**NASA DEVELOP National Program**



Mobile County Health Department

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Natchez Trace Ecological Forecasting

and Water Resources

Utilizing NASA Earth Observations to Assess Current and Historic Wetlands Extent along the Natchez Trace Parkway

 **Technical Report**

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# I. Abstract

This project partnered with the National Park Service (NPS) to produce needed land cover mapping products for the Natchez Trace Parkway and to address community concerns involving the past, current, and future wetland conditions of this area. The parkway occurs in Mississippi, Alabama, and Tennessee. Beavers have altered current and historic wetland conditions in the study area by changing streamflow along adjacent rivers and tributaries. While the ecological services provided by these beavers can benefit wetland ecosystems, indiscriminate and excessive dam building has caused issues with flooding, property damage, and road maintenance within the parkway. NASA Earth observations (Landsat 5 TM, 7 ETM+, and 8 OLI) and ERDAS IMAGINE were used to generate a time series of land use/land cover (LULC) classification maps from October 1992 to January 2015 showing wetland status occurring along the parkway. A projected LULC classification map was also produced using TerrSet LCM software. This LULC time series and modeled projection will aid the NPS in wetland conservation and beaver management plans throughout the Natchez Trace Parkway.

**Keywords**

Wetlands, Beavers, *Castor canadensis*, Natchez Trace Parkway, Landsat, Land cover, TerrSet Land Change Modeler, ERDAS Imagine 2015, ArcGIS 10.3

# II. Introduction

**Background**

Wetlands are a critical natural resource for species diversity and ecological services. They improve water quality through filtration, store excess stormwater runoff, and provide necessary habitats for thousands of species of reptiles, fish, birds, amphibians, mammals, and plants (EPA, 2001; EPA, 2002). The Natchez Trace Parkway contains many wetland ecosystems, including streams, ponds, lakes, and riparian woodlands, with swamps and bayous stemming from nearby rivers within its southern, lower-elevation regions (National Park Service, 2015). The parkway is managed by the National Park Service (NPS) and averages 800 feet wide, spanning 444 miles across Mississippi and into portions of Alabama and Tennessee. The Natchez Trace functions as a greenway habitat corridor for hundreds of species throughout the parkway (NPS, 2015).

Beavers (*Castor canadensis*) are a keystone species for wetland ecosystems. Beaver dams create ponds and slow stream currents which improves habitat conditions for aquatic species and connection between water bodies (Baldwin, 2013). Balancing beaver populations in wetland parks is a significant part of proper land use management and conservation planning (Baker & Hill, 2003). Beaver populations and their damming behavior along the Natchez Trace Parkway have had an increasing impact on wetland extent, river and streamflow, flooding, road maintenance, and private land quality (Deanna Boensch, personal communication, September 14, 2015). The NPS manages beaver dams with levelers (which allow water flow below dams), dismantling and removing dams, and trapping beavers. These methods are used as needed for parkway maintenance and in response to nearby private landowner complaints. The NPS is in the process of conducting an environmental impact assessment to determine best management practices to balance parkway quality, habitat preservation, and conservation planning (D. Boensch, personal communication, September 14, 2015).

**Objectives**

The objective of this project was to collaborate with the NPS to address community concerns involving shifting wetland extents as a result of beaver damming activity along the Natchez Trace Parkway, causing damage to roads, property, and private lands. NASA Earth observations data were used to produce a time series of land use/land cover (LULC) classification maps for wetlands along the parkway. This time series used the years 1992, 2002, and 2015 to show changing wetland conditions along the parkway throughout the past 23 years. A wetlands extent prediction map was generated using the TerrSet Land Change Modeler (LCM). This model used the land cover classifications for 1992 and 2015 to produce a map of projected land cover changes by the year 2020.



**Study Area**

The project study area included wetland extents within a 25 km buffered region around the Natchez Trace Parkway boundary (Fig. 1). Our study area included the buffered portion of the parkway contained within the Landsat path 22, using rows 36, 37, and 38, which stretched throughout Mississippi and into portions of Alabama and Tennessee.



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| Figure 1: Study area containing the portion of the parkway within Landsat path 22. |

**Study Period**

The study period ranged from October 1992 to January 2020. Landsat 5 Thematic Mapper (TM), Landsat 7 Enhanced Thematic Mapper Plus (ETM+), and Landsat 8 Operational Land Imager (OLI) data for the LULC classifications were collected incrementally for the years 1992 through 2015. USGS National Land Cover Database (NLCD) data were collected for the selected years between 1992 and 2011. Google Earth imagery were used for the selected years between 2002 and 2015. The TerrSet LCM produced expected land cover change by January 2020.

**National Applications Addressed**

This project addressed the Ecological Forecasting application area, which focuses on issues requiring the modeling and analysis of ecosystems to promote the management of ecological resources. The Water Resources application area, which focuses on the availability, supply, and quality of water, was also addressed with this project.

A land use/land cover classification time series for the Natchez Trace Parkway was provided showing wetland extents changes from 1992 to 2015. A prediction map showing future wetland extents was also produced in this same study area. This time series and prediction map will aid in the management of wetlands preservation, beaver populations, and parkway maintenance.

**Project Partners**

The project partner for this study was the National Park Service (NPS). Quality of roads, property, and parkway land are important concerns for maintenance. Current practices involve the management of beaver populations along the parkway in efforts to reduce the negative impacts of beaver dams (such as flooding, forest destruction, and changing river flow). Before this project, no products showing the recent historic or projected wetland extents specific to the parkway were available for the NPS to incorporate into management plans. The time series provides historical perspective on shifting trends in wetland extent changes, while the prediction map shows a modeled projection of potential wetland extents. These products will assist the NPS with wetlands conservation and management in current and future plans.

# III. Methodology

**Data Acquisition**

Landsat 5 TM, 7 ETM+, and 8 OLI data were collected from the USGS LandsatLook Viewer and EarthExplorer as level 1 GEOTIFF files for the LULC time series classification. Data were collected for leaf-on and leaf-off months for each year of interest (1992, 2002, and 2015). 1992 used the months December and October; 2002 used January 2002 and May 2001; and 2015 used February 2015 and November 2014.

Land cover data for accuracy assessment were collected from the USGS NLCD Multi-Resolution Land Characteristics Consortium (MRLC) for 1992, 2001, and 2011. Google Earth imagery for the dates 1994, 2004, and 2015 was also used for accuracy assessment.

Vector data for national parkways, roads, and state boundaries were downloaded from the USGS National Map Viewer for 2015. National hydrography data for 2015 were also collected from the USGS National Map Viewer. Deanna Boensch, the Natural Resource Specialist for the NPS for the Natchez Trace Parkway, provided a point layer of field-checked beaver dams along the parkway.

**Data Processing**

The LULC time series classifications were produced using Landsat 5 TM data for December and October 1992; Landsat 7 ETM+ data were used for May 2001 and January 2002; Landsat 8 OLI data were used for November 2014 and February 2015. Three Landsat scenes within satellite path 22 (rows 36, 37, and 38) were used to cover the extent of the study area.

The imagery was processed using DEVELOP National Program Python Package (dnppy) functions to calculate the top of atmosphere (TOA) reflectance and apply atmospheric corrections. Each Landsat date was stacked using the visible red, near-infrared, and shortwave infrared bands (Horler & Ahern, 1985). The leaf-on and leaf-off dates for each year of interest were stacked into a composite image that was used in the classification process.

ArcMap 10.3.1 was used to mosaic Landsat scenes for all months and clip them to the 25 km buffered extent of the study area. This buffered extent was used to improve accuracy during the classification process. ArcMap was also used to re-project all data to match the Landsat imagery projection (WGS 1984 UTM Zone 16N). After all processing, the classified time series maps and prediction map were clipped to a 500 meter buffered region around the parkway boundary to show land adjacent to the parkway.

**Data Analysis**

The LULC time series maps were created by classifying the land cover for each selected year within the study period (1992, 2002, and 2015). Each LULC classification was performed in ERDAS Imagine 2015 using an unsupervised classification process coupled with a cluster-busting method. Similar spectral signatures were converged into 35 classes using an unsupervised ISODATA classification. Afterward, classes which contained dissimilar sub-classes (“confused” classes) were determined.

Cluster-busting involved creating a mask in ERDAS to remove non-confused classes from the classified image. Another unsupervised ISODATA classification using 35 classes was performed on the confused classes to further refine the classification. The classes for the initial unconfused classes image and the “cluster-busted” image were then combined into 9 categories: woody wetlands, non-woody wetlands, coniferous forest, deciduous forest, mixed forest, agriculture land, bare soil, developed, and open water.

For the accuracy assessment, 180 randomly generated points (20 points for each class) were checked against Google Earth imagery and NLCD data to determine the accuracy for each classification (1992, 2002, and 2015) (Appendix I, Table 1). Points generated for classes which were not present in a year’s classification were removed from the random points. For example, no open water was classified for 1992; these 20 points were removed for the assessment, making the total points 160 for this year (Appendix I, Table 2).

We used the accuracy report to produce an error matrix, which compared the amount of random points that were correctly classified against points that were incorrectly classified. The accuracy report also produced a user’s and producer’s accuracy percentage for each class. An accuracy table was created from the error matrix to determine the total percent accuracy of each year’s land cover classification (Appendix I, Tables 2-4).

The prediction map was produced using the TerrSet LCM software. The LCM used the beginning date (1992) and the end date (2015) classified images to generate an output showing the expected change in wetland extents within the study area for the year 2020. A change map from 1992 to 2015 was created and depicted the change from one land cover class to another. Using the change map from 1992 to 2015, a transition potential model was run to analyze the potential for change between the different land cover pixels. The outputs from the transition potential model were then used as an input to create a projected land cover map for the year 2020.

# IV. Results & Discussion

**Analysis of Results**

The LULC classification for the time series showed a shift in wetland extents along the Natchez Trace Parkway throughout the study period (1992 - 2015) (Figs. 2 – 4). This showed areas that have consistent flooding in the study area. The time series revealed portions of the parkway may have had challenging maintenance conditions throughout recent years.

Figures 2 – 4: LULC classifications for a region of the parkway in Mississippi for the years 1992, 2002, and 2015, respectively.

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| C:\Users\NASA DEVELOP\AppData\Local\Microsoft\Windows\INetCache\Content.Word\1992_timeseries.jpg | V:\Fall2015\NatchezTraceEcoForecasting\Deliverables\Poster\images\2002_timeseries.jpg | V:\Fall2015\NatchezTraceEcoForecasting\Deliverables\Poster\images\2015_timeseries.jpg |
| 1992 Classification | 2002 Classification | 2015 Classification |
|  | | |

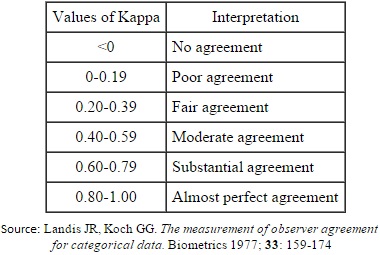
The NPS has four priority areas around mileposts (MPs) that fall within the section of the parkway used for this project. These priority areas have a history of beaver presence, resulting in flooding and maintenance issues. This creates a constant need for dam and beaver removal. These areas are: Main St., Tupelo, MP 259; Natchez Trace Visitor Center, MP 266; Tenn‑Tom Waterway, MP 293; and Rock Spring, MP 330 (Figs. 5 – 8).

Figures 5 – 8: 2015 LULC classifications for each NPS priority area.

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| V:\Fall2015\NatchezTraceEcoForecasting\Deliverables\Presentation\images\processed\MP259_2015.JPG |  |
| Main St., Tupelo, MP 259  2015 Classification | Natchez Trace Visitor Center, MP 266  2015 Classification |
| V:\Fall2015\NatchezTraceEcoForecasting\Deliverables\Presentation\images\processed\MP293_2015.JPG | V:\Fall2015\NatchezTraceEcoForecasting\Deliverables\Presentation\images\processed\MP330_2015.JPG |
| Tenn-Tom Waterway, MP 293  2015 Classification | Rock Spring, MP 330  2015 Classification |
| C:\Users\NASA DEVELOP\AppData\Local\Microsoft\Windows\INetCache\Content.Word\MP_Classification_Legend.jpg | |

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| Figure 9: Interpretation of kappa categories |

The overall percent accuracies for the LULC classifications were fairly low, but the kappa statistics were in fair to moderate observer agreement. The 1992 classification had an overall accuracy of 36.88%, with a kappa statistic of 0.2805. The 2002 classification had an overall accuracy of 46.25%, with a kappa statistic of 0.3857. The 2015 classification had an overall accuracy of 52.08%, with a kappa statistic of 0.4524. The kappa statistic compares observer accuracy with expected accuracy. It can be considered a better indicator of accuracy, as it takes into account random chance (Viera & Garrett, 2005). General benchmarks for kappa statistics are shown in Figure 9 (Landis & Koch, 1977). It is possible the overall accuracy was low due to the extensive size of the study area, which included drastic changes in topography. Another factor could include the general difficulty with classifying wetlands – as transition regions, their spectral signatures are often misclassified as forest, water, or open land.



The projected wetland extents performed in TerrSet LCM showed potential wetland boundaries along the parkway for the year 2020. The output raster indicated regions of likely land cover change to woody or non-woody wetlands. Of particular interest are the four priority areas selected by the NPS (Figs. 9 – 12). The LCM also produced graphs of landscape change from 1992 to 2015 and from 2015 to 2020 (Appendix II, Figures 13 & 14). Finally, a transition potential raster was generated to depict regions of possible landscape change to woody or non-woody wetlands based on pixel values.

Figures 9 – 12: 2020 predicted LULC change for each NPS priority area.

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| V:\Fall2015\NatchezTraceEcoForecasting\Deliverables\Technical Paper\Images\2020_MP259.JPG | V:\Fall2015\NatchezTraceEcoForecasting\Deliverables\Technical Paper\Images\2020_MP266.JPG |
| Main St., Tupelo, MP 259  2020 Classification | Natchez Trace Visitor Center, MP 266  2020 Classification |
| V:\Fall2015\NatchezTraceEcoForecasting\Deliverables\Technical Paper\Images\2020_MP293.JPG | V:\Fall2015\NatchezTraceEcoForecasting\Deliverables\Technical Paper\Images\2020_MP330.JPG |
| Tenn-Tom Waterway, MP 293  2020 Classification | Rock Spring, MP 330  2020 Classification |
| C:\Users\NASA DEVELOP\AppData\Local\Microsoft\Windows\INetCache\Content.Word\MP_Classification_Legend.jpg | |

**Errors & Uncertainty**

Comprehensively mapping beaver dams for the parkway was an initial goal for this project, and would have been useful for LULC analysis and future modeling. However, Landsat imagery has a 30 meter resolution, which is often much larger than most beaver dams. This made identifying them from satellite imagery very difficult and unreliable. High-resolution aerial photography was also not useful for this purpose, since this imagery is taken during leaf-on seasons when most dams are obscured by foliage.

There was also some difficulty in distinguishing between classes with similar spectral signatures during the classification process. Classes such as bare soil, urban, impervious, and barren were often identified as a single class. Topographic shadows were incorrectly classified as woody wetlands for all three years. Cluster busting was unable to resolve this issue. The error identified in the accuracy assessment for the input 1992 and 2015 LULC classifications and the improperly classified topographic shadows affected the accuracy of the LCM’s modeled output.

**Future Work**

Further LULC process refinement is needed to improve classification accuracy. The study area could be expanded (for example, from 25 km to 50 km) to provide more area for the unsupervised classification to improve its accuracy. This could also be useful for the NPS as a means of identifying potential developing problems in nearby regions that could affect the parkway in the future.

This project’s study area included the portions of the parkway contained within Landsat path 22. Future work could include the entire parkway to provide a more complete picture of its conditions. However, this may prove challenging as this would require using at least two additional Landsat scenes, totaling five Landsat scenes ranging across three paths. The topographic characteristics for the Natchez Trace Parkway also vary greatly from southern, low-lying, mostly flat regions, to northern, somewhat mountainous regions, as the parkway approaches the foothills of the Appalachians. These changes in topography could complicate the classification process by confusing classes and lowering accuracy.

Projecting further into the future could also be useful for the NPS, or modeling for specific years when new policies are planned. For example, if portions of a new step-wise beaver management policy are planned to be implemented for the years 2021, 2023, and 2025, it could be helpful to model those specific years to identify expected wetlands shifts for each year. Alternatively, modeling for expected LULC changes for the next 25 years could provide a more general idea of what changes are likely to occur in the near future.

Future work could also include using beaver dam presence points more extensively with the modeling process. This would require field checking all currently documented dams to determine their presence and condition. This point data could potentially be used in the TerrSet LCM to improve the model accuracy.

# V. Conclusions

From 1992 to 2015, the area around the Natchez Trace parkway experienced significant changes to its natural conditions. There was a drastic reduction in agricultural land and bare soil, roughly 580 mi2 and 300 mi2, respectively. Developed regions increased marginally by ~100 mi2. Coniferous forests saw the greatest gain of all the classes, increasing by over 1,100 mi2. Mixed forest also had a net increase by over 300 mi2, but deciduous forest decreased notably by ~400 mi2. The woody and non-woody wetland classes experienced a net loss of over 400 mi2 combined.

For the projection map, the woody and non-woody wetlands classes showed increases for all four focus areas, particularly in areas previously classified as wetlands. MP 259 had increases in the western portion and in some central regions. To the northeast of the milepost, a mid-sized section of woody wetlands is predicted to develop. MP 266 had wetland increases in the northern and middle portions. Directly north and south of the milepost, large developing pockets are notable due to their proximity to the parkway. MP 293 did not seem to experience much change in wetland presence near the parkway, though a few small pockets did appear on the bare soil sections of the map. MP 330 had significant portions near the parkway develop into wetlands, particularly in the northeast corner and along the eastern section of the map. Several narrow strips of wetlands are predicted to develop along the parkway.

# VI. Acknowledgments

Thanks are due to the following people for their assistance in the completion of this project: Bernard Eichold, M.D., Dr. PH (Mobile County Health Department), the team’s mentor; Dr. Kenton Ross (NASA Langley Research Center), DEVELOP’s national science advisor; and Joe Spruce (NASA Stennis Space Center), the team’s science advisor.

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

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# VII. References

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# VIII. Content Innovation

Audio Slides – “Wetland Conditions in the Natchez Trace Parkway”

Video Poster Session – “Mapping Wetlands along the Natchez Trace Parkway”

Glossary – terms and definitions

# IV. Appendices

**Appendix I. Land Use / Land Cover**

Table 1: LULC Category Descriptions

|  |  |  |
| --- | --- | --- |
| **Category** | **Description** | **Color** |
| Woody Wetlands | Established, wooded wetlands | **Dark Navy** |
| Non-Woody Wetlands | Herbaceous or emergent wetlands | **Dusty Blue** |
| Forest, Deciduous | Deciduous trees | **Light Green** |
| Forest, Mixed | Mixed coniferous and deciduous trees | **Middle Green** |
| Forest, Coniferous | Evergreen trees | **Dark Green** |
| Agriculture Land | Crops, pasture, managed land | **Pale Yellow** |
| Bare Soil | Empty crop lands, barren soil | **Light Orange** |
| Developed | Urban, roads, impervious surfaces | **Dark Purple** |
| Water | Open water (lakes, large ponds, rivers) | **Blue** |

Table 2: 1992 LULC Accuracy Assessment

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| **Class**  **Name** | **Reference Total** | **Classified Total** | **Correctly Classified** | **Producers Accuracy** | **Users Accuracy** |
| Water | 0 | 0 | 0 | --- | --- |
| Woody Wetlands | 9 | 20 | 3 | 33.33% | 15.00% |
| Non-Woody Wetlands | 0 | 20 | 0 | --- | --- |
| Forest, Deciduous | 37 | 20 | 7 | 18.92% | 35.00% |
| Forest, Mixed | 12 | 20 | 3 | 25.00% | 15.00% |
| Forest, Coniferous | 44 | 20 | 18 | 40.91% | 90.00% |
| Agriculture Land | 42 | 20 | 17 | 40.48% | 85.00% |
| Bare Soil | 3 | 20 | 1 | 33.33% | 5.00% |
| Developed | 10 | 20 | 10 | 100.00% | 50.00% |
| Total Points | 160 | 160 | 59 |  | |
| Overall Accuracy: **36.88%** | | | | | |
| Kappa Statistic: **0.2805** | | | | | |

Table 3: 2002 LULC Accuracy Assessment

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| **Class**  **Name** | **Reference Total** | **Classified Total** | **Correctly Classified** | **Producers Accuracy** | **Users Accuracy** |
| Water | 0 | 0 | 0 | --- | --- |
| Woody Wetlands | 12 | 20 | 7 | 58.33% | 35.00% |
| Non-Woody Wetlands | 4 | 20 | 1 | 25.00% | 5.00% |
| Forest, Deciduous | 45 | 20 | 16 | 35.56% | 80.00% |
| Forest, Mixed | 12 | 20 | 4 | 33.33% | 20.00% |
| Forest, Coniferous | 25 | 20 | 16 | 64.00% | 80.00% |
| Agriculture Land | 33 | 20 | 17 | 51.52% | 85.00% |
| Bare Soil | 19 | 20 | 9 | 47.37% | 45.00% |
| Developed | 10 | 20 | 4 | 40.00% | 20.00% |
| Total Points | 160 | 160 | 74 |  | |
| Overall Accuracy: **46.25%** | | | | | |
| Kappa Statistic: **0.3857** | | | | | |

Table 4: 2015 LULC Accuracy Assessment

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| **Class**  **Name** | **Reference Total** | **Classified Total** | **Correctly Classified** | **Producers Accuracy** | **Users Accuracy** |
| Water | 0 | 0 | 0 | --- | --- |
| Woody Wetlands | 10 | 18 | 4 | 40.00% | 22.22% |
| Non-Woody Wetlands | 3 | 18 | 2 | 66.67% | 11.11% |
| Forest, Deciduous | 31 | 18 | 11 | 35.48% | 61.11% |
| Forest, Mixed | 32 | 18 | 13 | 40.63% | 72.22% |
| Forest, Coniferous | 12 | 18 | 12 | 100.00% | 66.67% |
| Agriculture Land | 27 | 18 | 14 | 51.85% | 77.78% |
| Bare Soil | 15 | 18 | 9 | 60.00% | 50.00% |
| Developed | 14 | 18 | 10 | 71.43% | 55.56% |
| Total Points | 144 | 144 | 75 |  | |
| Overall Accuracy: **52.08%** | | | | | |
| Kappa Statistic: **0.4524** | | | | | |

**Appendix II. Land Change Modeler**

Figure 13: Overall gains and losses in land cover types between 1992 and 2015

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Figure 14: Net gains or losses in land cover types between 1992 and 2015

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