

GIS Use for Analyzing the Riparian Buffer of the Catawba River

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Introduction

Nonpoint source (NPS) pollution, in general, is carried by runoff, commonly referred to as rainwater. This is to say that NPS pollution is any pollution that can be delivered to a stream through water, and the source of pollution is not directly identifiable through the means of pointing. For example, sediment is by far the largest and most common form of pollution in streams (US EPA, 2015) and is caused by the erosion of soil, which occurs more or less everywhere. Erosion is the process by which rocks, soil, and matter is broken up and distributed elsewhere, typically downstream (Preece, 1977). One study specified that slopes greater than 20% had a high amount of runoff compared to smaller slopes and that slope and runoff quantity have a linear relationship (Akbarimehr & Naghdi, 2012). Another notable pollutant that is carried by runoff is nutrient pollution. This can be caused by agricultural runoff from a farm or from fertilized grass on a golf course and consists of three major elements: nitrogen, phosphorus, and potassium. These elements come in many different compounds such as potassium nitrate, phosphate, Ammonia, nitrate/nitrite, potassium chloride, etc (National Management Measures for the Control of Nonpoint Pollution from Agriculture, 2003). All forms of these nutrients have the potential to cause eutrophication in streams and lakes. Eutrophication occurs when primary producers (PP) of an aquatic ecosystem are not limited in growth by a lack of nutrients. When PP's, like Algae and cyanobacteria, grow to extreme proportions they cause green foggy water and eventual hypoxia (Kuwayama et al., 2020). Phosphorus is most often the limiting factor for algae's reproduction in aquatic ecosystems according to some studies, but nitrogen still plays a large role in Eutrophication. Therefore, phosphorus and nitrogen based compounds are the most likely causes of algae blooms (Kazama & Watanabe, 2018)(Hao et al., 2012).

The riparian zone can be understood as the area of land along the edge of a river or stream. This zone has no exact limit and is dependent on what one is looking for. For the purposes of this project, it was defined at 100 meters from the center of the river due to the hydrologic data delineated using aerial imagery (*Protocols for Mapping and Characterizing Land Use/Land Cover in Riparian Zones*, 2005). Consequently, the actual land area will vary depending on precipitation and season. Alternatively, significant changes in precipitation, like a 10 year flood, are generally short lived and are somewhat rare. A riparian buffer refers to the capacity of a riparian zone to resist some type of input to or from a river. The buffering capacity is almost entirely dependent on the size and the vegetation present on the edge of the river. This was exemplified in a study that found the removal of streamside vegetation resulted in degraded water resources, and reduced the value for recreation and other uses (Hawes & Smith, 2005). The buffering capability of plants is partially due to their ability to hold soil with their roots. Additionally, for inputs such as nutrient pollution, plants can absorb and put to use nutrients before they flow into the river.

The Catawba River has not experienced any particular threat, but it is still useful to categorize the river's riparian zone for conservation. Lake James Environmental Association (LJEA) has a mission to protect Lake James and its watershed, and to enhance the natural beauty held within it. LJEA has a vested interest in reducing water pollution in any way possible. This is done partly through internships, like the one that conducted this analysis, and through community partnerships and educational programs. In addition, LJEA helps to facilitate biological and chemical stream water monitoring for rivers flowing into Lake James. LJEA's specific goals for this project were to assess and document the riparian buffer zone of the Catawba River. The Catawba River, upstream from Lake James, is the

water body of focus. However, indirectly, Lake James is also of concern because the Catawba River is a tributary of Lake James. So, it is important that the integrity of the riparian buffer be restored in areas and conserved in others. LJEA will establish conservation easements based partly on the final product of this project. This project used Geographic Information Systems (GIS) to classify land and associate potential risk levels based on those classifications. In a similar project, it was found that intense agricultural use of the land was linked to stream water pollution. This was discovered through the use of Geographic Information Systems (GIS) and nutrient budgeting techniques (Anbumozhi et al., 2005). However, the product created here is a partially interactive story map of the Catawba River and a web-based application to calculate risk levels based on land classification. A story map is essentially a blog with maps, but instead of personal stories, there are descriptions of what is going on in the maps. The stories provide information about the environmental state of the riparian zone in an easily interpreted form for the layman to understand. Providing information in an accessible format is necessary for reaching a wider audience. Concurrently, accessible information allows one's interest in conservation to grow without getting caught up in the tedious nature of science. In addition, this project provides conservation values for the entire reach.

The story map was constructed through Esri Story Maps, an online open access tool. To do this, it required several maps displaying specific aspects be brought into a single cohesive story that outlines the riparian conditions separated by parcel. To accompany the images, a short description of what is going on at that area for each map/location was added. Alongside with the maps there are charts displaying the overall state and condition of the river based on the riparian zone. At the bottom of the story map there is a link to the

interactive application that displays the entire reach. Both the story map and the application are posted to LJEA.org for both LJEA and the general public.

Methods

This project required the use of Python code, QGIS, Google Sheets, and Datawrapper. Aerial imagery and google maps were used to observe the river and the 100 meter riparian zone. The aerial imagery allowed for better targeting of high risk areas and provided for a better understanding of the riparian zone and surrounding areas. It was also used to delineate the Catawba River to increase the accuracy of the hydrologic layer. Data was gathered from NConemap that included parcel identification numbers, addresses, and the geographical outline of the parcel were used to analyze the river. This project employed the use of hydrologic, elevation, and slope data to get a sense of the Catawba River's physical characteristics.

All of the aerial photographs and the digital elevation model (DEM) were gathered from NConemap.gov. The imagery was simply used to give context to the National Land Cover Dataset (NLCD) classifications. This method was validated by Xiang in 1996, when aerial imagery was used to identify land use and cover data. Shapefiles are a commonly used data file type that can be uploaded into QGIS. All of the data described earlier come in shapefiles.

QGIS

The riparian buffer was studied using aerial imagery. USGS National Land Cover Database was then used to provide land classifications such as “Deciduous Forest,” “Evergreen Forest,” “Crop land,” and “Developed.” Each classification is a 30 by 30 meter pixel. Aerial imagery from 2017 was used, which was the most up-to-date available for this region in North Carolina. Hydrologic data was gathered from NConemap but was found to be significantly inaccurate when overlaid on the aerial imagery. A new delineation was created to solve this issue, which consisted of drawing a line with QGIS using the aerial imagery as a guide. Once parcel data and topological data were uploaded to QGIS, data prep could begin. Using a slope function on QGIS, slope data derived from a digital elevation model (DEM) was created. Afterwards, two buffer zones of 100 and 500 meters stretching out from the center of the river to each side were created using the buffer tool. For the purposes of this project, the 100 meter buffer layer is considered the riparian zone. The riparian buffer zone was used as a layer to cut the parcels and DEM out so that both only showed 100 meters from the center of the river. The use of a DEM to further understand the land and its potential risk was as demonstrated by Turner in 1989. Running a histogram tool created a list of land classification values that were then added to the attribute table associated with the parcels. The same was done for the slope. These steps were repeated for the 500 meter buffer. Additionally, pixel counts of each classification were gathered for both the 100 and 500 meter buffer.

Google sheets

The parcel dataset derived from NConemap with histogram values added to it was downloaded from QGIS and then uploaded into google sheets. From there, the land classification values were added together by column to retrieve the total amount of classified land for each parcel. Each parcel classification amount was then divided by the total to retrieve the percent of that classification, which was then added to a new column at the end. The same was done for slope. One study for urban areas uses a metric consisting of forest, buildings, and other; however, this project required the use of 15 classification from the NLCD (Herold et al., 2003). The pixel count of the entire reach for both the 100 and 500 meter buffer were used to calculate the total acreage of each classification based on the knowledge that each pixel is 30^2 meters. The total acreage of each classification was then used to produce two pie charts each displaying the 100 and 500 meter statistics.

Python

The dataset from QGIS is a mix of categorical and numerical values in which a numbering system was created that denotes the level of risk from each site/parcel. The meaning of “risk” in this case is the potential for any NPS pollution input. However, that risk level is not awarded equally to all, but is instead differentiated based on classification. The actual risk number assignment came from a discussion over research with Marshall Taylor, a representative from LJEA. The main conclusion from this discussion was that the number did not matter as much as its relative size compared to other number assignments between classifications. This in combination with the category of land use is enough to determine to a reasonable degree *what* pollution and *how much* potential input there is. A normalized numbering system on a zero to one scale was used to assign risk value to all 15

classifications. The slope data was created based on the number of pixels in a parcel that were above 20% gradient based on the 2012 study by Akbarimehr and Naghdi described earlier. Therefore, only the pixels over 20% slope were considered and a separate factor for slope was added that proceeds as follows. For instance, If the percent of land cover is over 20%, then the risk gets assigned the value 4; if the percent of land cover is greater than 40%, then the risk gets assigned the value 6; and so on to a max of risk value 10. The application can provide two easily understandable metrics, the first being the cumulative risk number and the second the land use Category. Conservation values gathered from the Water Research Foundation were added to the existing dataset (*Quantifying the Potential Benefits of Land Conservation on Water Supply to Optimize Return on Investments*, 2019).

A visually appealing interface was created through a python package called Mapbox to display the risk associations with each land categorizations. A color gradient was assigned based on the risk level to make it understandable and convenient for a layman user. Two drop boxes for adding new data were added to the interface. One drop box for updating any parcel information and another for updating conservation values. This interface is hosted on a server through Heroku, a subscription based website server service.

The final product of this project is a display of all of the QGIS derived maps in an ArcGIS story map. As stated earlier, several descriptive statements to help viewers understand what they are looking at was provided. Several tables of descriptive statistics were added right below the maps to describe more about the landscape, such as percentages of what classifications make up the majority of land type. These have been crafted in an online web service called DataWrapper. Creating the story map was quite

simple, adding text, images, charts, and headings into the software by uploading or writing directly into the map. At the end of the story map is a link to the application built in python and a link to the code repository.

Results/Uses

The results for this project will not be seen for some time after its release. LJE A will be using this story map and application to help with obtaining conservation easements from property owners throughout the reach. All the maps produced of the reach are displayed in the story map accessible at <https://arcgis.com/arcgis/storymapjs/index.html?appid=1ujie10> and shown in figures 1-4. Two pie charts showing the land cover by acres were also created to help show the relative quantities of most categories as seen in figures 5 and 6.

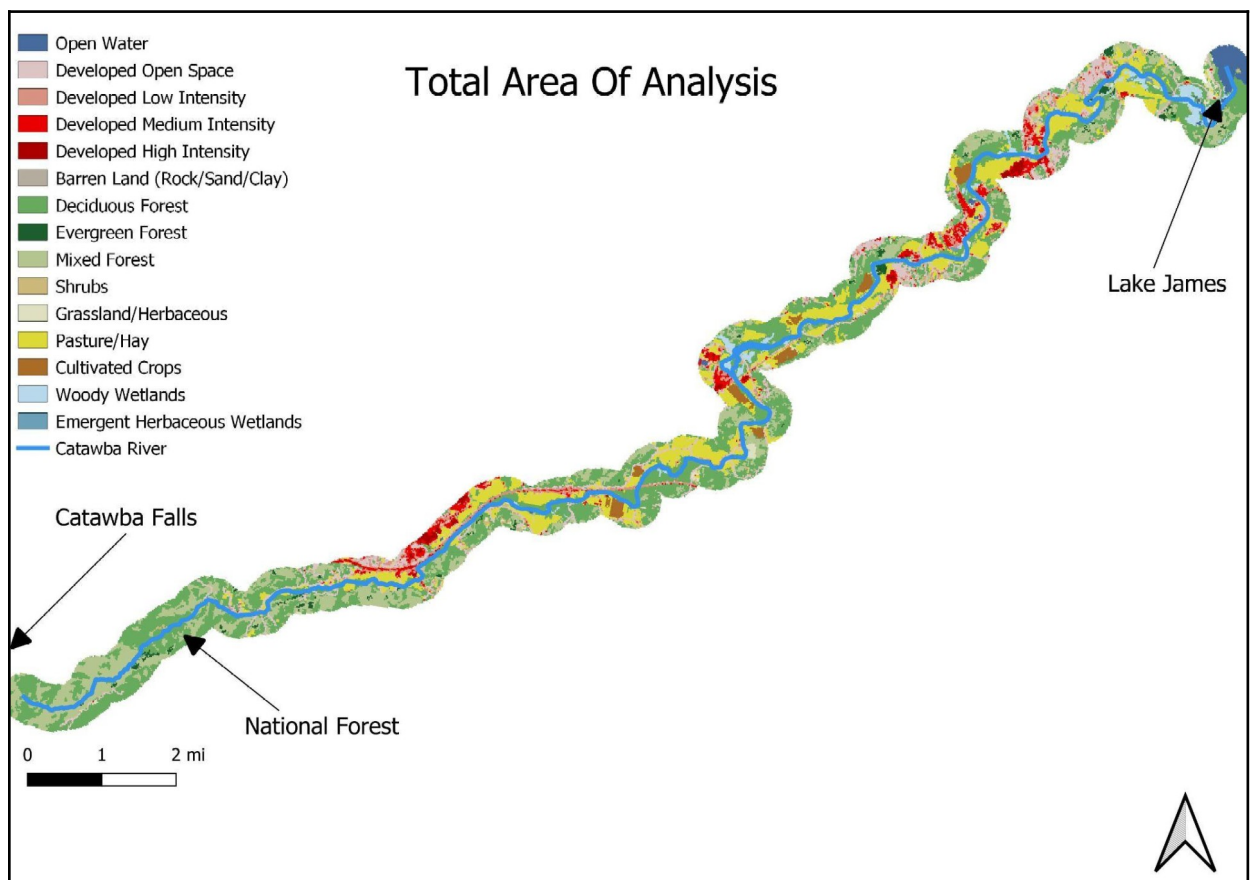


Figure 1. This map shows the 500 meter buffer classified by the NLCD. The 500 meter was chosen for this map because the 100 meter was too small to see the entire reach clearly.

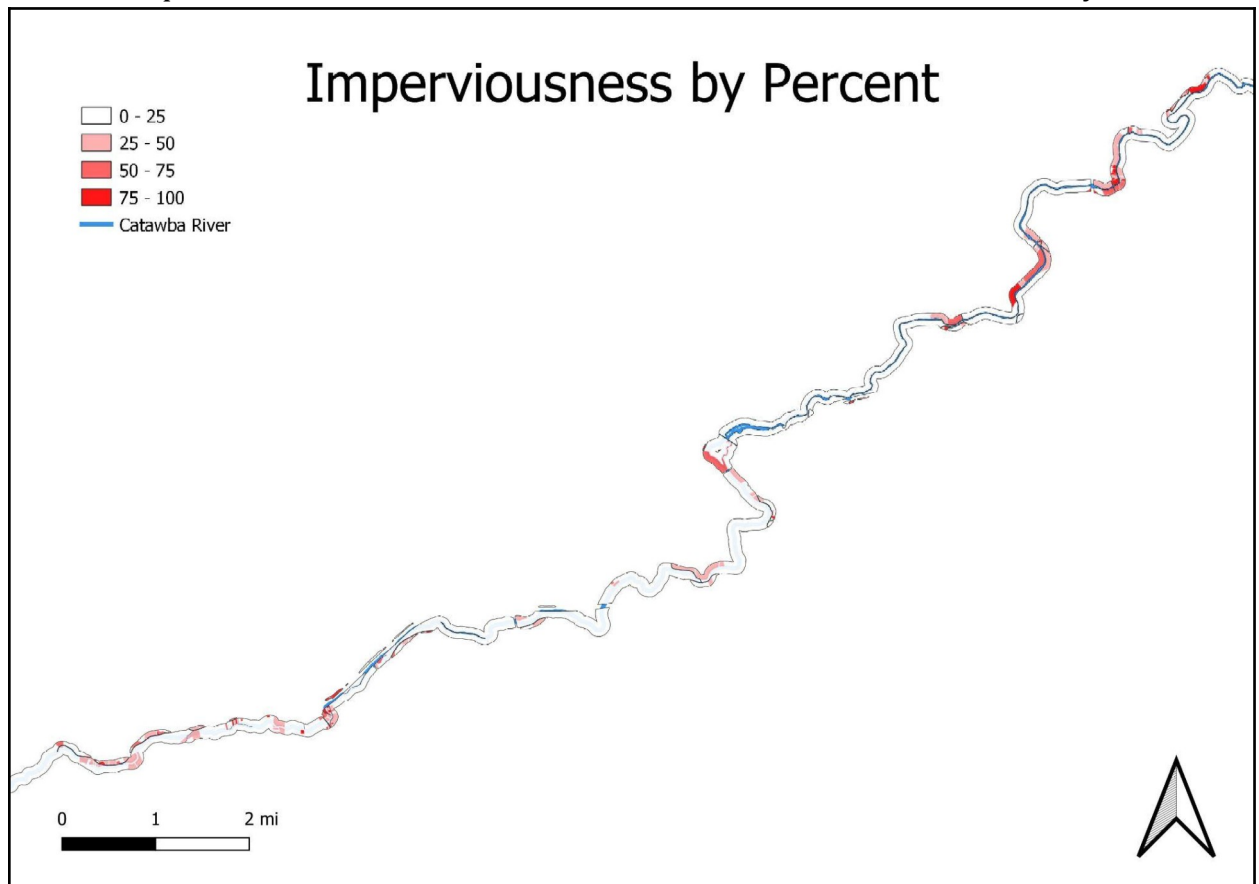


Figure 2. This map displays the amount of all developed land classifications by percent.

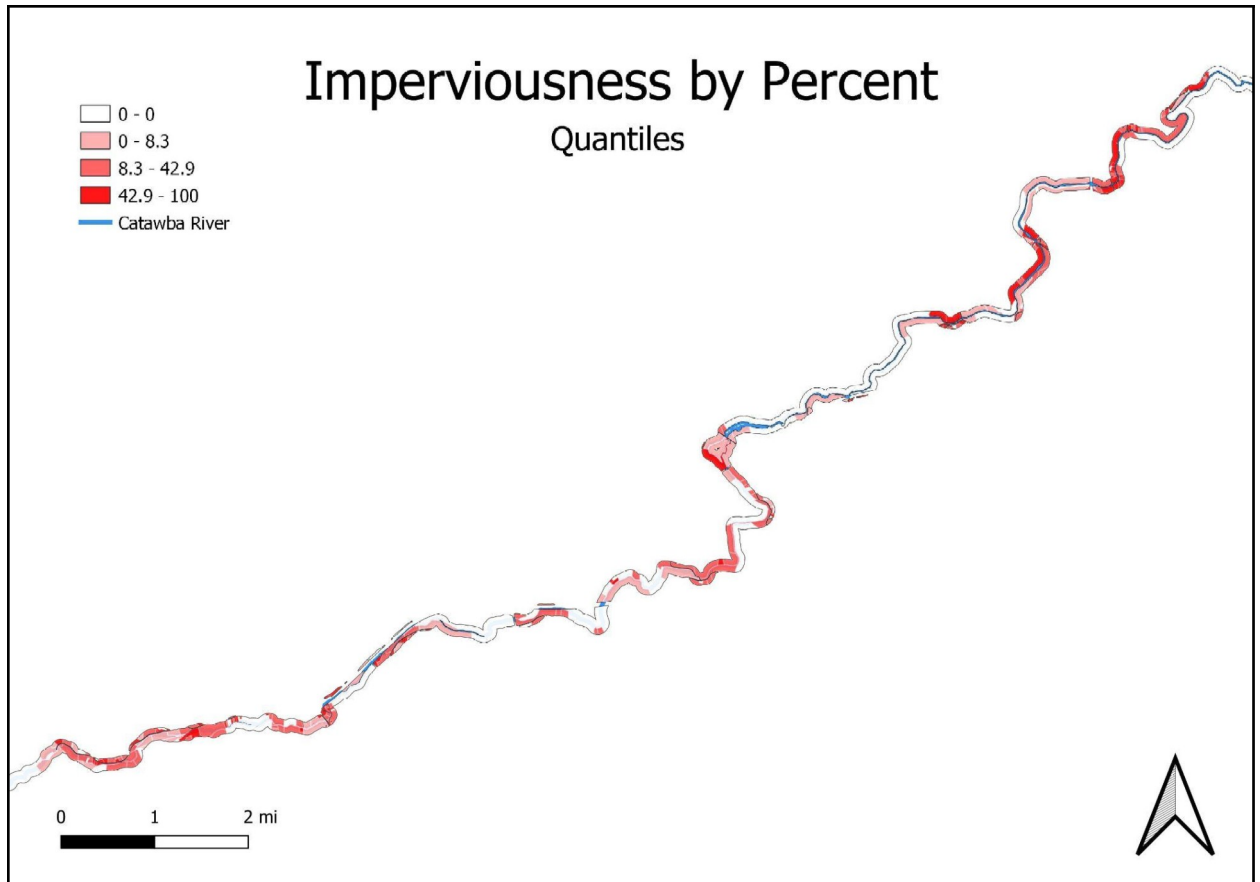


Figure 3. Displays the same classifications as the previous map except instead of data being spaced by equal percentages ranges it is spaced by an equal count of parcels. Notice how the legend changed from the figure 2 to 3. This was done because most of the data lies within a lower percentage range.

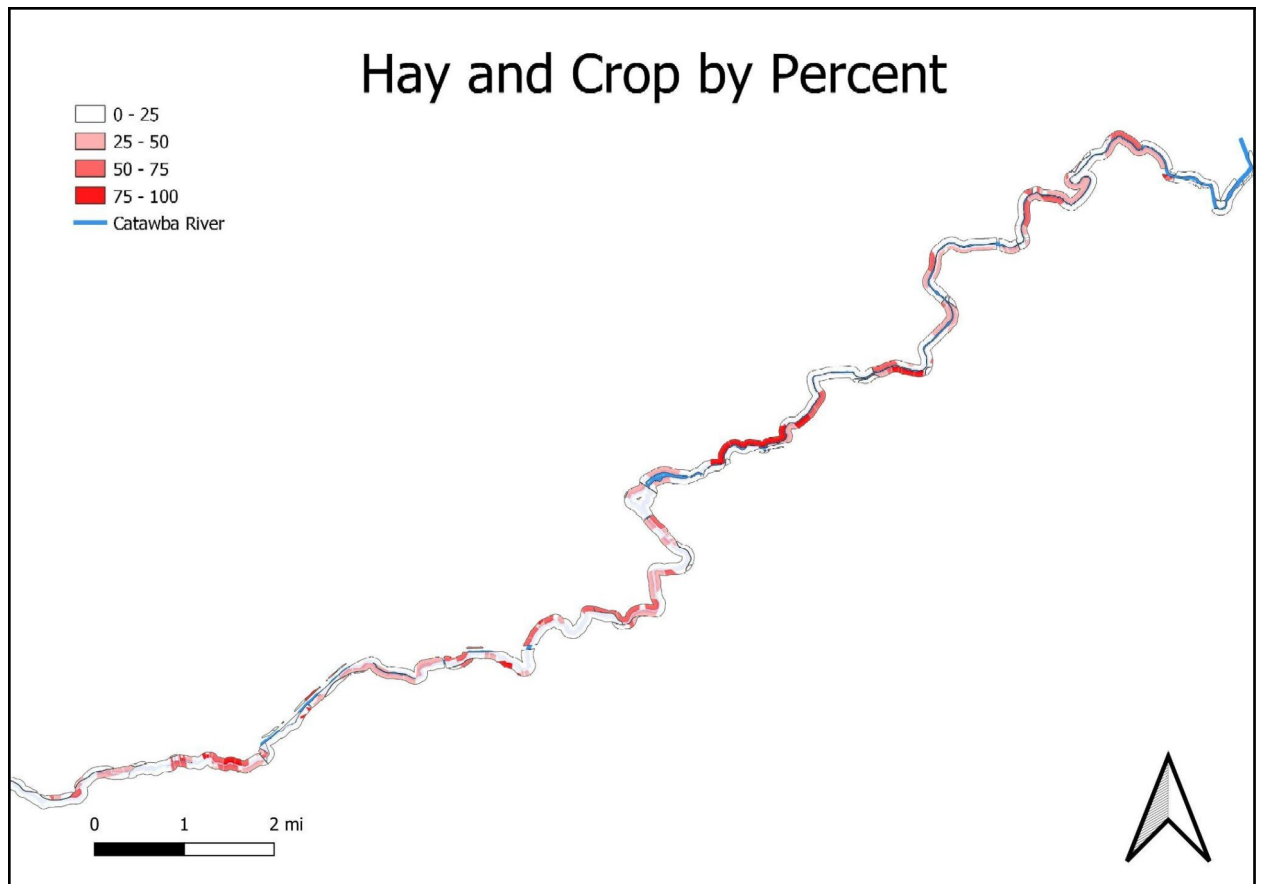
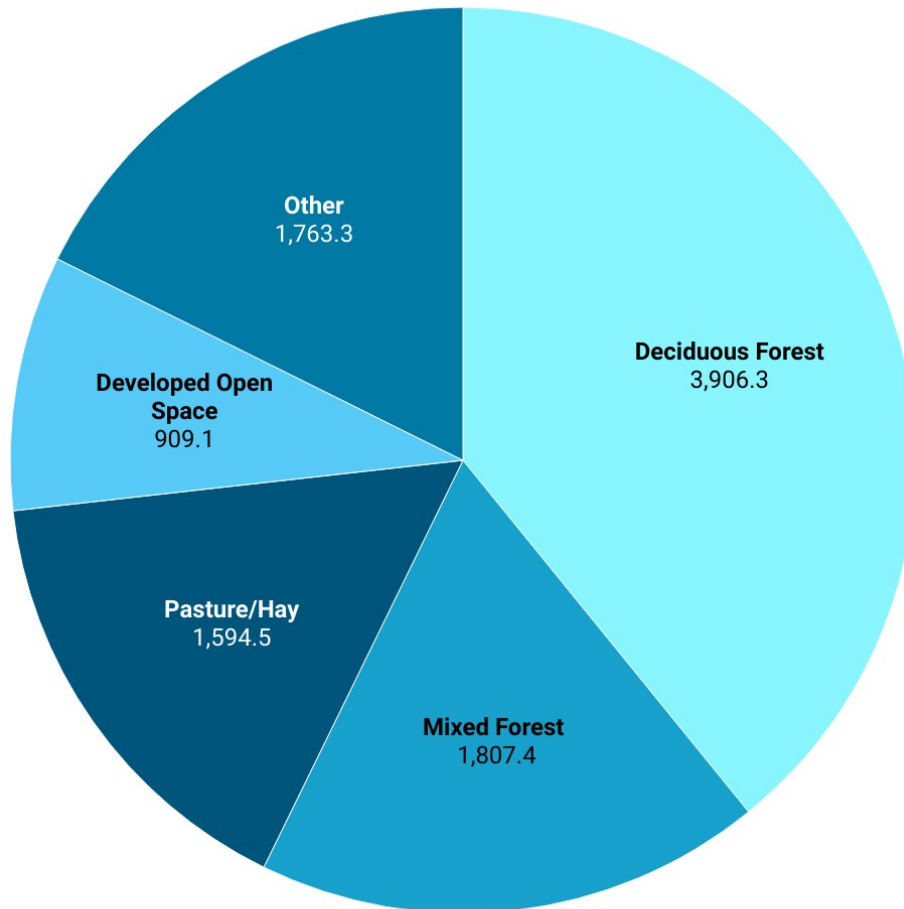


Figure 4. This map shows crop and hay land classifications by percent.

500 Meter Buffer by Acres

Deciduous Forest Mixed Forest Pasture/Hay Developed Open Space Other

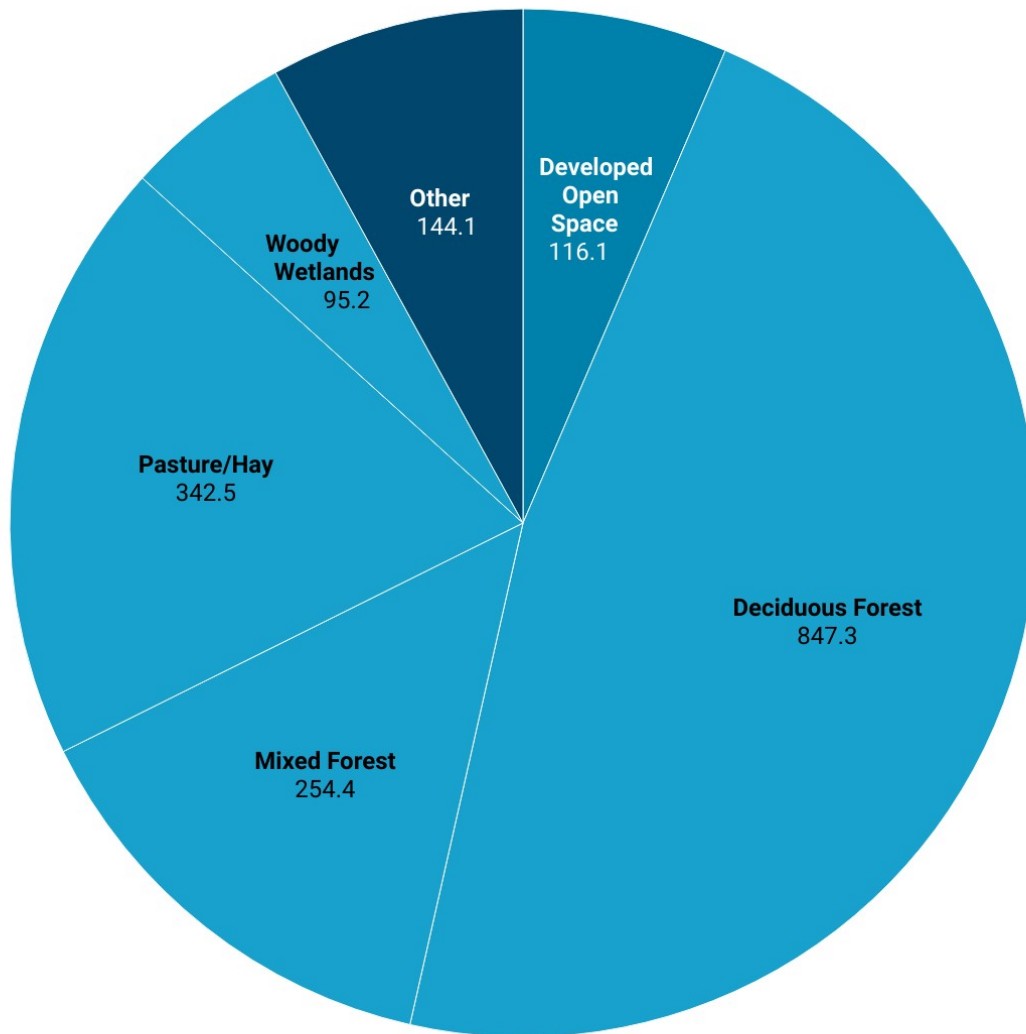


Created with Datawrapper

Figure 5. As shown, more than half of the 500 meter buffer is forested land and more than a quarter is of risk classifications being Developed Open Space and Pasture/Hay.

100 Meter buffer

■ Developed Open Space
 ■ Deciduous Forest
 ■ Mixed Forest
 ■ Pasture/Hay
 ■ Woody Wetlands
 ■ Other



Created with Datawrapper

Figure 6. This chart also shows acres and tells a similar story to the 500 meter buffer. However, the amount of forested land is slightly higher and the amount of Developed Open Space has decreased too. Pasture/Hay seems to make up close to the same percent as in the 500 meter.

The application displays the entire reach that can be zoomed in on any parcel or area as shown in figure 7. The app also has conservation values associated with each parcel that, if selected, will populate as seen in figure 8. The application is also adaptive to updating the data sets and has a file uploader area for when new info is obtained. On the left hand side there are slidable tabs for each land classification. The tabs go from zero to one and they start on a specific parcel's calculated value. This allows the user to see how the risk level could change depending on the percentage of a certain land classification. There are also some cosmetic additions such as an option to change the color ramp and the map style as shown in figures 7 and 8.

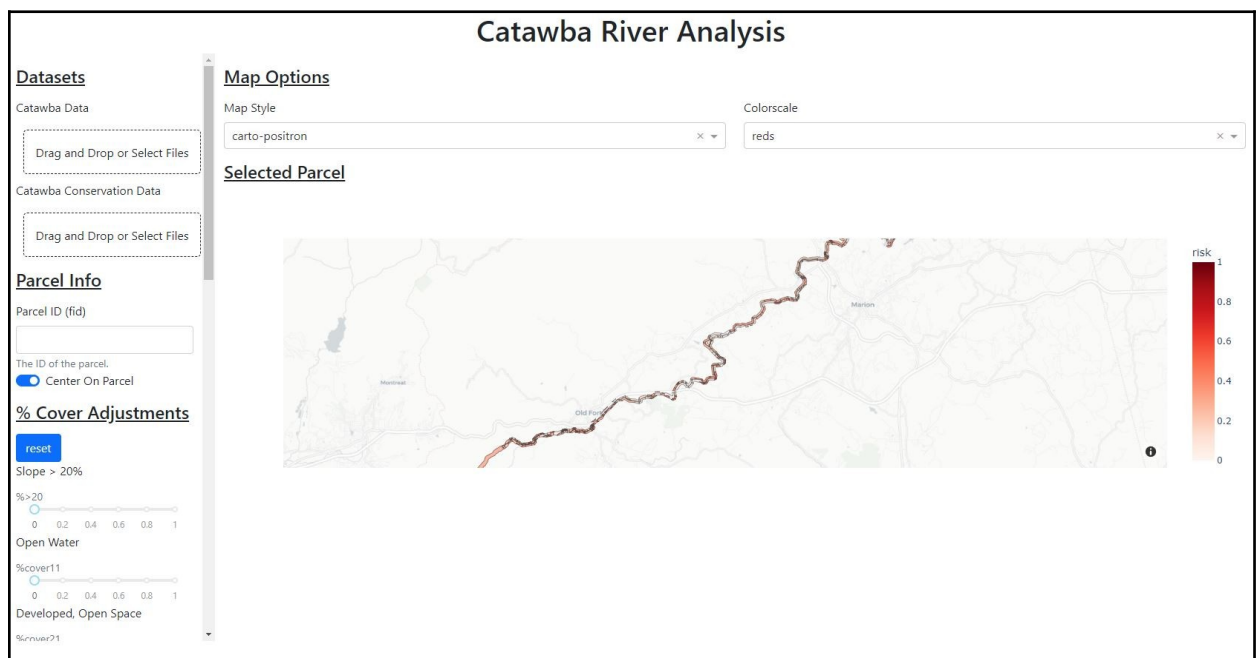


Figure 7.

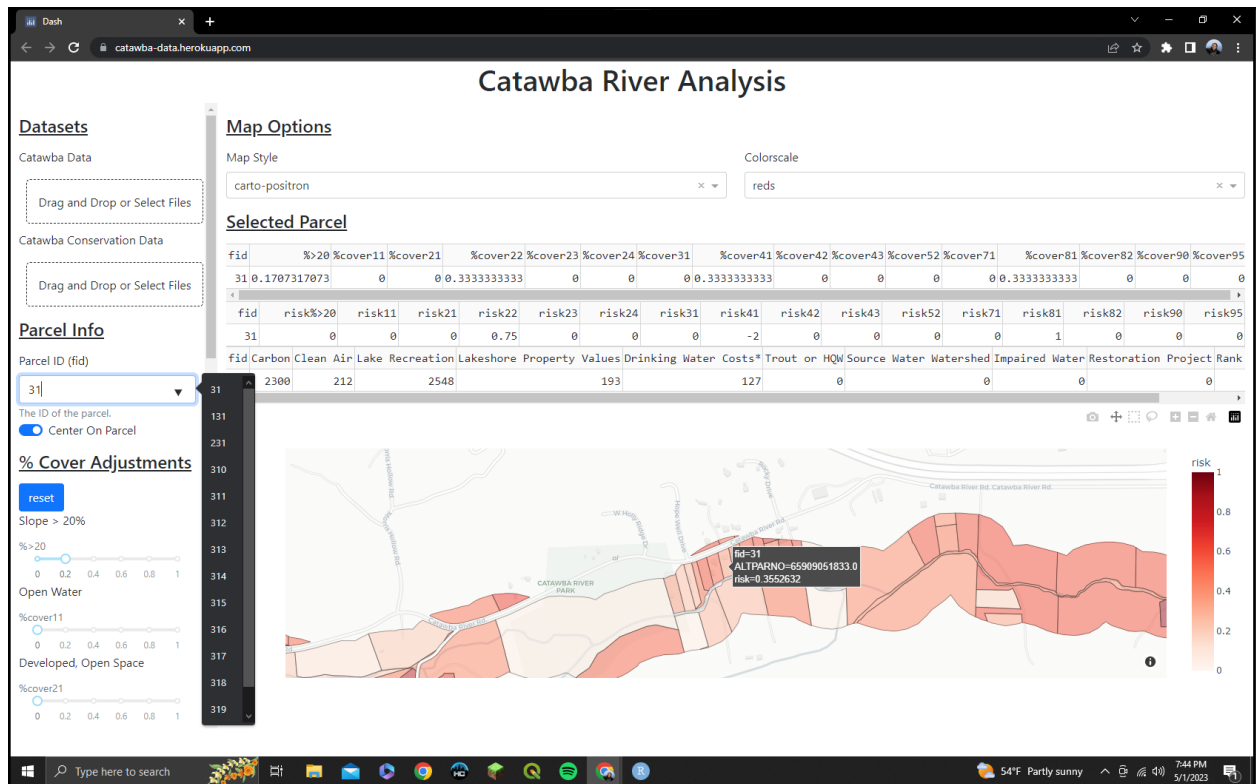


Figure 8. Once the parcel ID number is selected, the map automatically zooms in and centers on that parcel. If the mouse is hovering over any parcel, a popup with the ID number, Alternate Parcel number, and the risk level are displayed as shown.

Discussion

Based on the results, a project such as this appears to be effective for presenting spatial information in an accessible manner. Considering the validation for this project is still in question, more time is needed to understand how useful the application and story map will be in contributing to the creation of conservation easements. However, there is significant potential for spatial data available like the NLCD, and this project has potentially highlighted new avenues for its use. The risk number specifically should be understood in context rather than as a concrete value on its own— because these scores are normalized on a zero to one scale. Nutrient risk land classifications were given values slightly less than that of barren land because according to the EPA, sediment pollution is the number one

water pollutant (EPA, 2015). Once again, The EPA suggests that nutrient pollution is considered the second most common and detrimental form of water pollution. So the accuracy of the risk number is just in its relativity to other land classifications.

The application can be used to show land owners that their actions, such as conserving their riparian zone, can directly lead to a lower risk level on their property. LJEAs intend to use the project as a tool to create conservation easements for areas of high risk along the river. For example, using the slider bars on the left side of the app, LJEAs can demonstrate the impact of altering the land classification in that parcel. LJEAs can also add new data into the application by simply adding it to the drop box labeled Catawba Data or Conservation Value Data. Ideally, this application will also help the general public and local residents understand more about their watershed and the importance of the riparian buffer zone.

Projects such as this are important for making data and conservation work more accessible. Especially with the amount of new spatial data being generated by governments and private organizations, projects like this help to put that data to use in an interpretable form. LJEAs have stated that they plan to add contributing streams to this project in the future and potentially add other rivers. The application and story map will act as a scaffolding for future endeavors into conservation and data analysis.

Budget Sheet

Expenditure	Cost
Heroku Server Subscription(3 months)	\$5/month
Total:	\$15

Budget Justification**Heroku Cost**

To host the application created in python, a Heroku subscription was required to validate the code. After completion, the rights to the application were transferred over to LJEA so that they can pay for the subscription.

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