & Anbarjafari, G., (2010). Satellite image contrast enhancement using discrete wavelet transform and singular value decomposition, IEEE Geosciences and remote sensing letters, 7 (2), pp. 333-337

Gross, J. E., Goetz, S. J., & Cihlar, J. (2009). Application of remote sensing to parks and protected area monitoring: Introduction to the special issue. *Remote Sensing of Environment*, *113*(7), 1343-1345.

Nowak, D. J., Maco, S., & Binkley, M. J. A. C. (2018). i-Tree: Global tools to assess tree benefits and risks to improve forest management. *Arboricultural Consultant*, *51*(4), 10-13.

Rudolph, D. C., & Conner, R. N. (1991). Cavity tree selection by red-cockaded woodpeckers in relation to tree age. *The Wilson Bulletin*, 458-467.

Rudolph, D. C., & Conner, R. N. (1991). Cavity tree selection by red-cockaded woodpeckers in relation to tree age. *The Wilson Bulletin*, 458-467.

https://www.fs.usda.gov/detail/texas/about-forest/districts/?cid=fswdev3_008443

Hansen, M. C., Potapov, P. V., Moore, R., Hancher, M., Turubanova, S. A., Tyukavina, A., Thau, D., Stehman, S. V., Goetz, S. J., Loveland, T. R., Kommareddy, A., Egorov, A., Chini, L., Justice, C. O., & Townshend, J. R. G. (2013). High-Resolution Global Maps of 21st-Century Forest Cover Change. *Science*, *342*(6160), 850–853. https://doi.org/10.1126/science.1244693

Mutanga, O., & Kumar, L. (2019). Google Earth Engine Applications. *Remote Sensing*, *11*(5), 591. https://doi.org/10.3390/rs11050591

i-Tree Canopy. (n.d.). Retrieved May 6, 2023, from https://canopy.itreetools.org/report.