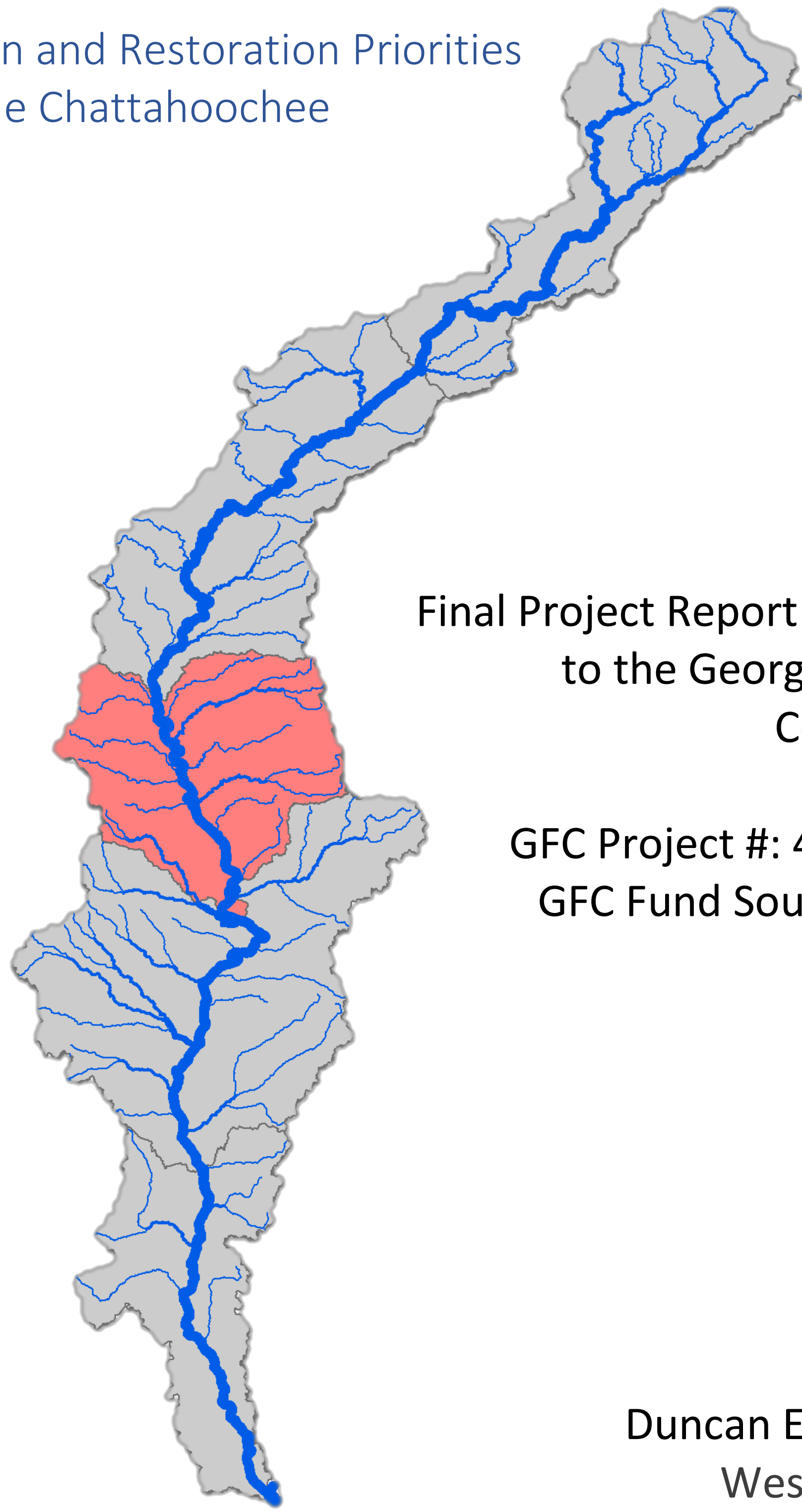
Conservation and Restoration Priorities in the Middle Chattahoochee River Basin



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Introduction

Description of watershed

The Chattahoochee River originates in the Southern Blue Ridge Mountains above Helen, Georgia, and drains almost 5.6 million acres (8770 mi^2) of piedmont and coastal plain landscape in Alabama and Georgia. With a length of 430 miles, it is commonly divided into three segments, with the Upper Chattahoochee flowing through Atlanta before becoming the Middle Chattahoochee through Columbus. From Lake Walter F. George, the Lower Chattahoochee flows south toward Lake Seminole, where it joins with the Flint River to form Lake Seminole, which drains, in turn, into the Apalachicola River and the Gulf of Mexico. Along the way, the Chattahoochee provides drinking water for more than half of all Georgians and recreation opportunities on the reservoirs above the 13 dams that punctuate its course.

The hierarchical Hydrologic Unit Codes developed by the USGS to describe the rivers of the United States divides the Chattahoochee into four sub-basins, the Upper, Middle-Lake Harding, Middle-Lake Walter F. George, and Lower, with the border between the two middle sub-basins falling just upstream of Columbus. Both the natural landforms and the human landscapes differ among these four sub-basins; developed land uses are quite prevalent in the Upper portion and generally decrease toward the south, while a majority of the area of the middle sections is a mix of evergreen and deciduous forest types, and row crops cover almost a quarter of the lower sub-basin (Figure 1).

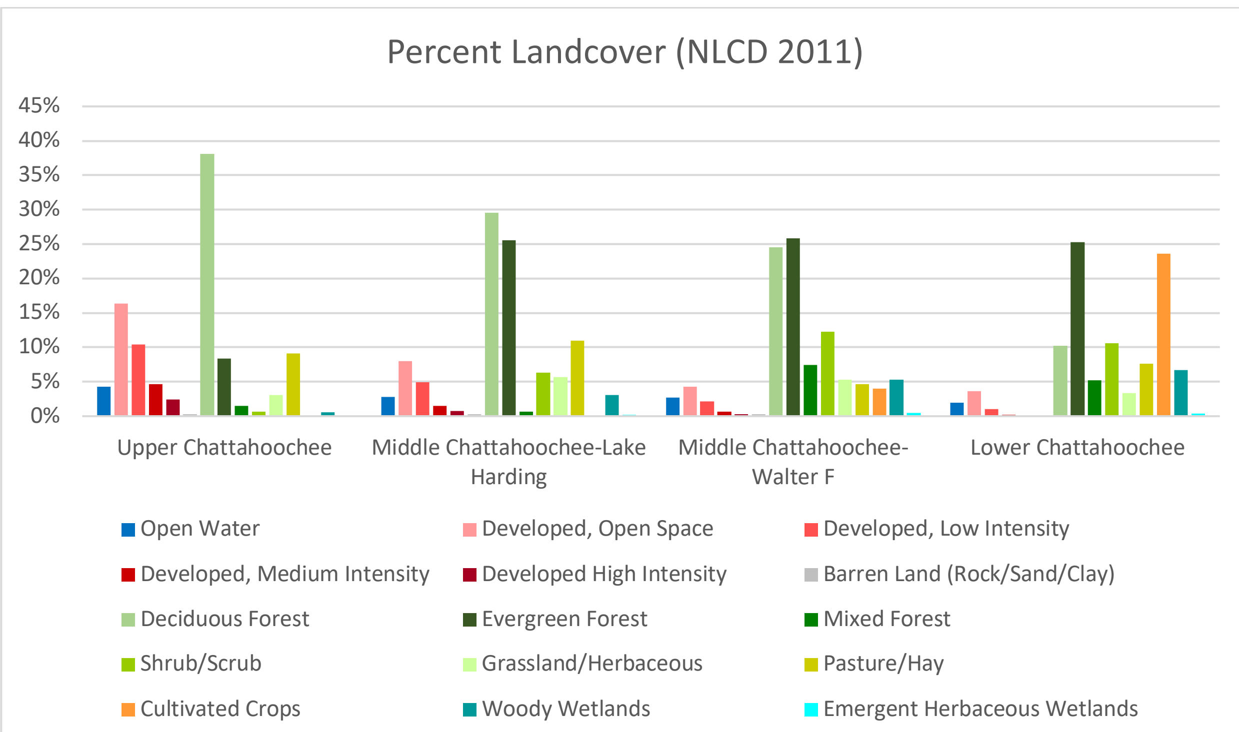

Figure 1: 2011 NLCD land cover for the four HUC-8 sub-basins of the Chattahoochee River.

Sediment & Land Use Change

Forested landscapes are important sources of ecosystem services, including the provision of clean drinking water; over half of the surface drinking water supplies in the lower 48 states derive from forested lands (Brown et al. 2008) Yet almost all of the US's forests are facing pressures from urbanization and agriculture (Riitters et al. 2002). These development pressures are expected to increase, leading to ongoing loss and forest fragmentation (Johnson and Beale 2002, Radeloff et al. 2005), even in the most ecologically valuable areas (Poudyal et al. 2016, Carter et al. 2019) and with these losses, the landscape becomes less able to provide key ecosystem services (Foley et al. 2005).

The findings of recent studies estimating the increased water treatment costs associated with reductions in source water quality are summarized in Warziniack et al. (2016), which revisits the negative relationship between water treatment cost and watershed forest cover described in Ernst (2004) and a larger study which found that both turbidity and total organic carbon (TOC) in source water increase as forest cover declines and a positive relationship of increasing TOC and treatment costs (Freeman et al. 2008). Based on survey responses from 37 water treatment utilities in watersheds averaging 60% forest cover, Warziniak et al. estimate that conversion of forestland equal to 1% of the watershed area would increase turbidity by 3.9-6.3%, depending on the ultimate land cover type. However, they did not detect a similar relationship between land cover change and TOC, which their data suggest is over twice as expensive for utilities to treat for the same marginal increase. Nevertheless, this study estimates that converting 10 percent of the average watershed from forest to developed area would increase chemical treatment costs from $2.52 to $20.48 annually per million gallons treated and speculates that the variation in their estimates relative to previous studies (Ernst 2004, Freeman et al. 2008) may be due to small sample sizes that include watersheds that are predominantly over or under the 60% forested threshold noted by Ernst at which treatment costs begin to increase rapidly with additional forest loss.

Study Objective

Based on 2011 satellite images, the middle portions of the Chattahoochee River system are still above the 60% threshold for natural land cover, if wetlands and grasslands are included, but slightly below 56% when only forest cover is included. If recent land use trends continue, sediment delivery to the main stem of the river is expected to increase. Nutrients, particularly phosphorous, are frequently bound to these sediments and the continued runoff of these nutrients will contribute to eutrophic conditions in the reservoirs that may include harmful algal blooms, potentially raising treatment costs above those required to abate turbidity, alone. This study seeks to identify parcels which, if conserved or restored, are expected to contribute most to the protection of surface water quality in the Middle Chattahoochee basin, with the intent to inform land conservation and restoration decisions that maximize surface water quality and minimize future water treatment costs.

Coordinating Projects

This modelling effort was accompanied by a monitoring project conducted by Dr. Susan Bennett Wilde of the Warnell School of Forestry at the University of Georgia, which established stations in the reservoirs of the Middle Chattahoochee River to track water quality, submerged macrophytes, and the algal community in an effort to understand and better predict the dynamics of harmful algal blooms. We are also deeply indebted to Dr. Mattew N. Waters at Auburn University for his work on the nutrient dynamics associated with sediment transport and deposition in the Chattahoochee River reservoirs.

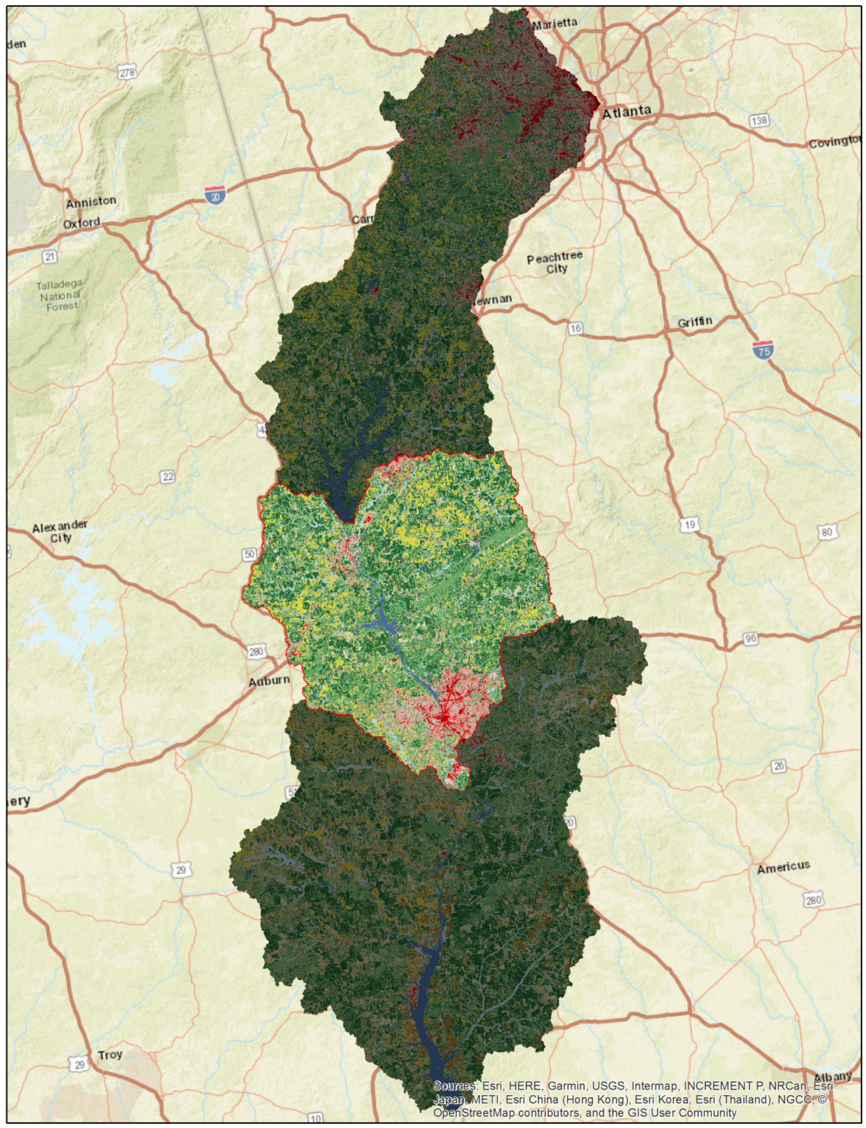

Figure 2: Satellite-derived landcover of the Chattahoochee River basin, with the study area highlighted. Pixel colors as in Figure 1.

Focus Area

Large reservoirs act as sediment traps, essentially “resetting” the signal of upstream land-use. For this reason, this analysis will focus on the portions of the watershed below West Point Dam that contribute to the water supply of Columbus, Georgia, including the watershed of Little Uchee Creek. Although Uchee Creek joins the main stem Chattahoochee River below Columbus, the watershed contains the northeast corner of Russell County, part of the Columbus MSA, and portions of the cities of Smiths Station and Phenix City, Alabama.

Watershed Threats

The population of the Georgia counties that lie primarily in the study area, Harris, Meriwether, Muscogee, and Troup, is projected to grow by 23% between 2015 and 2050, according to estimates constructed by David Tanner of the Carl Vinson Institute of Government for the Georgia Governor’s office of Planning and Budget (available at https://georgiadata.org/sites/default/files/population_estimates_projections.xlsx). Approximately half of that change is projected to occur in Harris and Troup counties, which are currently much less urbanized than Muscogee County. On the Alabama side of the watershed, the Center for Business and Economic Research at the University of Alabama projects the population of Chambers, Lee, and Russell Counties will grow by 38% between 2010 and 2040, with all of that growth occurring in Lee and Russell counties (https://cber.cba.ua.edu/edata/est_prj/AL_copop2000-2040_2018mid-series.xls). Although the current populations of the more rural counties on both sides are relatively small, Meriwether County in Georgia and Chambers County in Alabama are both projected to lose 3-4% of their baseline population, which suggests that there may be restoration opportunities in these areas. Another estimate of the extent of development comes from urban growth model estimates conducted for the Southeast Regional Assessment by the Southeast Climate Adaptation Center at North Carolina State University (http://www.basic.ncsu.edu/dsl/urb.html). Using the SLEUTH urban growth contagion model estimates of areas that are at least 50% likely to be urban land cover, the study area will go from 11.4% in 2009 to 29.6% urbanized in 2050. However, this model of urbanization potential does not factor in local dynamics such as climate or economics, so the estimates may be biased by broader regional trends.

Watershed Priorities for the Middle Chattahoochee Basin

Although large portions of the Upper Chattahoochee River Basin are developed, the water quality effects of the urban land uses on the middle and lower sub-basins are mitigated by the presence of several large reservoirs. The Middle Chattahoochee sub-basin remains well forested, overall, yet the reservoirs above Columbus show evidence of eutrophication, including algal blooms, that typically indicate elevated nutrient inputs from the local watershed. Development pressures in the basin are ongoing, but not yet so extensive that no opportunities remain for meaningful land protection. Both watershed science and experience in similar watersheds indicate that land protection is a sound practice to protect water quality.

The project area is just under 950,000 acres, of which about 531,000 acres were forested in 2011, yielding 56% forest cover. However, just 3.9% (37,306 acres) of the project area is currently protected (PAD-US, https://www.usgs.gov/core-science-systems/science-analytics-and-synthesis/gap/science/pad-us-data-download) in all categories (parks and other publicly-owned lands, easements and other restrictive covenants) and a third of this land has no known conservation mandate. Thus, there is a clear necessity to expand the area under protection, through a variety of conservation vehicles, and perhaps some opportunity for restoration to maintain the watershed close to the 60% forested level.

The Watershed Management Priority Index

The WMPI (Zhang 2006, Zhang and Barten 2009) is a GIS-derived analysis that uses layers of landscape factors known to affect water quality. We employed two of the WMPI's three sub-modules: the Conservation Priority Index (CPI) and the Restoration Priority Index (RPI). Since the Middle Chattahoochee remains close to 60% forest cover, we focused on the CPI, which targets of existing natural lands based on soil and landscape factors that, if protected, will best preserve existing water quality. We also derived the RPI for the focus area, which is a similar analysis that focuses on lands in grassland or pasture that, if re-forested, would be expected based on their soil and landscape factors to have a positive impact on water quality.

Conceptually, the WMPI attempts to identify area where aspects of the soil and slope coincide to pose an erosion risk. Since soils in this region tend to be clay-rich and have high cation-exchange capacity, runoff-bearing soil also has a high potential to carry bound nutrients, such as phosphorous. In this model, activities that disrupt the natural landcover are more damaging to water quality if they occur on highly erodible soils that are close to a stream or river. For example, construction or the presence of impervious surfaces in the floodplain or within stream corridors will have immediate negative consequences to water quality. These same activities will also have negative consequences on sites distant from streams but on slopes or areas with low soil infiltration potential, because rainfall does not percolate downwards and runs off readily from such areas. Using the WMPI, such land-disturbing activities can be sited on gentle slopes and high infiltration soils located away from streams where they are expected to have much less impact. However, given the scale both of the model and the source data used for this analysis, the WMPI cannot be used to project a specific amount of contamination that may occur from a given activity, or the specific nature of chemical constituents or dissolved oxygen demands that may result from activities in particular places.

Visualizing CPI and RPI

Since the satellite-derived landcover data at the heart of the WMPI is based on imagery, the calculation of the index is performed on pixels, which were 30 x 30 meters for this analysis. Proximity to a wetland, stream, or river and position on the floodplain are both components of the WMPI calculation, so pixels with CPI in the highest range (roughly 16-21) frequently track the stream network closely. This is clearly evident in the map of the CPI for the focus area (Figure 3), though there are areas where high-value pixels are found at some distance from the river, as in Russell, southern Lee, and southwestern Chambers Counties, Alabama, and there are broad bands of moderate-to-high values in central and southern Harris County, Georgia. Southern Harris County and the eastern edge of Muscogee County, Georgia, both have clusters of high-value pixels, as well. Northern Troup county and much of Muscogee County, Georgia, and portions of Chambers, Lee, and Russell Counties, Alabama, appear in the dark greens assigned to low priority pixels (CPI scores of 0-5), largely due to developed land cover in these areas.

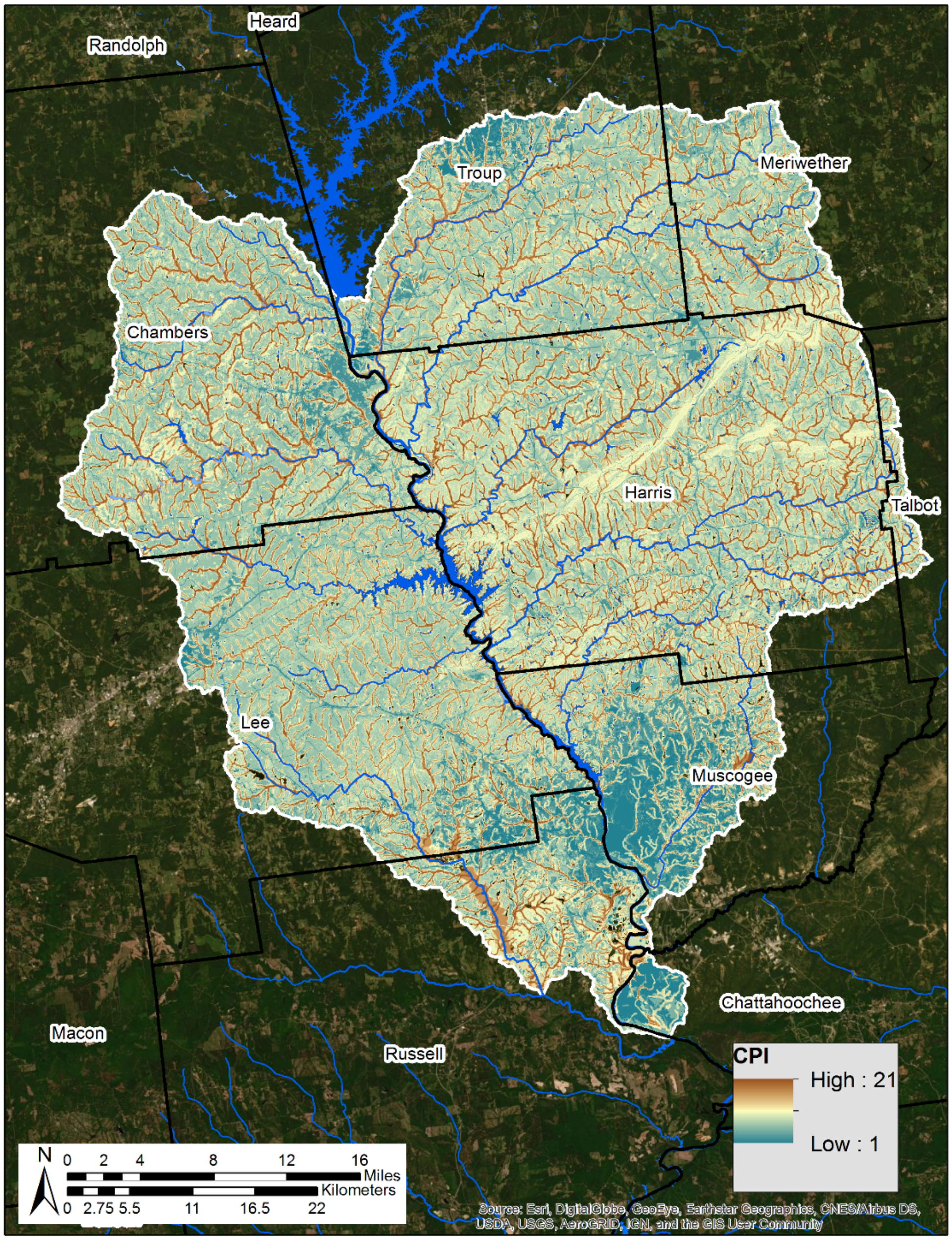

Figure 3: Conservation Priority Index scores for the Middle Chattahoochee project area. Conservation potential is low in areas without natural landcover, particularly urban areas.

The RPI analysis shows much less potential, due in large part because this index is designed to identify non-forested pixels with the potential for re-forestation that are not yet in developed land classes. Just 16% of the of the overall project area was in grassland or planted/cultivated land uses in 2011, and much of this is not in areas with the erodible soils or steep slopes that cause pixels to score high on the RPI. Nevertheless, in Figure 4**,** some scattered areas in Chambers and Russell Counties, Alabama, show clusters of pixels along stream-courses that score moderately high for restoration potential.

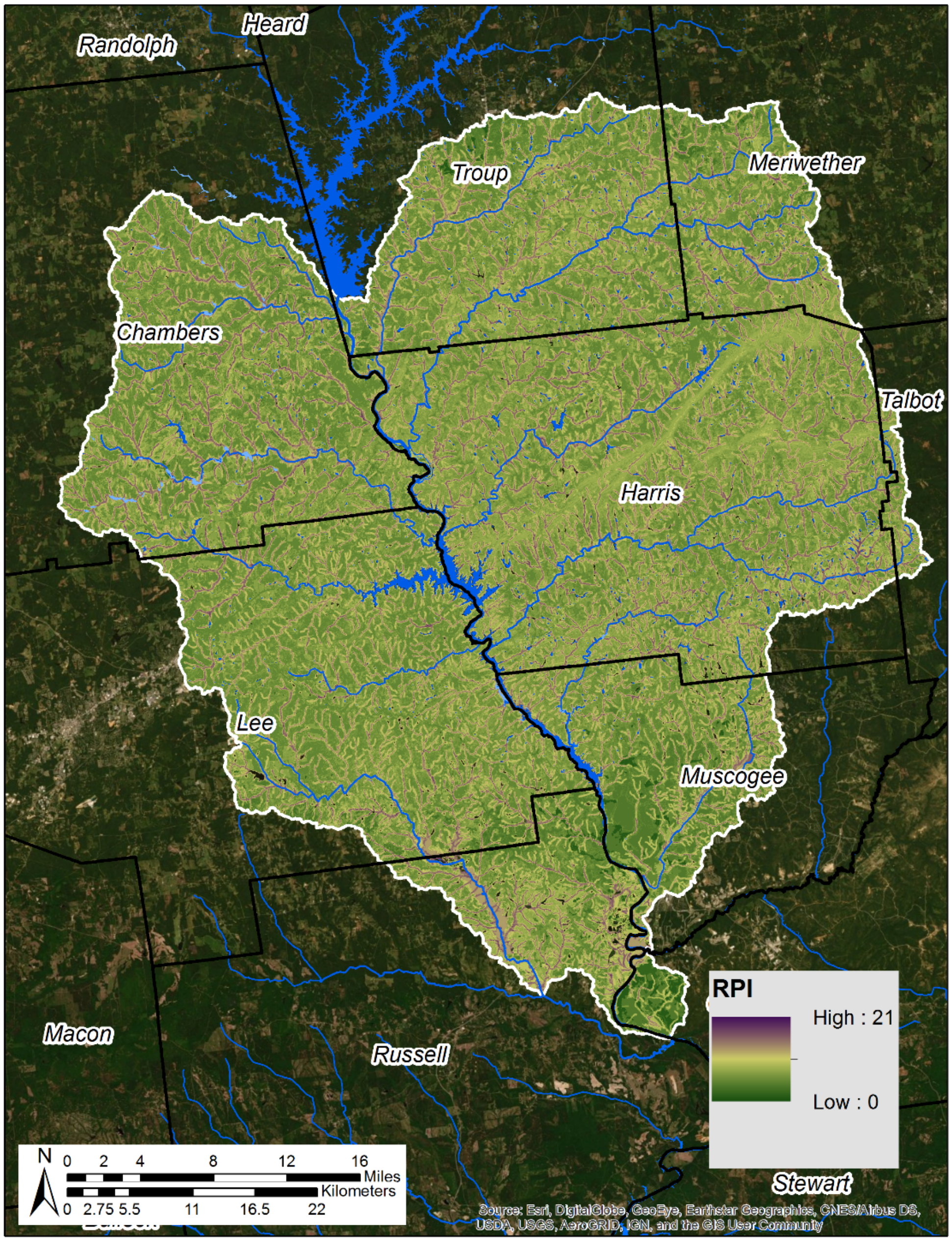

Figure 4: Restoration Potential Index scores for the Middle Chattahoochee project area. The RPI scores highest on sites with non-forested landuses on steep slopes with erodable soils. Due to the prevalence of natural landcover, most of the area scores low.

A key feature of this analysis is the incorporation of tax parcels, since land conservation is most often negotiated as a real estate transaction and not at the scale of 30 x 30 meter pixels. We used the fine-scale CPI in Figure 3 to derive scores for individual parcels by summing the values of all pixels enclosed by parcel boundary and dividing by the parcel area. Scores ranged from 4.5-16.5 for all tracts of at least 100 acres. (Since the transaction costs do not typically scale with parcel size, it is more efficient to target land protection efforts on larger parcels.) We then clustered the scores into four natural classes, to which we assigned a priority from 1 (high) to 4 (low). These priorities provide a quick rank for the conservation value of individual tracts with respect to raw water quality. These results are shown in Figure 5. Again, river corridor properties constitute obvious protection targets, such as in southern Lee County, Alabama, but there are also many non-riparian properties with moderate to high water quality scores, particularly in Harris County, Georgia.

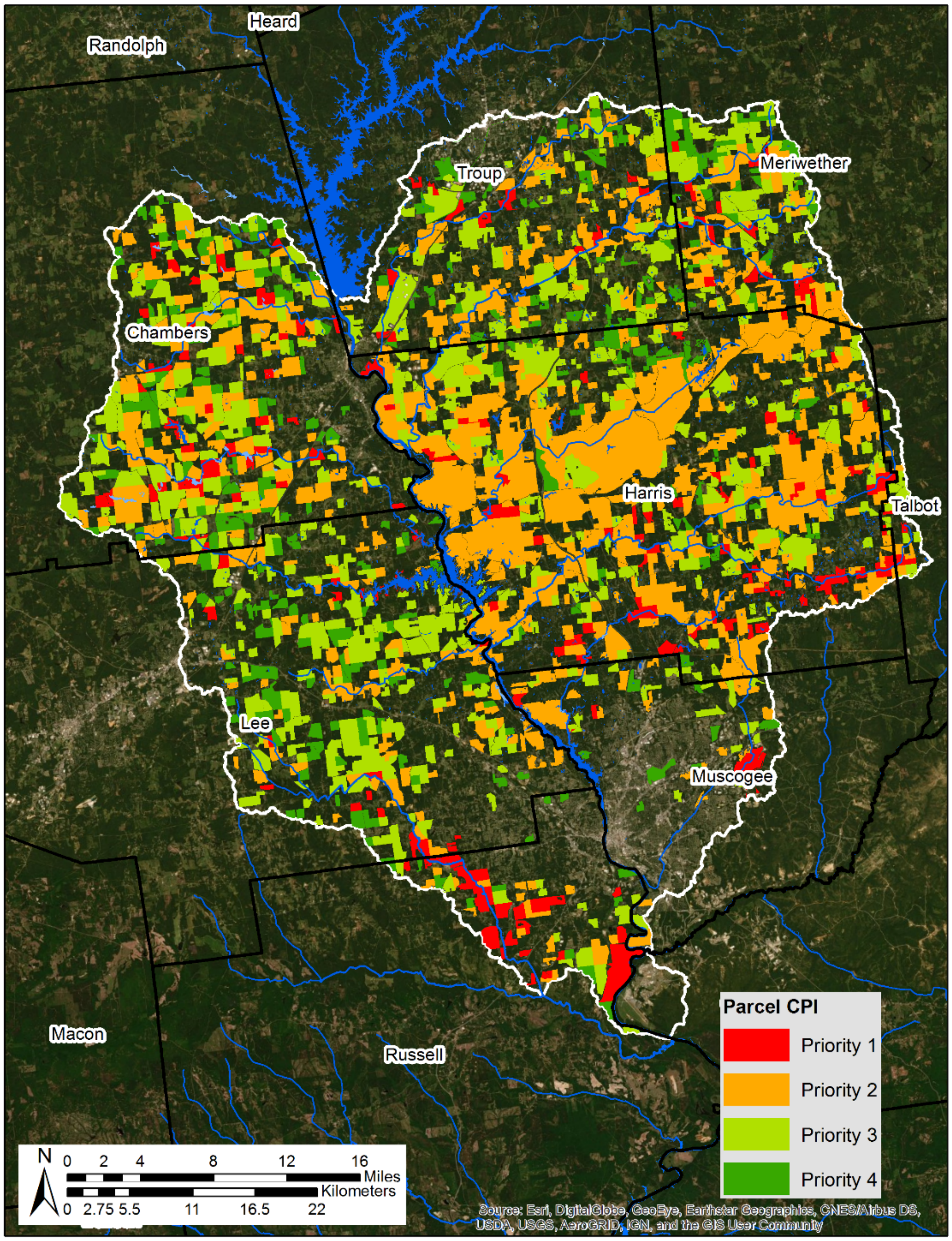

Figure 5: Tract-level CPI analysis for tax parcels larger than 100 acres. (A gap is present for Muscogee County, Georgia, due to unavailability of digital parcels.)

Extending the Analysis

There there are almost certainly benefits that accrue to conservation measures on parcels that are adjacent protected lands; beyond the aesthetics of contiguous greenspace, such areas likely provide enhanced value as wildlife habitat. Although the amount of formally protected area in the project watershed is relatively small, there are nevertheless a number of moderate-to-high CPI parcels near or adjacent to protected areas in Harris County (Figure 6).

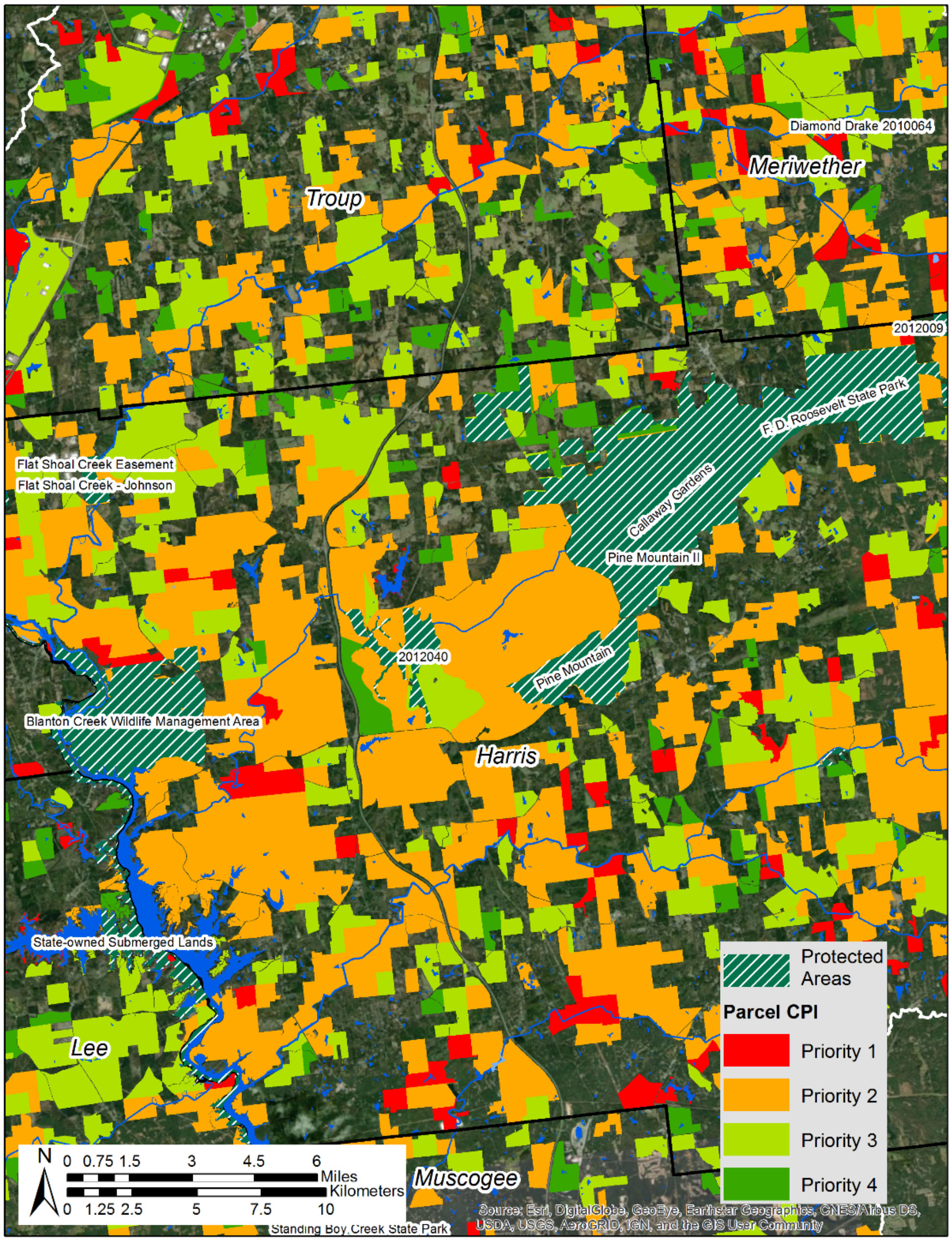

Figure 6: Tract level detail for CPI analysis, showing potential to add conservation parcels adjacent to existing protected areas.

While restoration potential may not be obvious at the watershed scale, the ongoing monitoring for nutrients and harmful algal blooms being conducted by Dr. Susan Wilde's group may provide an opportunity to use the RPI maps at a smaller scale. Many of these monitoring sites are in coves where tributaries join the reservoirs on the main stem. Should conditions at one of the fifteen sites indicate high nutrients are contributing to algal growth, an examination of the

RPI map for the local contributing area (Figure 7) may identify opportunities for small-scale site restoration and revegetation where such would have a high likelihood of intercepting or preventing nutrient runoff.

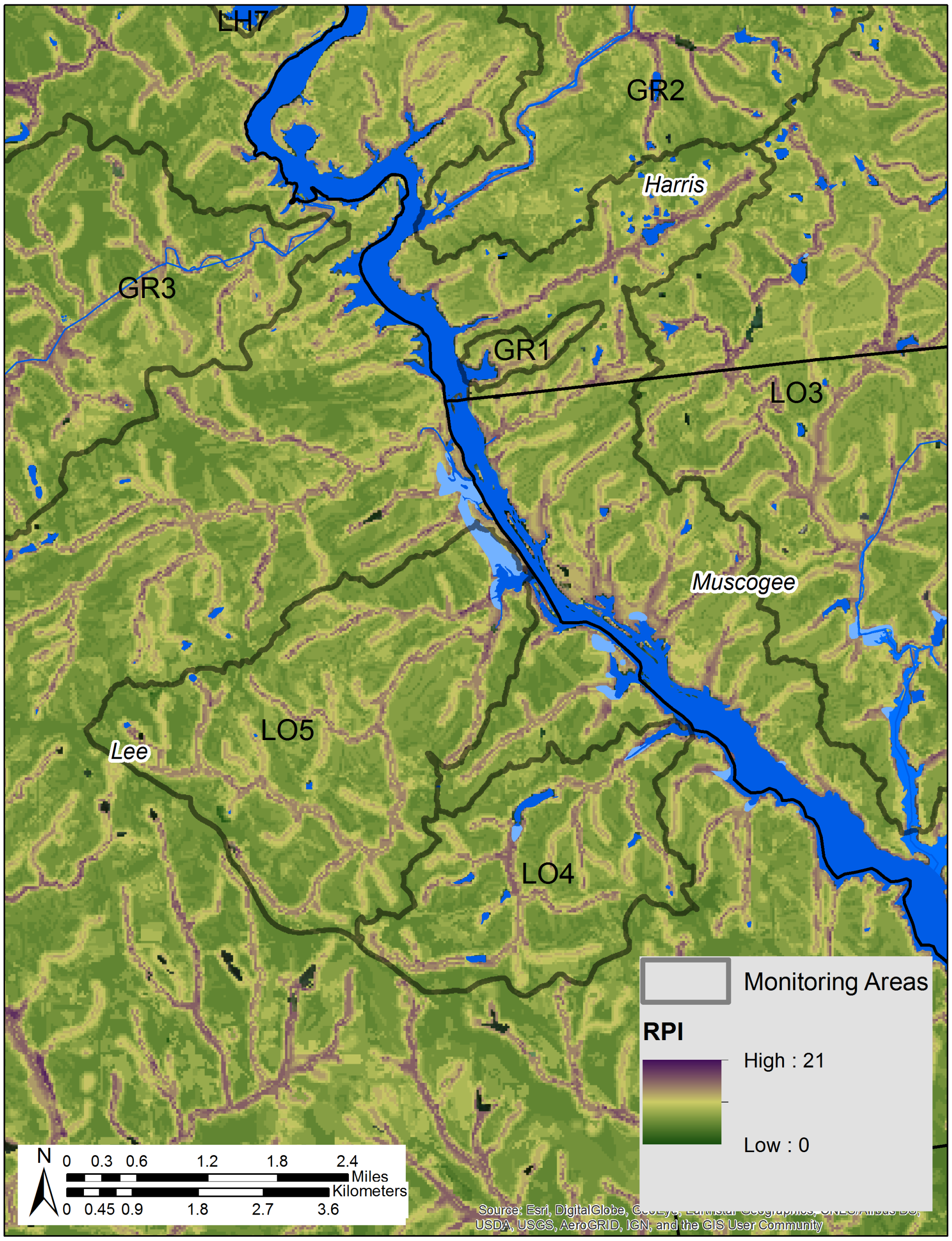

Figure 7: Local watersheds contributing to monitoring stations in coves of the main stem reservoirs. Should ongoing monitoring indicate nutrient loading from the adjacent landscape, the RPI analysis may be used to identify sites for restoration efforts.

Conclusion

Forest cover accounted for almost 56% of the 2011 landcover in the focal area, so land use change in the Middle Chattahoochee basin is beginning to push the watershed below the 60% forested threshold. Nevertheless, there remains a clear opportunity to preserve raw water quality, while still maintaining a substantial level of development options for local communities and citizens, through targeted protections and perhaps judicious restorations. Although the upper portions of the watershed are severely impacted by urbanization, it is still possible to protect the rural landscape that maintains the water quality for users in the Columbus area and downstream. The Middle Chattahoochee has a strong set of partners involved in research, monitoring, and planning for the multiple user groups in the area and this consortium of interests is well poised to embark the sort of strategic conservation measures that will be necessary to preserve this essential resource.

Model Description

This study uses a modelling approach adapted from the analysis for the Savannah River performed by Krueger and Jordan (2014), which calculated the conservation priority sub-module of the Watershed Management Priority Index (Zhang 2006). This GIS algorithm uses physical (soils, slope), hydrologic (streams, wetlands), and biological (landcover) data to predict the delivery of sediment to streams.

Deriving the WMPI Factors

The WMPI is built upon seven (7) factors, and the sub-modules are derived from different arrangements of the factors. This section will briefly describe the GIS procedures used to develop the data layers that were combined to calculate the RPI and CPI. Original data sources are listed in Table 1.

Slope: Slope was derived from the 30 meter digital elevation model (DEM); US Geological Survey National Elevation Data of September 2010. As our analysis is focused on the lower sub-basin, the slope ranges given by the WMPI framework were not descriptive of the sub-basin. We addressed this by identifying the range of slopes present in the analysis area, and dividing them into three ranges with equal number of pixels (0 - 3.43, 3.43-7.48, and 7.48- 58.14). The ranges were assigned scores 1, 2, or 3 respectively.

Proximity to Streams: Streams were defined as all flowlines in the NHD (High Resolution) data set for Basins 031300002 and 031300003 (Middle Chattahoochee Lake Harding and Middle Chattahoochee Walter F. George; Version 2.1). The Euclidean Distance function in Spatial Analyst 10.6 was used to develop a distance-to-streams raster. Cells (30x30m) were then assigned scores according to Table A-1 to produce a continuous scored raster surface.

Proximity to Ponds / Wetlands: All wetland polygons from the National Wetlands Inventory. The Euclidean Distance function in Spatial Analyst 10.6 was then used to develop a distance-to-wetlands raster. Cells (30x30m) were then assigned scores according to Table A-1 to produce a continuous scored raster surface.

100-Year Floodplain: We used the Active River Area (ARA) model as a substitute for the 100-year floodplain and assigned all material collection zones identified in ARA as floodplain, scoring those areas as 3. Although the ARA product for this region was the product of a different team at The Nature Conservancy, see Kreuger and Jordan (2014) for a discussion of the ARA development.

Soil Erodibility Factor (K): Soil erodibility is the propensity of a soil to erode when exposed to rainfall. The full range of soil erodibility was then split into three equal groups (<.15, .15-.23, >.23) and assigned scores 1, 2, or 3 respectively.

Soil Group: For soils with multiple classes, we let the more restrictive group determine the score, such that 'A/D' , 'B/D' , 'C/D' , 'D' , and 'C' were set to 3, 'B' was set to 2, and 'A' was set to 1.

Soil Depth: We assigned scores using a Jenks 3-group natural classification on the Wtdepannmi factor in the SSURGO attributes, which describes the annual minimum water depth, as follows. Depths less than 41 were assigned a 3, depths between 41 and 91 were assigned a 2, and depths between 91 and 191 received a 1.

Land Use: Land use was identified from the 2011 NLCD land cover product. Together, the forest classes (deciduous, evergreen, and mixed), vegetated (shrub/scrub, grassland/herbaceous), and wetlands (woody, emergent herbaceous) classes comprised the "natural" land uses that were taken to contribute positively to water quality for the CPI calculation. For the RPI analysis, we scored pixels with water (11) as NoData, Barren (31) and Cultivated Crops (82) as 3, on the assumption that barren pixels were likely recently cleared, and Pasture/Hay (81) and Grassland/Herbaceous (72) as 2.

Completing the CPI and RPI

Once all CPI layers were complete, each layer was visually reviewed for accuracy. All raster processes used the 2011 NLCD as the snap raster and no significant processing or alignment issues were found at this stage. The seven layers were then overlaid using the Sum function in Spatial Analyst 10.5 to produce the maps shown as Figures 3-7, above. Total sum scores for individual pixels range from 0 to 21.

Parcel Preparation

We obtained electronic parcel data for most Georgia counties from Jimmy Williamson at the UGA Information Technology Outreach Service (ITOS), but boundary files for the counties not in the ITOS database (Harris, Heard, Troup) and all counties in Alabama (Barbour, Bullock, Chambers, Lee, Randolph, Russell) were purchased from Real Estate Portal USA, LLC (http://reportallusa.com). Parcels were not readily available for Muscogee County, Georgia, which we deemed inconsequential for the analysis since this county makes us a small portion of the most downstream end of the project area. Many areas contained overlapping polygons, either as a result of subdivisions where the original parcel outline was retained or due to condominium-style shared tax parcels. We used topology rulesets in ArcMap 10.6 to identify overlapping polygons and developed scripts in ArcGIS Pro to flatten these stacked parcels and subtract overlapping areas. We used a procedure similar to Krueger and Jordan (2014) to score tax parcels using the Zonal Statistics function within the Spatial Analyst extension (ESRI) to calculate the mean CPI score of the 30x30m CPI pixels they enclose.

To aid the use of tract-accumulated CPI scores in program development and implementation, we culled out tracts below 100 acres (total of 389,593 acres), and assigned four score ranges as Priorities 1 through 4 using a Jenks classification of natural breaks. A histogram showing the distribution of values within each class is shown in Figure 8.

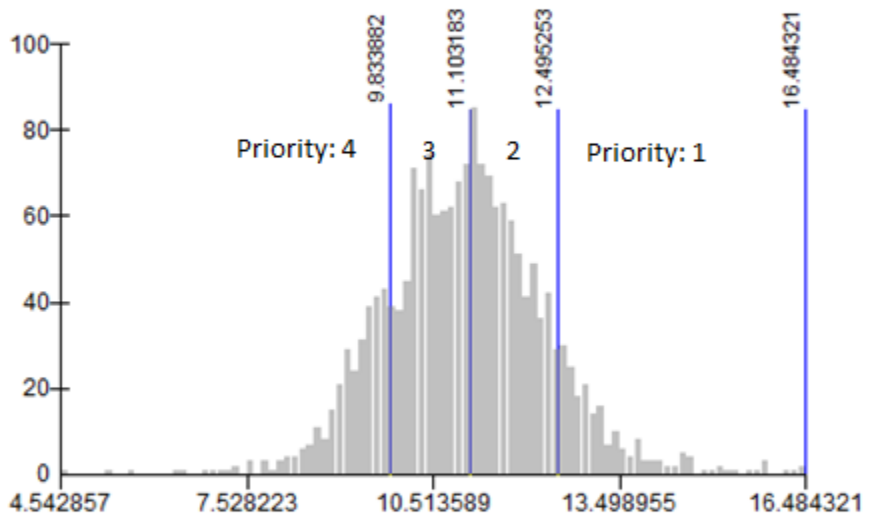

Figure 8: Histogram of CPI vales for tracts larger than 100 acres with breakpoints for the four priority classes shown in Figure 5.

Table 1: Electronic Data Sources used to construct input layers for WMPI.

Layer	Source	Date	URL
Soils	SSURGO (January 2017 snapshot) map packages for Lake Harding and Walter F. George HUC8s	2017	ESRI SSURGO downloader (https://esri.maps.arcgis.com/apps/View/index.html?appid=cdc49bd63ea54dd2977f3f2853e07fff)
Slope	USGS NED 1 arc-second 20140924 1 x 1 degree IMG	09/24/2014	http://nationalmap.gov/viewer.html
Landcover	NLCD 2011 Land Cover	2011 (Amended 2014)	https://www.mrlc.gov/
Hydrology	USGS National Hydrography Dataset Best Resolution (NHD) for Hydrologic Unit (HU) 8 – 03130002 and 03130003	04/26/2018	https://www.usgs.gov/core-science-systems/ngp/national-hydrography
Floodplain	Southeast Landscape Conservation Cooperative ARA map (10 meter pixels)	Accessed 1/29/2018	https://www.conservationgateway.org/ConservationByGeography/NorthAmerica/UnitedStates/edc/reportsdata/freshwater/floodplains/Pages/default.aspx
Wetlands	USFWS National Wetlands Inventory	Accessed 8/1/2018	https://www.fws.gov/wetlands/data/Mapper.html

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