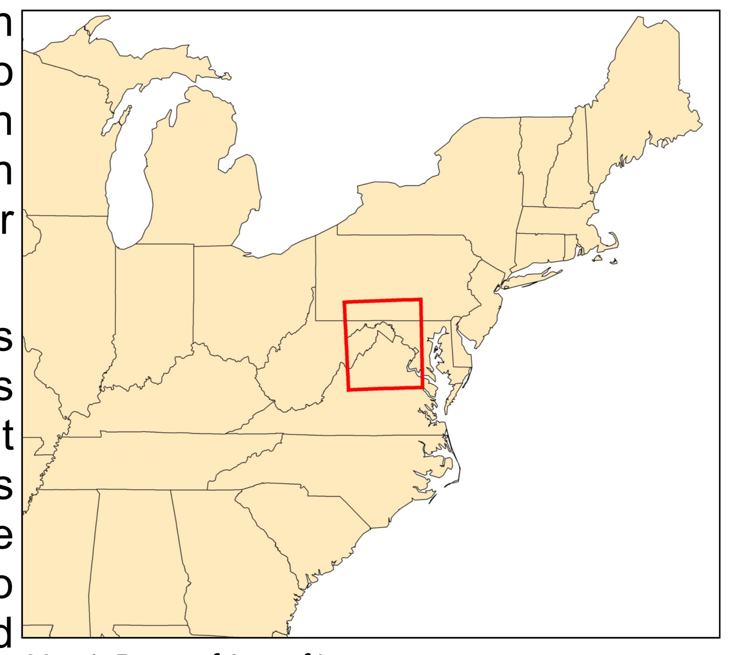
The Impact of Land Use on Water Quality in the Potomac River Watershed

INTRODUCTION

Rivers in the Potomac Watershed supply drinking water, irrigate crops, support aquatic ecosystems and are used for recreation throughout Maryland and Virginia. (Map 1) As a result it is important to understand what factors affect water quality in these rivers.

The goal of this project was to determine the effect of land use on water quality in the Potomac River Watershed. The study evaluates water quality based on levels of nitrogen, phosphorous and dissolved oxygen. High nitrogen and phosphorous levels can lead to algal blooms which harm aquatic ecosystems and can cause elevated toxins and bacterial growth which impact human health. The analysis seeks to determine if there is a correlation between these water quality parameters and how much of a watershed is forested, agricultural or urban.

A common strategy to reduce water pollution is to leave areas adjacent to streams undeveloped and uncultivated to screen out pollutants; these areas are referred to as "riparian buffers". In this project land use in the areas within 50 ft. of streams was analyzed to determine if land use in the buffers presented any additional correlation to water quality.


Map 1: Extent of Area of Interest

METHODS

The geospatial analysis consisted of three major steps, delineating watersheds, reclassifying a land use raster and computing zonal statistics.

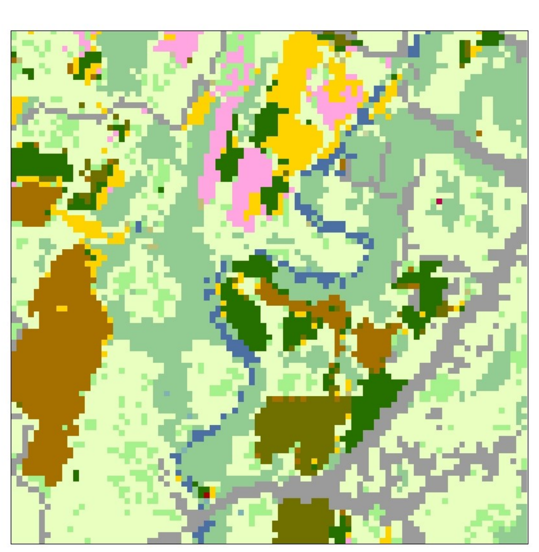
Watershed Delineation

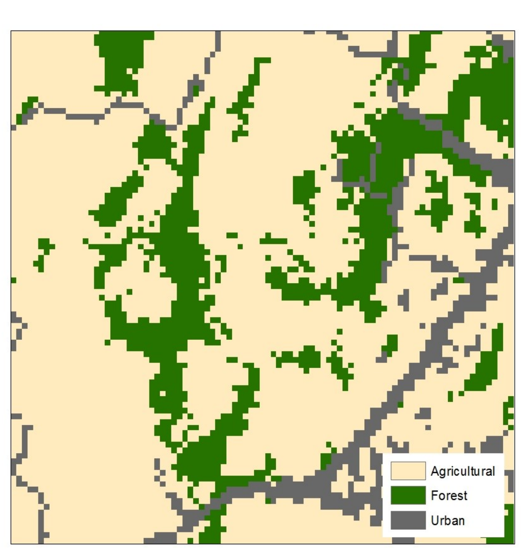
Water quality data was available at 15 monitoring stations in the Potomac River Watershed (collected 2015-2016). Calculated watersheds were based off of 1-arcsecond Digital Elevation Model raster tiles. The raster was "filled" to eliminate false depressions then analyzed to determine surface flow direction and areas of high flow accumulation. Then the water monitoring stations points were relocated to the nearest area of high flow on the flow accumulation raster. The watershed tool then used this information to designate drainage basins corresponding to each monitoring station. (Map 2 & 3)

Reclassification

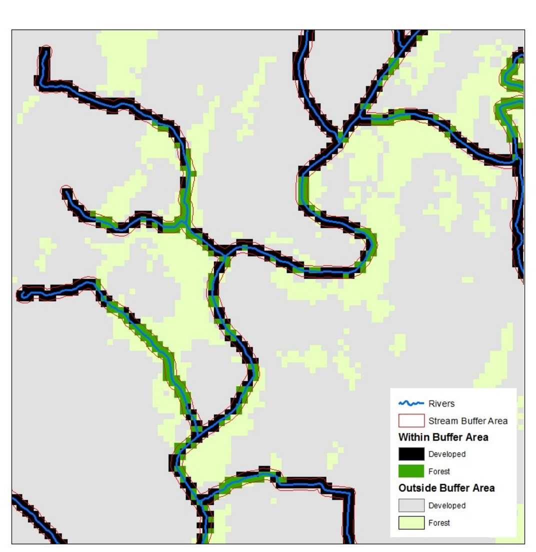
A land use raster (Map 4) was reclassified to generalize use within in the area of interest (Map 5). Areas corresponding to deciduous, evergreen, forest and shrubland were designated as forest. All lightly developed to heavily developed areas were designated as urban. All other land uses were designated as agricultural.

Zonal Statistics


Map 4: CropScape Land Use Raster Input



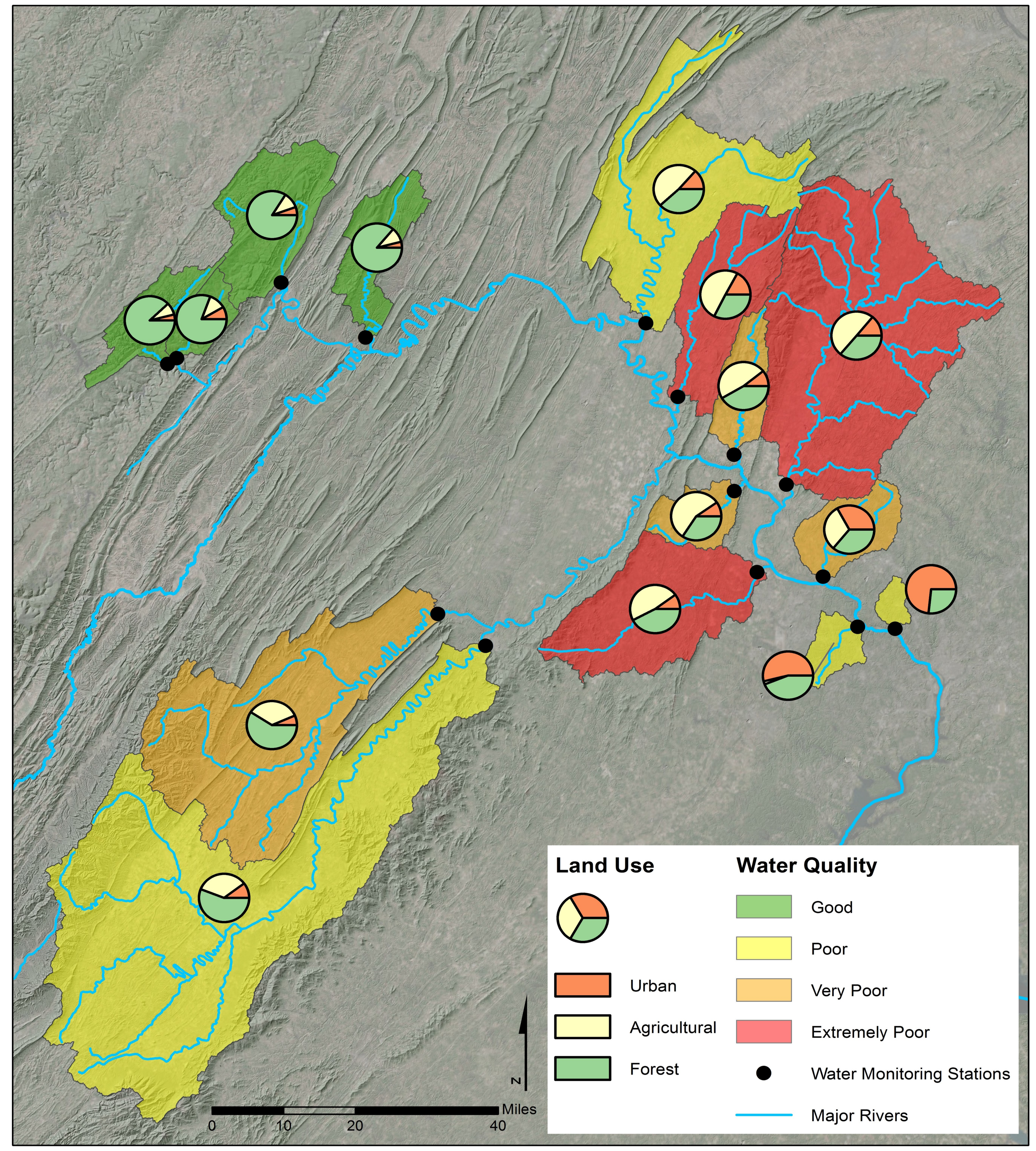
Map 5: CropScape Raster Reclassified by Generalized Land Use


Map 6: Amount of Forested Area Within 50ft Buffer of Streams

The zonal statistics tool was used to calculate the percent of each land type within each watershed. (Map 2) Then, a 50 ft. buffer around the streams in each watershed was generated. The zonal statistic tool was again used to determine the percent forest within each riparian buffer area. (Map 6)

The nitrogen, phosphorous and dissolved oxygen data for each water station were combined into an overall water quality rating out of 10.

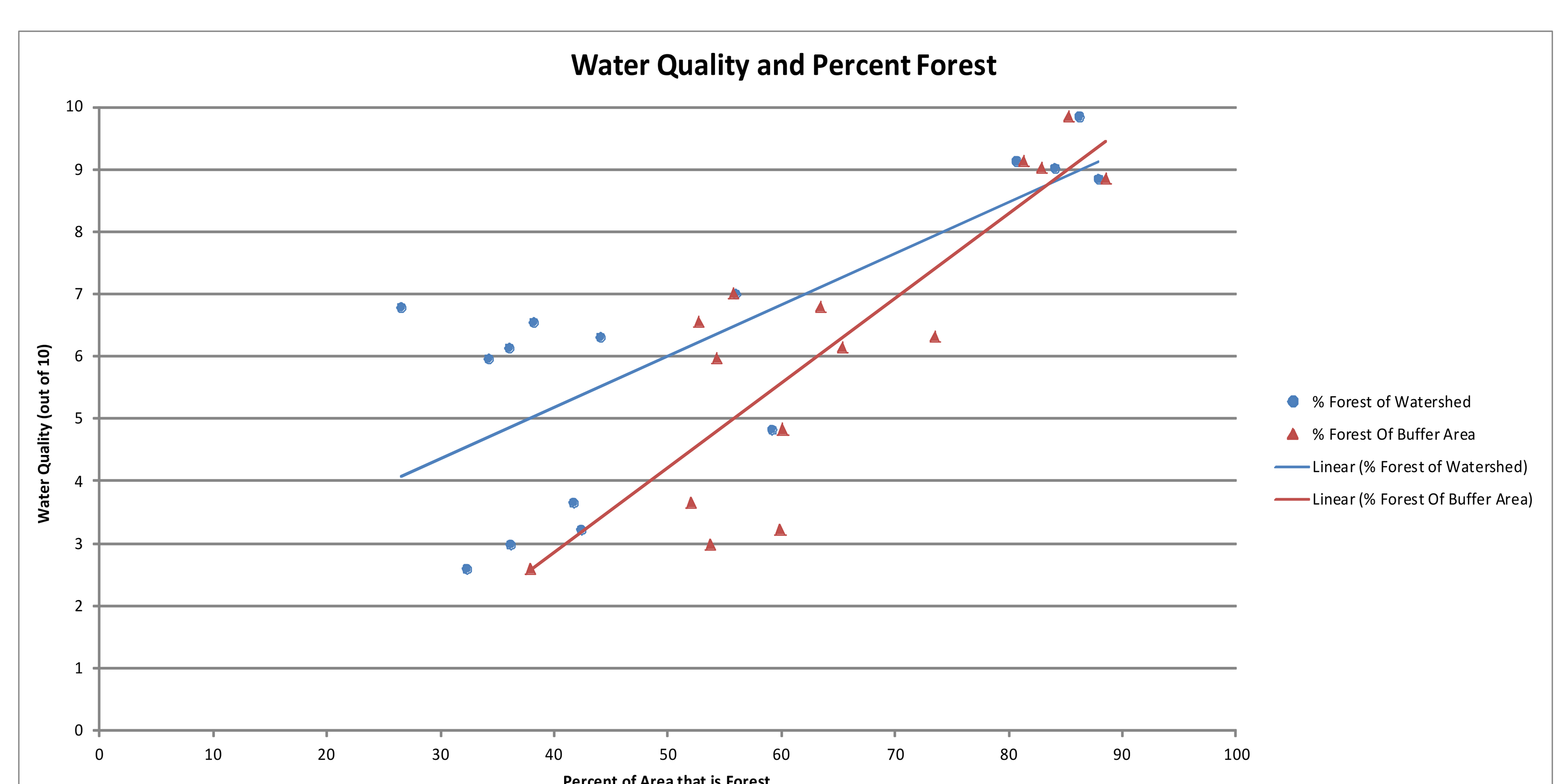
Land Use and Water Quality by Watershed



Map 2: Pie charts show land use distribution in each watershed. Watersheds symbolized by water quality.

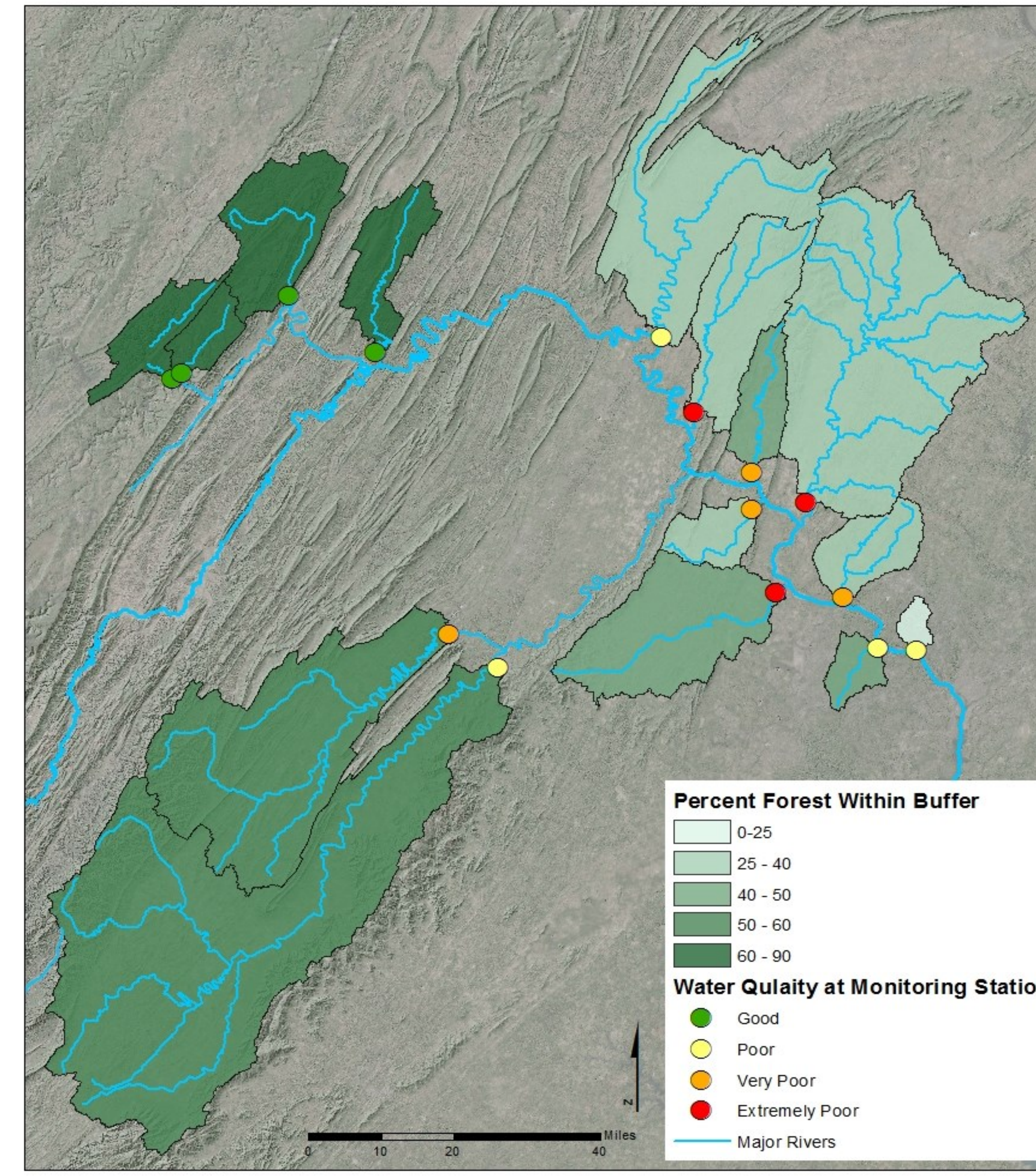
RESULTS

The most obvious conclusion of this analysis is that watersheds with less forest and more agriculture tend to have inferior water quality. (Map 1 & Graph 1) This is likely because the most significant contributor to nitrogen and phosphorous load is agricultural fertilizer and manure. The analysis does not show a significant correlation between water quality and amount of developed, non agricultural land (urban). (Map 2) Analysis of the stream buffers showed an even stronger correlation between percent forest and water quality. (Map 2 & Graph 1) This may suggest that the percent of trees in the areas near a river are more important in determining the water quality then the percent of forest in the watershed as a whole.



Graph 1: This plot illustrates the correlation between the % of the watershed or buffer area that is forested and overall water quality

Effect of Forest Buffers on Water Quality



Map 3: Watersheds symbolized by percent forest within 50 ft. of rivers, by watershed. Monitoring stations symbolized by water quality.

CONCLUSIONS

The key implications of this analysis are that agricultural development is well correlated with decreasing water quality and as a result, focus should be placed on improving agricultural processes and standards that benefit water quality. Additionally, the analysis demonstrates that planting forest stands adjacent to rivers can do more to improve water quality than simply reducing the amount of agricultural use within the entire watershed.

This analysis only considered one water quality sampling per site. Water quality parameters are extremely variable because they depend on weather and seasonality. Additionally, the health of a stream is dependent on other parameters beyond dissolved nitrogen, phosphorous and oxygen. As a result the water quality measurements used in this study are not the best representation of each stream's total water quality. In the future it would be beneficial to use a larger number of water quality samples per watershed and look at a wider range of parameters.

A further limitation of this project is the analysis of buffer areas. In order to truly determine the effect of planting buffer vegetation near streams, analysis would need to be performed on two areas with similar overall watershed land use but different buffer area land use. The sample size in this study was insufficient to perform this analysis. Future analysis involving more watersheds could more accurately determine the effect of leaving buffer areas undeveloped and uncultivated.

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Projection: NAD 1983 UTM Zone 18N

SOURCES

United States Department of Agriculture: CropScape-Cropland Data Layer (https://nassgeodata.gmu.edu)

United States Geological Survey: National Hydrography Dataset & National Elevation Dataset (https://viewer.nationalmap.gov)

National Water Quality Monitoring Council: Water Quality Dataset (https://www.waterqualitydata.us)

Basemap Provided by ESRI