# Vegetation Cover Classification and Change Detection utilizing NAIP Imagery from 2005 to 2019:

## Lexington County, South Carolina

Internship with the Planning and GIS Department at the County of Lexington, SC

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# Introduction

As an upcoming graduate of Appalachian State University, I am extremely grateful for the knowledge, experiences, and opportunities presented to me within the department of Geography and Planning. In pursuing my Bachelor of Science degree in Geography with a concentration in GIS, I have met so many wonderful people along the way. Those who initially introduced me to the field, taught me so much about myself and the world, and prepared me for my future as a GIS professional have fulfilled me as a student and as an individual. While I was met with many challenges, I also have shared many accomplishments. The incredible faculty within the department of Geography and Planning have provided me with the knowledge and abilities that helped me in my internship and will continue to help me as I pursue my career.

As a part of my core program requirements, I was expected to obtain and organize an internship to be completed over the course of the summer semester in 2021. I decided to start applying for open positions in and around Boone, as well as around my hometown of Columbia, South Carolina. After multiple interviews, I was lucky to have been contacted with two prospective offers and had to choose which one would best benefit me and my goals as an intern as well as provide me with the necessary opportunities for future growth in my career. I decided to take a position with the County of Lexington in South Carolina, working under the Planning and GIS Department for the county. I first contacted the Chief GIS Analyst and my future supervisor at the county, Alan Rickenbaker, around March and was eventually offered the position in April. It was noted prior to my acceptance of the position that along with offering my assistance in completing daily tasks for the department, I would be working on an individual project to show for my time there and that I would be given the ability to generate an original idea to showcase my skills and to benefit the department. Now that my internship has been completed, I am reflecting on all that I have experienced and learned while working for the Planning and GIS department at Lexington County, and how GIS benefits local government.

Within this report, I will discuss the host organization of my internship, the County of Lexington, outline a general overview of my responsibilities as an intern including specific projects, tasks, and participation within the department and county administration. This report will focus primarily on the organization, workflow, products and analysis of the project that I completed for my department: a Vegetation Cover Classification and Change Detection Analysis using NAIP imagery from 2005 – 2019 in the county of Lexington.

# Host Organization: County of Lexington

At the beginning of my internship with the Planning and GIS department for Lexington County, I did not fully recognize the complicated and interconnected role that local government has in the community. I also did not understand the technicalities that come with the distribution of local/regional governmental responsibilities, such as county, state, and municipal government (i.e. who does what). On my first day of work, my supervisor Alan suggested I review the county's website to get accustomed and familiar with all the different departments and offices that work together to make up the county's administration and what services they provide, including the Planning and GIS department. The County of Lexington's administration incorporates many different and important agencies, offices, and services including but not limited to GIS and planning, community development, permits and regulations, zoning, county council, emergency services, public works, register of deeds, and the assessor's office. All these offices and departments work together towards a mission to provide quality services to their citizens at a reasonable cost, with a vision for planned growth in their communities with abundant opportunities for all in a quality environment (County of Lexington). There are fifteen incorporated municipalities within the county, however the jurisdiction of the county resides only in the unincorporated areas (all property that does not fall within an incorporated municipality).

### *Planning and GIS Department*

My department, Planning and GIS, has three main aspects; it handles much of the planning, addressing, and mapping for the county. The Planning Director at Lexington County is Holland Leger, and he supervises all the work done within the department as well as reports directly to the county council and planning commission. My supervisor whom I would report to, Alan, is the Chief GIS Analyst for the Planning and GIS Department and oversees and maintains all the county's GIS data, resources, and assigning of tasks to be completed within the department. There are a total of eight positions within the department that span the responsibilities of commercial and residential addressing, road maintenance, parcel and tax mapping, and general mapping for other agencies or organizations. Over the course of the ten weeks that I worked as an intern for the department, I was given quite a few tasks and responsibilities that I was always happy to assist with. From meeting with other employees to gain a sense of the work they do to attending county council and planning commission meetings, I was an engaged and welcomed member of the department and communicated regularly with staff to assist them as well as gain insight on how they operate as a county GIS department.

*Overview of Responsibilities*

My first week of working as an intern was very informative, eye-opening, and busy. The daily work schedule I followed was set to be full-time, working from 8 a.m. to 5 p.m. Monday through Friday. As stated, on the first day, I was directed to review and examine the county's webpage to gain familiarity with all the different resources that are available to the general public. This was helpful for me to understand how all the departments work together and keep track of all important resources and where their locations are found within the site for future reference. The main documents and programs I reviewed were the county's comprehensive plan, the county fact book, and the OneMap that includes all the county's addressing, zoning, and parcel data. For the rest of the week, I met with different colleagues each day and spent a few hours with each of them to gain a sense of their jobs and how their work comes together. I met with employees in charge of commercial addressing, where I learned about the process involved in subdivision approval; residential addressing and parcel mapping, where I learned about the processes involved in creating and updating GIS layers from plats and deeds of sale as well as tax mapping; customer service representatives and software specialists, who showed me great resources to use for potential project ideas as well as ideas for what type of project I might like to work on. I also met with various other employees who showed me more about how GIS was done before computer systems we have today, and how they would use and transfer hand-drawn data to the very first GIS computer software.

From meeting with the professionals in my department, I gained a better understanding of all the work and specific GIS and job-related tasks that are done utilizing various software programs specific to each person’s duties. For example, my supervisor Alan is the Chief GIS Systems Analyst, meaning he oversees and assigns tasks to be completed and maintains all the data in the county’s GIS. He taught me how to create web maps, interactive sites using ArcGIS Online, and even broke down some coding languages that he used in order to create the county’s website and various map viewers. During the following weeks, I became even more acquainted with performing duties related to the county’s GIS. Alan suggested that I become familiar with scanning plats (which are large blueprints of proposed development such as subdivisions, residential and commercial structures) in order to gain a sense of where and how the data we manipulate on the screen originates. Although scanning takes lots of time and work, this was an important step in gaining a full understanding of how paper maps (or plats) become geocoded and eventually editable using programs such as ArcMap or ArcGIS Pro.

GIS is a fundamental tool that is used to benefit not only the local community but the world. From a local standpoint, the efficient use of GIS software and systems directly impacts the community through the deployment of emergency services. In 911 call routing, it seems obvious that spatial data would be one of the most important components needed to accurately and timely asses the location of an emergency and direct emergency officials to provide aid and assistance. However, until this year 911 systems did not include any use of advanced or even basic GIS data. My county and department were the first in the state of South Carolina to make the transition to Next Generation 911, which gives dispatchers access to GIS data such as address points, road centerlines, EMS, fire, and law boundaries, provisioning boundaries and PSAP (Public Safety Answering Point) boundaries. This new 911 system also requires changes to the fields attributed to address points and street abbreviations – all street names and directional abbreviations must be spelled out so that there is no confusion or guessing involved when dispatching officials to the location of an emergency. My responsibilities took the place of reviewing some of these data fields and ensuring that all the values and attributes were listed correctly and accurately in order to successfully implement the new system. Next generation 911 involves the use of GIS data to aid in emergency response like never before, and I am grateful to have been able to be a part of the process and put into perspective how the important work we do in turn keeps the community safe.

*Projects and Tasks*

The final few weeks of my time as an intern at Lexington County were being spent completing a self-guided GIS project. Alan, my supervisor, wanted me to come up with an idea to base a project from on my own, and I spent a lot of time brainstorming ideas and relating those ideas to current issues in the county so that my work would not only benefit myself but also my department and the county as well. Since the county is undergoing a dramatic increase in growth and development just in the past few years, I decided that it would be helpful to complete a vegetation change analysis by classifying multiple years of aerial imagery in order to show that growth and development through the change and loss of vegetation cover in areas where the development is/has been occurring. This would also be beneficial to my department as well because the vegetation layer being used in all the current maps was generated from 2011 imagery, so it is quite outdated.

Alan helped me to narrow down this idea and provide me with some appropriate data and imagery to use, as well as some common workflow practices to get started. I quickly realized that image classification is a very tedious, slow process and relies on a lot of trial and error. After running into many issues during the first few attempts at classifying the first images, I was able to find a workflow that produced results I was looking for and could use in an analysis. Finally, after all the images are classified and results are represented appropriately, I created a project deliverable in the form of an Esri StoryMap that can then be shared, posted, and reviewed for everyone to see and understand the analysis through an easy to use and immersive interface.

While I worked on many different tasks in the Planning and GIS Department for the County of Lexington, the Esri StoryMap that I published of vegetation cover analysis and change detection was the main project that I worked on during my time as an intern there. The data organization, project workflows, classification and change detection processes took the most time and effort in completion of this project. On my last day of work in presenting my final products to the department, I was honored to have been recognized by the Planning Director, Holland Leger, commending my work and making mention of how beneficial it would be to show as a part of the county's Comprehensive Plan that they are currently working on implementing.

## Project Workflow

Deciding on a project idea was difficult, and I spent lots of time brainstorming and planning out different ideas. In organizing my goals for this project, I knew that whatever I did had to be not only beneficial for myself but the organization as well, and achievable given my skills and time limitation. From my first meeting with the County's GIS Technician II, Steve Pierce, I was interested in the way he represented growth in the county through interactive maps and animations showing historical data through a time series of images. Steve and I discussed some ideas for my project as I decided that I wanted to create something that had to do with illustrating growth and development scenarios, given the dramatic increase in growth that the county is currently experiencing. This would be not only beneficial to myself as much as the department in order to handle growth in the county by visualizing the change.

Once I narrowed down my ideas with the help of my supervisor as well as other colleagues in the department, I began organizing what data I needed to collect to start. Since my project involves classifying imagery it combines the use of GIS as well as the field of remote sensing. This meant that I would need to not only acquire vector data in the form of county boundaries, hydrological polygons, and other shapefiles, but raster data in the form of aerial or satellite imagery as well. I had taken a few remote sensing and image processing courses before that had given me the general knowledge and expertise to achieve my project goals, but I also read many peer-reviewed journals and reports published on image processing, classification and analysis to learn more.

### *"Land Use and Land Cover Classification and Change Detection Using NAIP Imagery"*

This report focuses similarly on image classification and change detection and describes the use of NAIP imagery and subsequent NDVI datasets as a more time-friendly alternative to traditional classification techniques. While the study performed within this report focuses on land use and land cover classification within a region, the literature outlines various techniques and processes to aid in a simpler workflow given that image classification and processing can be extremely time consuming and tedious. It is explained that the use of NAIP (National Agricultural Imagery Program) imagery in vegetation classification is essential, as the NAIP program obtains high spatial resolution aerial photographs during vegetation peak growing season to assist with agricultural monitoring (Sha Sha, p. 17). Secondly, the NDVI (Normalized Differenced Vegetation Index) is an accurate estimator of vegetation density and useful to extract vegetation change results (7). Finally, through analysis of their study it was determined that "compared with other pixel-based and object-based approaches, the random tree classification technique was verified to be the most optimal classification method for NAIP [imagery] in terms of efficiency and accuracy" (56). I decided to utilize and apply this information in the workflow of my own project to achieve the desired results.

### *"Detection of Vegetation Cover Change in Gospers Mountain using Landsat OLI Data"*

The study performed in this analysis uses satellite imagery acquired from Landsat data as compared to aerial imagery acquired from NAIP data. It is beneficial to understand the availability of remote sensing data to gather the most accurate and useful data pertinent to the study being performed and is noted that the Operational Land Imager (OLI) on the Landsat 8 satellite "provides a seasonal coverage of the global landmass with a spatial resolution of 30 meters" and "captures data with high radiometric precision…" (Sahbeni et. al.). While the satellite imagery does provide high quality data useful for an environmental analysis, NAIP imagery is acquired at a higher spatial resolution of one meter and would be better to use in my analysis as to most accurately highlight vegetation patterns across varying years of imagery.

*Study Methodology*

Taking note of the image processing tips and techniques examined in the literature that I researched, I followed this general scheme of the study methodology outlined in Figure 1:

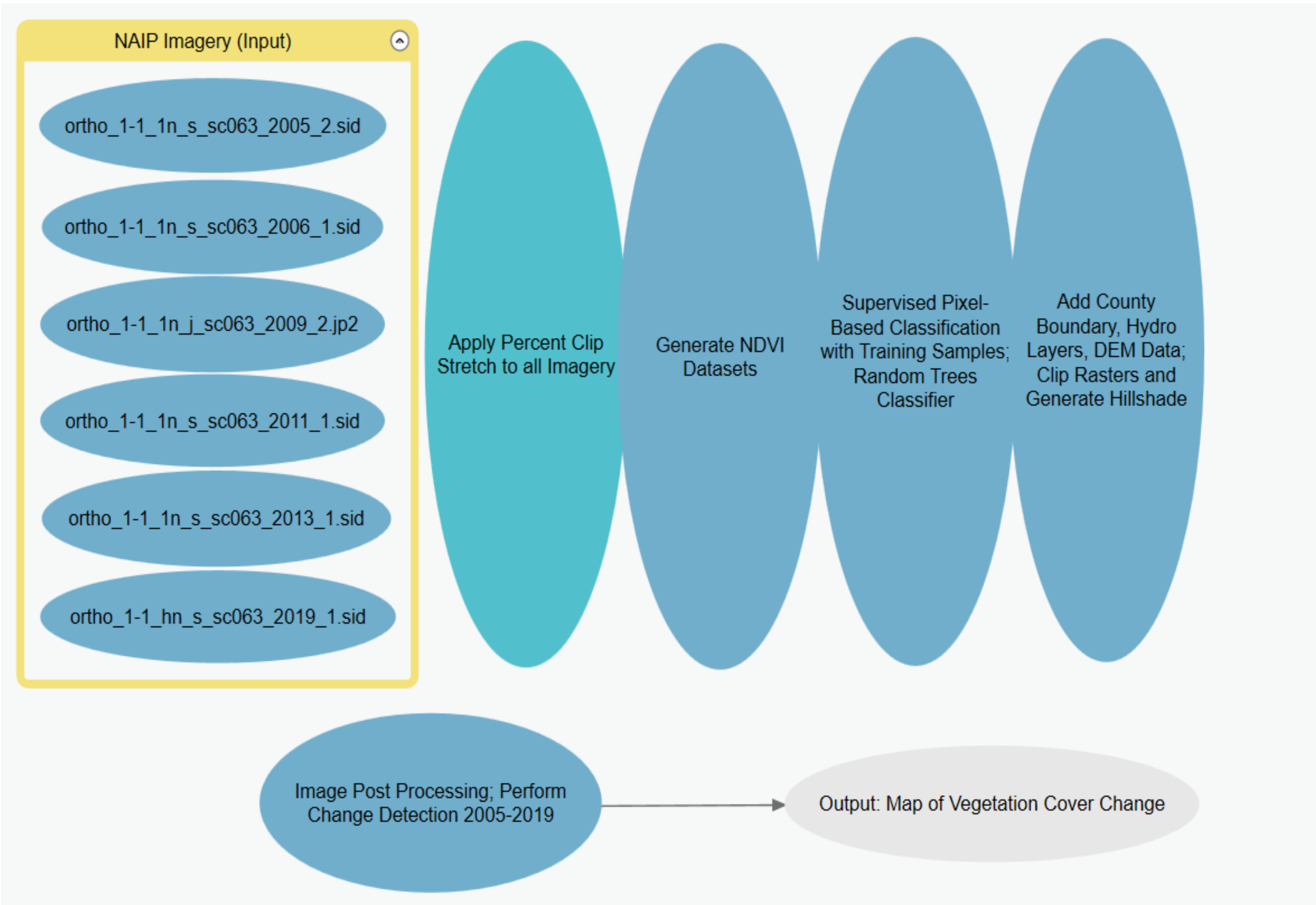



Figure 1

This workflow model and its steps were generated and implemented in ArcGIS Pro prior to completion of my project, as some of the processes and steps involved had to be manipulated to gain the desired output. The steps that took the most time were that of classifying each year of imagery, and then performing a change detection geoprocessing function to generate an output dataset highlighting only the changed areas in the time span of the study. Data organization was the most time-consuming step prior to the start of this project, specifically in figuring out what data was required to produce a final product as well as how to acquire that data.

# Data and Organization

There is a wealth of informative and spatial data held within the department's SDE database, and my supervisor pointed me in that direction to start. ArcSDE (Spatial Database Engine) is a server-software sub-system produced by Esri that aids in database management for spatial data that can then be used as a part of a geodatabase. I would need to create my own file and project geodatabase to store all the data needed to use in my project, and that was a major aspect of this project's organization.

### *Raster Data*

The raster data contained within this project took the place of datasets derived from the input aerial imagery. This includes all the NDVI datasets generated for each year of imagery as well as the resultant classification of the NDVI. Since the input source of the data (the imagery) is in a raster format, by default each processing function used will generate a new layer with the output in raster format as well. Some of the datasets generated from input imagery are included in the figures below and note that these datasets have been clipped to the county boundaries.

Figure 2: NAIP Imagery

Figure 3: NDVI Dataset

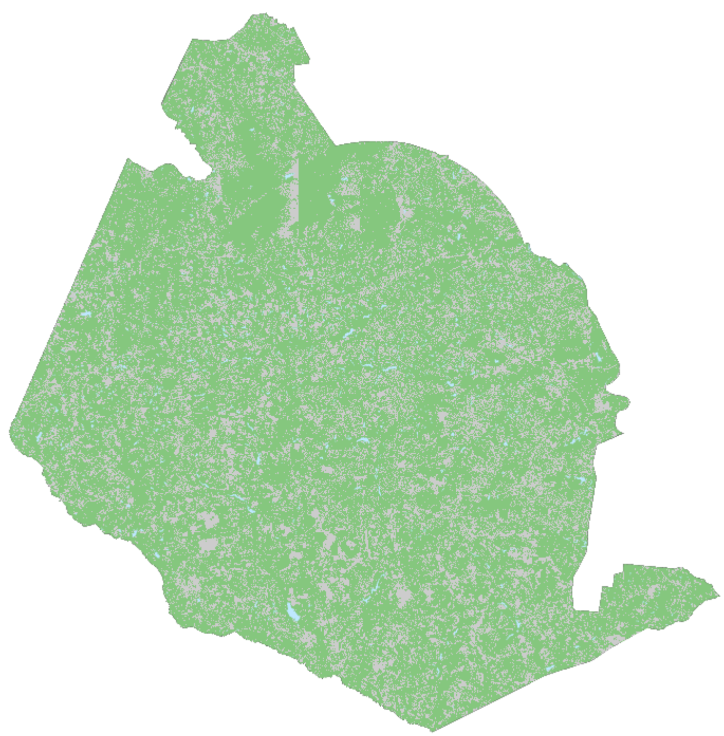


Figure 4: Classified Dataset

*VECTOR DATA*

As stated previously, the SDE database holds much of the spatial data for the department. From this database I collected data for lots of variables relative to my project as well as some data that was not, but still interesting to display. This data included economic development information such as building sites and other planned construction sites, growth data including traffic counts, planning data such as landscape ordinances, political and socioeconomic data, weather data, and more.

The most important data that I needed to collect in order to complete my project were the county boundary polygon, lake polygon, and hydro layers such as ponds and stream network shapefiles. This would overlay polygons atop of features such as the lake in the county which can sometimes be included in classification as vegetation due to the spectral signature of the water. Along with these polygon features, it would be necessary to include DEM data of the county after classification of the imagery and with the other data is added to the map. DEM data is a raster format, however in the workflow of this study I have included it within the group of data that is generally added after raster calculations and classifications are complete. After adding the DEM data to the map, I generated a hillshade and applied appropriate symbology to highlight the classification layers as well as illustrate topography in the region.

Some products and layers generated after including hydrologic shapefiles and DEM data are included in the figures below:

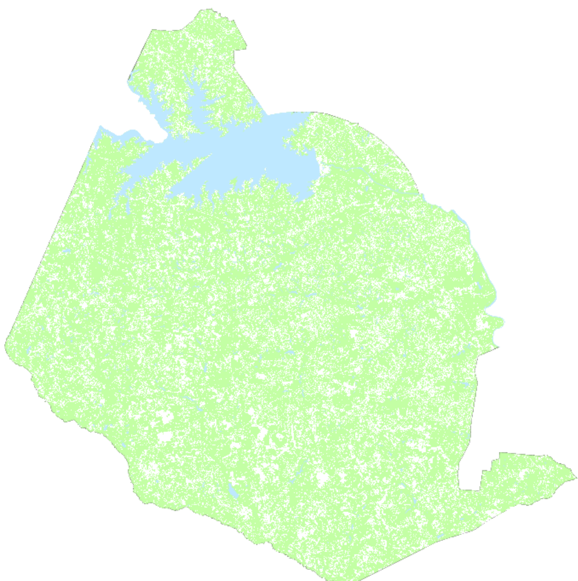


Figure 5: Hydro Layers

Figure 6: DEM Overlay

### *NAIP Imagery*

The imagery used in this study was acquired through the NAIP program and span the time period between 2005 to 2019. Each input image needed to be preprocessed using image enhancement techniques such as applying a percent clip stretch to each image in order to better highlight green vegetation prior to calculation and classification. As stated previously, NAIP imagery is high spatial resolution data with acquisition during vegetation peak growing season, or “leaf-on” periods. This is an essential aspect to this study as NDVI calculation and vegetation classification depends highly on the spectral signatures of features on the ground and use the bands of an image as input values.

### *NDVI Calculation*

In generating NDVI datasets from the input rasters, it is important to note the spectral resolution of the imagery. NAIP imagery contains four bands in each image (red, green, blue, and near-infrared). NDVI calculation depends on the reflection of vegetation in the near-infrared band of an image as well as the red band. This is due to vegetation’s strong reflection in the near-infrared bands and its strong absorption in the red bands. Thus, NDVI detects green vegetation by comparing these two bands of an image to generate locations with vegetation and locations without. The equation for NDVI calculation is listed below:

$$NDVI = (NIR - RED) / (NIR + RED)$$

NDVI is calculated on a scale between -1 to 1, and this ratio is a measure of photosynthetic activity (healthy vegetation as 1, and no vegetation as -1, generally). Low NDVI values can indicate either stressed vegetation or other surfaces such as rock or bare soil, while higher values indicate a density of healthy green vegetation (Gessesse & Melesse, 2019). In this study, NDVI datasets were generated for each of the years of imagery in order to create a time series of vegetation change across time. This time series is most easily accessed and viewed in the final project StoryMap that is linked at the end of this report. I have included a shortened timeline of the NDVI time series in the figure below (clipped to a smaller scale):

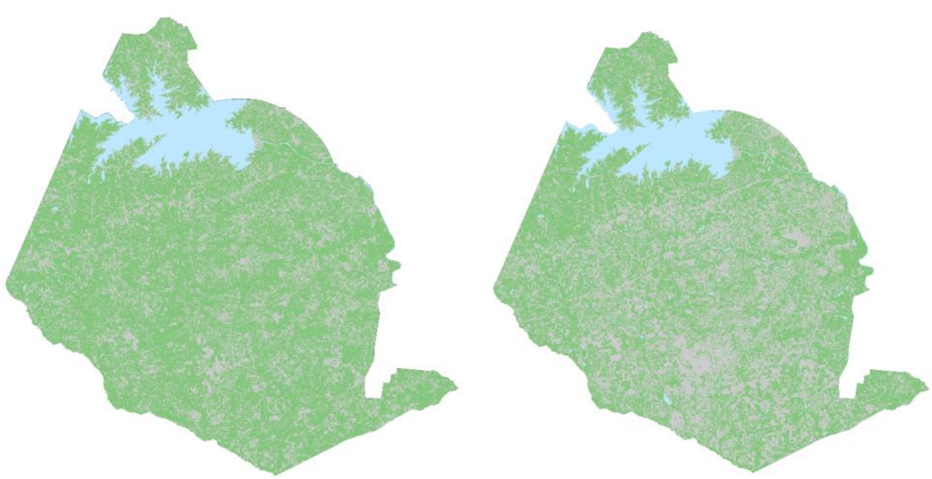


Figure 7: Time Series of NDVI data from 2005, 2006, and 2009 (left to right)

*CLASSIFICATION SCHEMA*

After generating each NDVI dataset, they were classified and symbolized using the Classification Wizard tool in ArcGIS Pro. I collected training samples for each image for two categories of classification, areas with forest cover and impervious areas such as parking lots, building roofs, and roadways or fields. Once all I had collected training samples for each category and ensured that there was ample coverage across the study area of the county, I generated the output classification dataset by running the tool. This took a lot of processing time, however once the first image had been classified I was able to use that output dataset as a classification schema by saving the training samples and relative classification categories as a feature layer to be utilized in classifying the rest of the imagery.

An important step in image classification that can be easily overlooked is that of reclassification of misrepresented areas that could possibly be due to accuracy or producer error. Prior to producing a final classification output of any image, the initial classification run by the geoprocessing tool allows the ability to reclassify areas that the tool did not classify correctly the first time. Most of the reclassification that needed to be done were in the southern portions of the county, where most of the agricultural farmland are located in the region. Much of the areas of bare soil, unused fields, and barren land would be represented in conjunction with impervious surfaces and this is only notable for the southern portion of the county. Most development and impervious surface are located in the north and northeastern portions of the county, around the lake and near the city of Columbia and Town of Lexington. It was also interesting to note the drastic change in classification of barren fields in the year 2009, as most of the farmland in the southern portion of the county is noticeably much more stressed due to a severe drought in the region between the period of 2007 – 2009. The classified imagery of the years 2006 and 2009 are included in the figure below to illustrate this:



The classified image from 2006 (left) shows healthy vegetation across the county, while the image from 2009 (right) shows a drastic change in the form of stressed vegetation across the county, most noticeably in the southern portion.

# Findings

Through this analysis, I represented growth and development in the County of Lexington by processing and classifying aerial imagery to show vegetation patterns across a temporal scale. The final classified imagery and data included tells a story of development patterns through time within the county and provides a useful classification of these patterns to aid in future planning and development practices. The results also demonstrate that NAIP imagery can be used to produce accurate land cover classifications and statistics. Overall development patterns found in the County of Lexington through this analysis were (1) most changes in terms of development and biomass loss are occurring along the main thoroughfare in the Town of Lexington (Sunset Blvd., northern portion of the county), (2) neighborhoods and large-scale subdivision development is occurring sporadically throughout the county but mainly in the northern and northeast portions, and (3) moisture-stressed vegetation and bare ground are difficult to differentiate between in years where environmental patterns are conducive to drought.

This analysis explores the possibilities and uses of multispectral and remote sensing data as those derived from NAIP and Landsat imagery as well as NDVI values in vegetation density classification. This approach offers a simplified and inexpensive workflow to estimate temporal land cover changes over time which can be further used in environmental and predictive modeling.

### *Analysis*

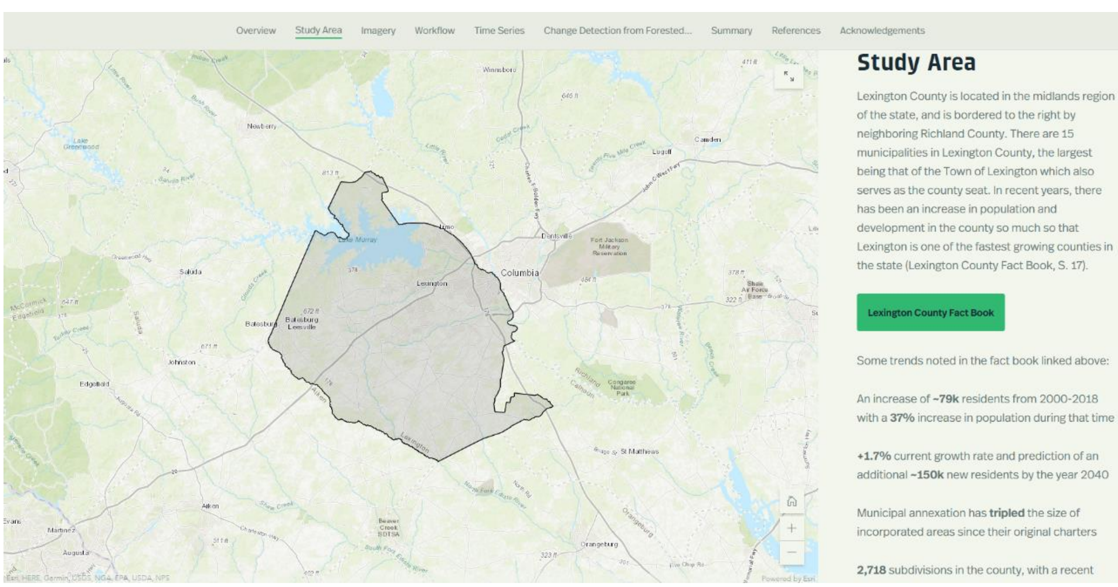
Most of the development occurring in the county of Lexington is taking place along main arteries of the town of Lexington and into the city of Columbia. Most large-scale development in the form of subdivisions, schools, and recreation sites are being developed along these arteries including I-20 and US-378. In performing a change detection Classification between 2005 and 2019, this development is highlighted in order to illustrate these patterns. These final products are highlighted in the sections below and explained in further detail. Forested areas that changed to developed areas make up much of the eastern portion of the county, and more sporadic development has occurred in the western portions and southern portions of the county. The percentage of forested area that changed to impervious area within the study time period increased by around five hundred-thousand square meters or an area equivalent to the size of about one hundred and twenty-four acres. No areas changed from impervious to forested.

# Results and Products

### *Esri StoryMap*

The final product of this project and its analysis is included in the form of an Esri StoryMap that is linked below. This is an easy-to-use immersive interface that tells a story of development patterns in the County of Lexington with facts and descriptions as well as the products of this analysis.

https://storymaps.arcgis.com/stories/0c59de8aa68a4a1088bf2510d65abaa1


To navigate the StoryMap, simply scroll down to view the different headings and content.

## CLASSIFIED IMAGERY

The final classified imagery is included below to view at a larger scale.

FIGURE 9: CLASSIFIED AND SYMBOLIZED DATASET

2005

FIGURE 10: CLASSIFIED AND SYMBOLIZED DATASET

2006

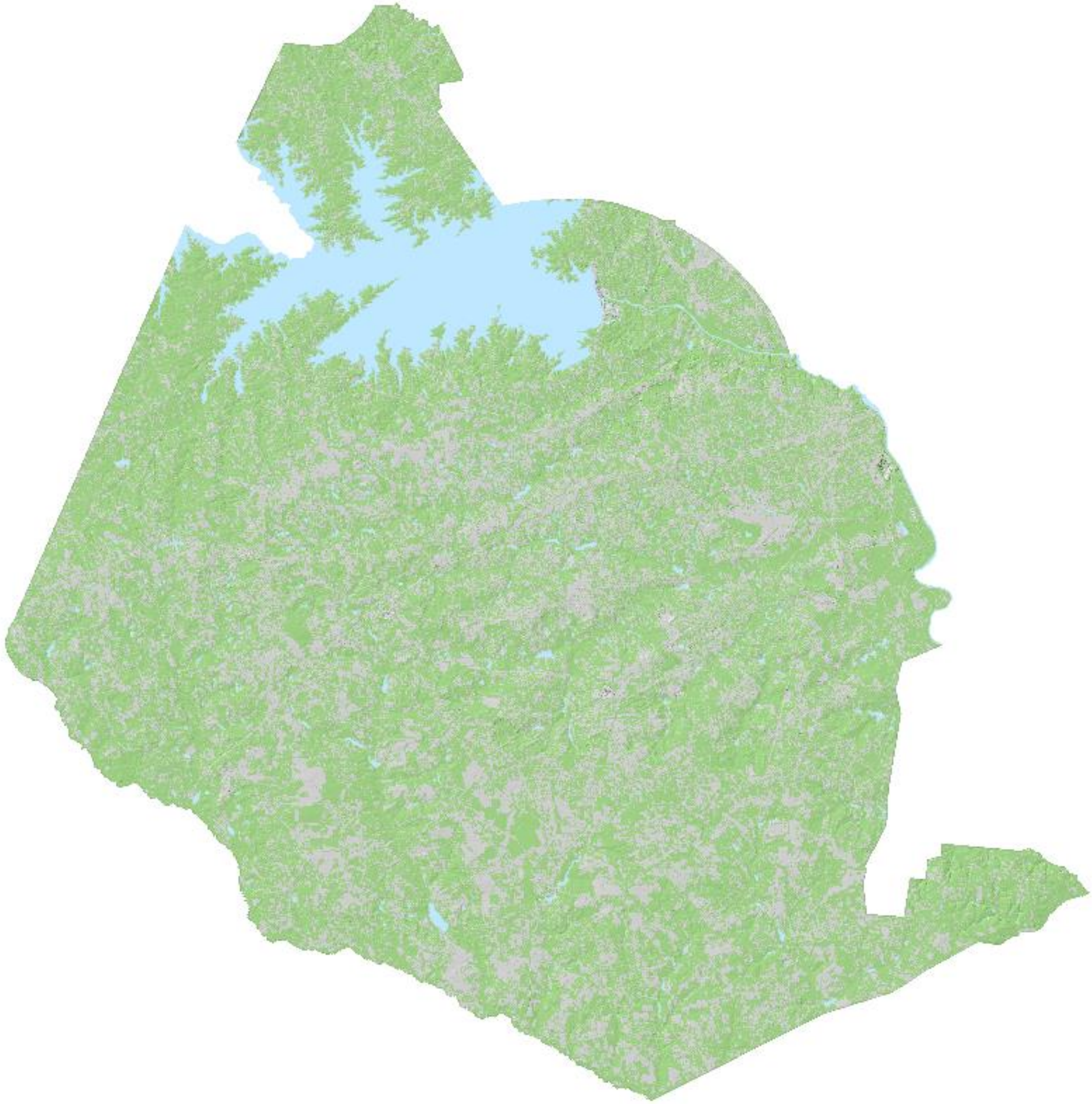


FIGURE 11: CLASSIFIED AND SYMBOLIZED DATASET

2009

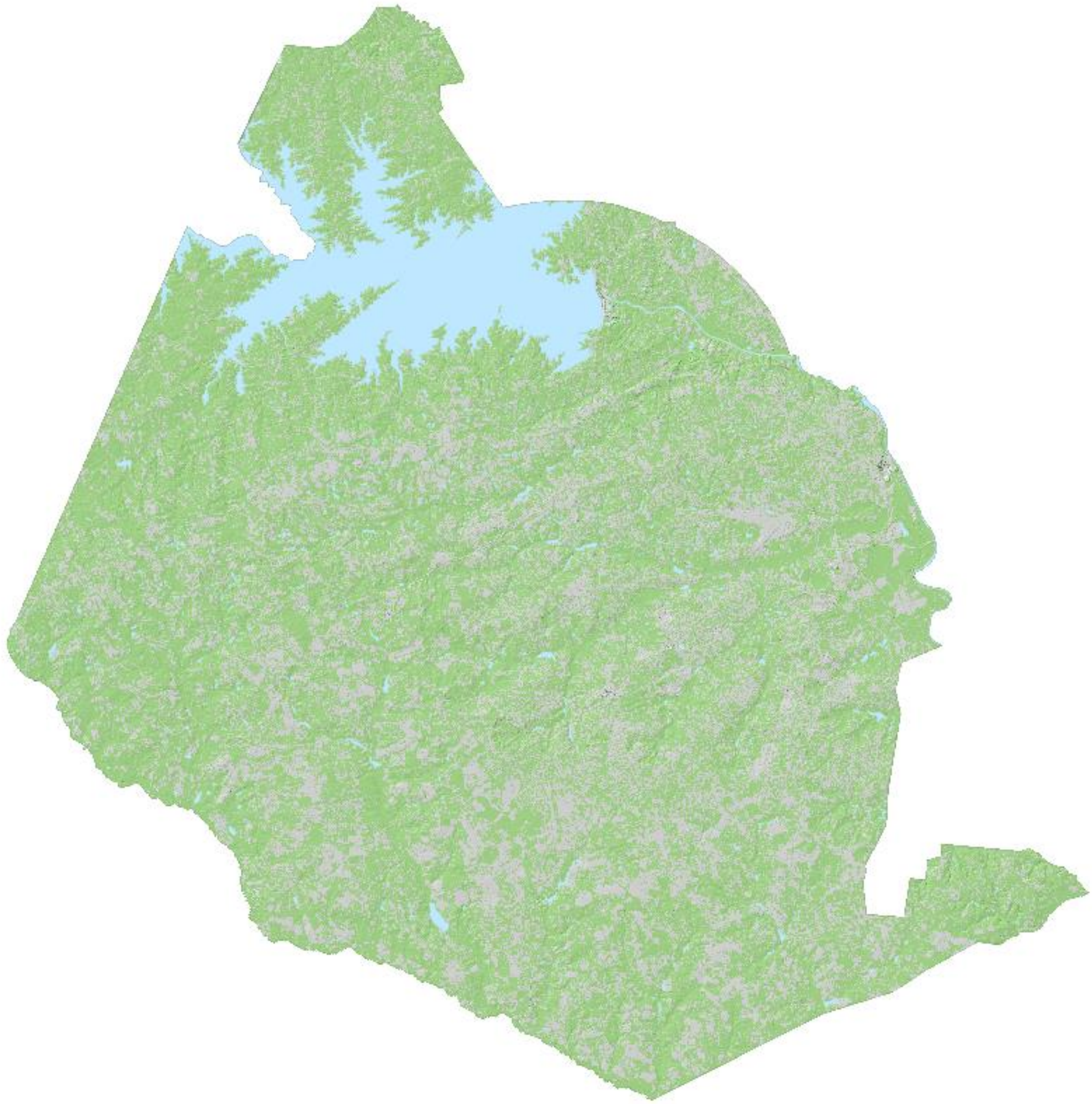


FIGURE 12: CLASSIFIED AND SYMBOLIZED DATASET

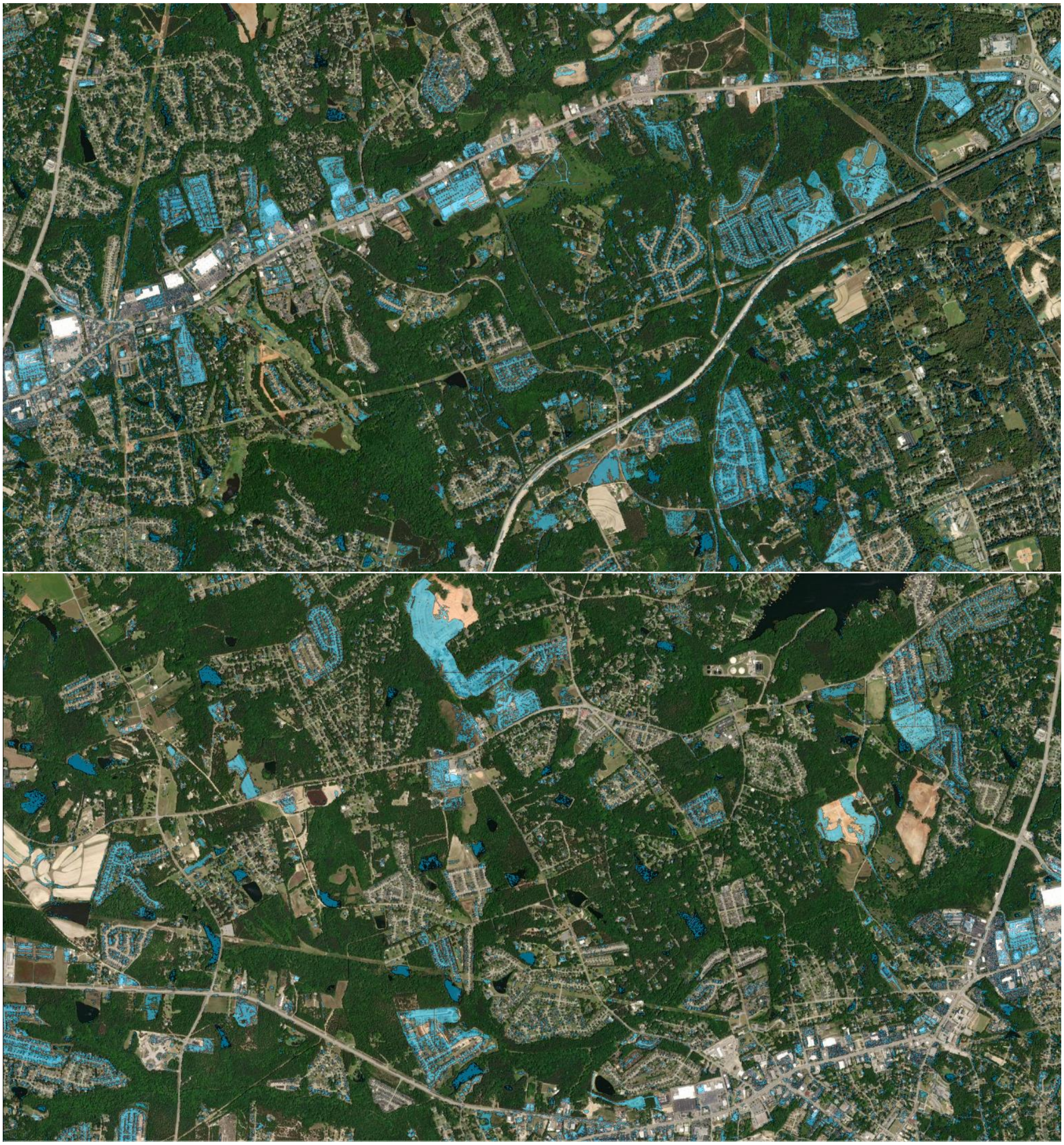
2013

FIGURE 13: CLASSIFIED AND SYMBOLIZED DATASET

2019

## Change Detection

From the use of the classified images from 2005 and 2019, change detection was performed to produce the following map of development during this time period.



Areas that are highlighted in blue are new construction and development taken place between 2005 and 2019.

## Evaluation and Conclusion

Throughout my time as an intern with the County of Lexington, SC, I gained lots of knowledge and experience that have better prepared me for my future as a GIS professional. During my experience, I met with many professionals and gained valuable connections within the field as well. As a student in the Department of Geography and Planning at Appalachian State University, I was already off to a head start with the broad and applicable skillset I have acquired in my program of study. I am incredibly grateful for the curriculum and teaching that was offered to me as a student there, as I realized after meeting with the coworkers at my internship that many Geography programs in colleges elsewhere do not include some of the fundamental and necessary training with programs such as the Esri suite of applications and information technology software.

I was able to use the skills I have learned as a student to complete the tasks asked of me in a professional manner, as well as build on those skills in the workplace environment. I was also able to learn many new skills as well and develop stronger interpersonal and technical skills that will aid me in all of my future goals and endeavors. Specifically, I learned more about Esri's suite of applications and found a better understanding of the network of programs and software/applications such as ArcGIS Hub, ArcGIS Dashboards, ArcGIS Online, StoryMaps, Survey 123, and ArcGIS Enterprise. Building on the skillset I had previously established as a student, I learned more about the functions and use of programs such as ArcGIS Pro and ArcMap in a professional setting.

In thinking about what could have been done differently, I would have been more prepared to be working within a government administration by researching those aspects of local government that I had not known about before. However, I was able to learn about the technicalities of local government as it relates to the county, municipalities, and state as well as the impact of GIS within those organizations. I would have also learned more about ArcGIS Online capabilities and the Esri network of applications as these are becoming more widely used in professional GIS organizations. My coursework prior to this internship gave me the general preparation and knowledge to help me complete this internship, and with the assistance of professionals in my department I was able to accurately communicate and gain the help I needed in the instance that I did not know how to complete a certain task. In conclusion, this internship experience was extremely beneficial to my growth as a GIS professional. I was able to make connections and learn about important aspects of the field as well as create a project that can be used as an example of my work in the future.

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