Upper Neuse River Basin Conservation Assessment

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Final Report

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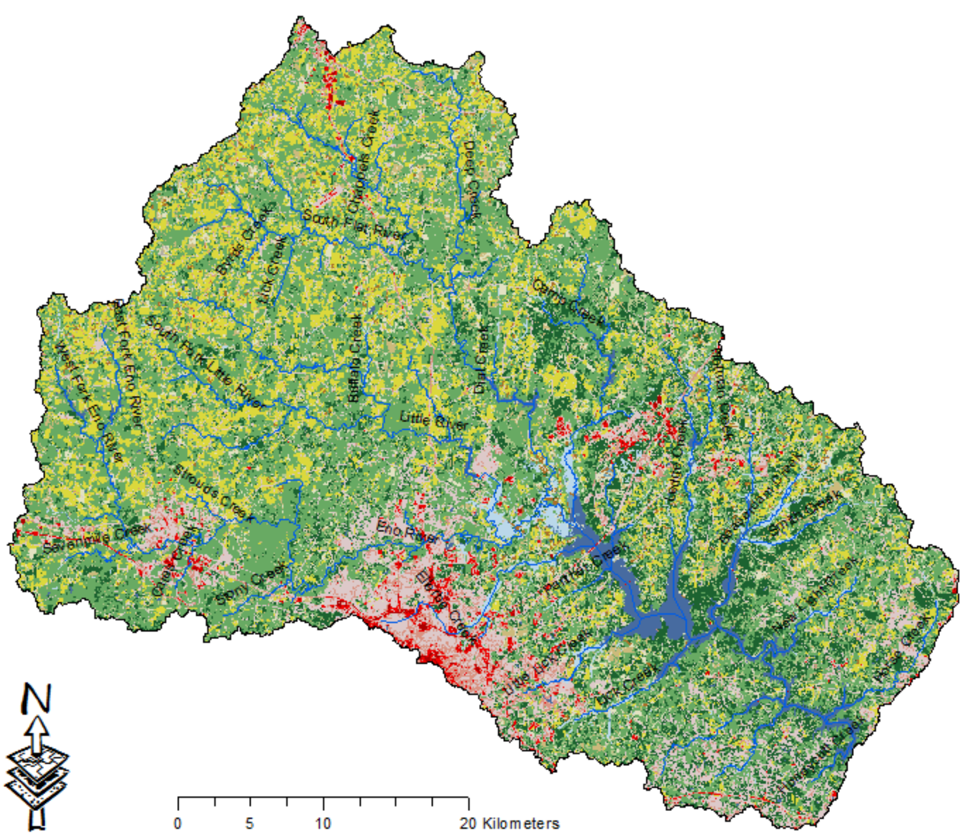

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*****GIS file outputs available by request to NatureServe (Current contact: Rickie White, rickie_white@natureserve.org**

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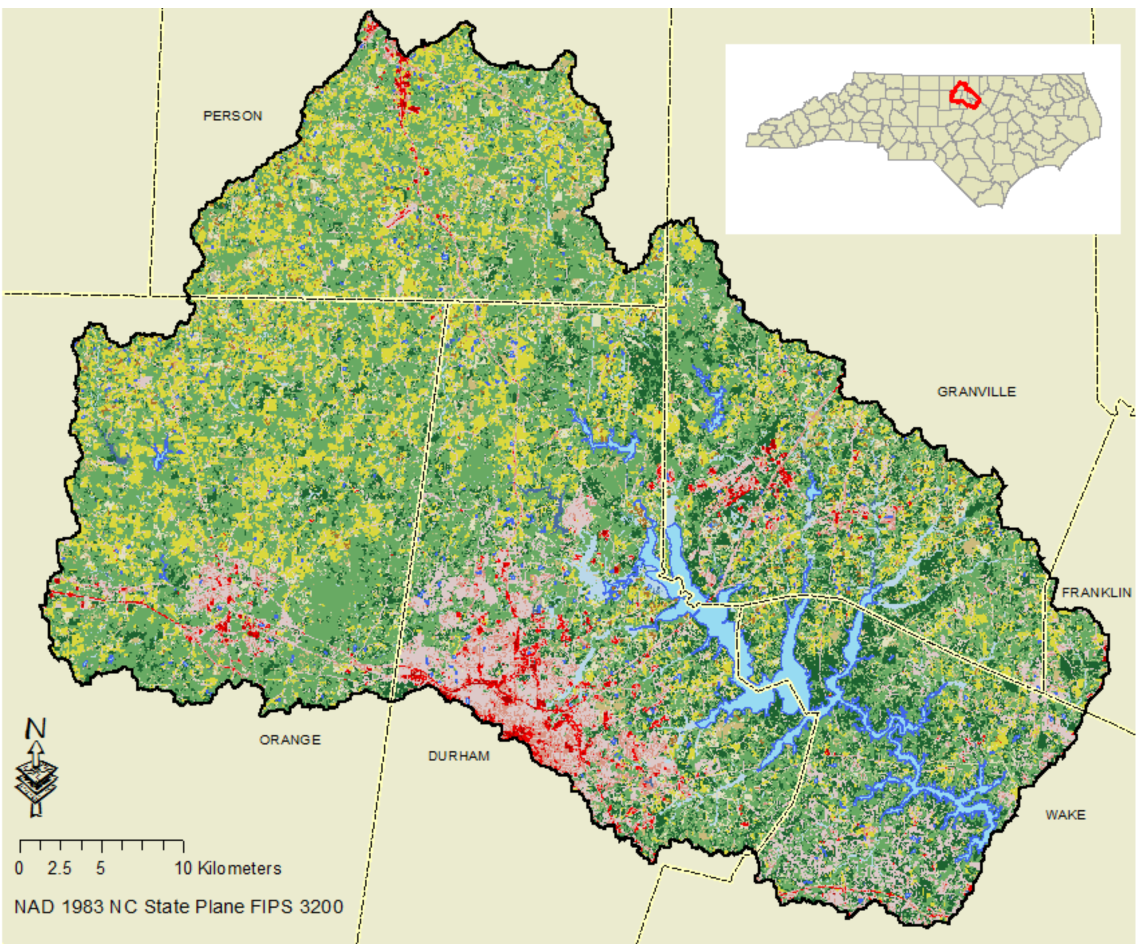
Introduction

The UNRB is a 200,000 ha watershed in the Piedmont region of NC (Figure 1). It includes portions of six counties and is home to 251,482 people (U.S. Census Bureau and USEPA 2010). Through eight public reservoirs, it provides drinking water to over half a million people (UNRBA 2000). Population growth has been brisk over the last decade: Wake County grew over 43% from 2000 to 2010 (U.S. Census Bureau 2010). Drinking water customers are projected to double between 2002 and 2030 (TLC and TRC 2010). Concurrent with population growth, forest land has been lost to residential, commercial, and agricultural uses.

Figure 1. The Upper Neuse River Basin in the Piedmont Region of NC. The Basin contains 8 drinking water reservoirs, the largest of which is Falls of the Neuse Reservoir, in the eastern half of the watershed.



According to a recent analysis developed by the Upper Neuse Clean Water Initiative (UNCWI), overall forest cover in the UNRB was just under 60% in 2001 (TLC and TRC 2010), well below the 70% threshold noted in some studies to maintain biological condition of receiving streams (e.g., Black and

Munn 2004). Furthermore, a recent study projects that timber harvest rates will increase in the U.S. South in response to unprecedented non-sawtimber price increases fueled by the European Union wood pellet market (Abt et a. 2014). In fact, the northern part of the watershed is within the service radius of at least one large wood pellet factory (Jovian Sackett, Southern Environmental Law Center, personal communication). In light of the already borderline forest cover and the expected development and logging pressure in the basin, the goal of this study is to:

1) identify catchments and parcels important for preservation of water quality,

2) identify high value areas in terms of biodiversity,

3) compare maps developed in 1) and 2) above with areas of recent forest loss, and

4) prioritize parcels for biodiversity conservation.

Methods

All analysis was performed in ArcGIS 10.1 (ESRI 2012). Spatial data layers were obtained from online sources (Table 1), projected into North Carolina State Plane FIPS 3200 (NAD 1983) and clipped to the boundary of the UNRB. Raster analysis was performed at 30 m resolution, unless otherwise noted.

Table 1. Data sources

Data layer	**Author**	**Source**
NLCD 2011 NLCD 2006	U.S. Geological Survey (USGS)	http://www.mrlc.gov
CropScape (CDL)	U.S. Department of Agriculture	http://nassgeodata.gmu.edu/CropScape/
Integrated Statewide Road Network	N.C. Department of Transportation	https://connect.ncdot.gov/resources
Streams, catchments, waterbodies	U.S. Environmental Protection Agency and USGS	http://www.epa.gov/waters
Protected areas	USGS	http://gapanalysis.usgs.gov/PADUS
Biodiversity/Wildlife Habitat	N.C. Department of Environment and Natural Resources	http://portal.ncdenr.org/web/cpt
Wetlands	U.S. Fish and Wildlife Service	http://www.fws.gov/wetlands/Data
Elevation	U.S. Geological Survey	http://ned.usgs.gov/index.html
SLEUTH model implementation	Belyea and Terando, 2013	http://www.basic.ncsu.edu/dsl/urb.html

Watershed Assessment and Forest Cover Analysis

To assess the potential value to water quality in the UNRB of each NHDPlusv2 catchment (USGS and USEPA 2012), I performed a multi-attribute synthesis of forest cover, impervious surface, drainage density, wetland cover, mean slope, drainage accumulation and biodiversity/wildlife habitat (Table 2). Biodiversity is an indicator of good water quality whereas other indicators contribute to good water quality. This assessment of catchment water quality potential is derived but slightly modified from the UNCWI Technical Report (TLC and TRC 2010). I used the Cropland Data Layer (CDL) to maintain consistency with that report (USDA 2013).

Table 2. Watershed assessment indicators adapted from the UNCWI: Technical Report. In this model, the mean score by catchment of the NC NHP Biodiversity/Wildlife Habitat layer, July 2013, is substituted for the Significant Natural Heritage and Core Areas.

Indicator	Source	Method	0	1	2	3	4
Forest cover (%)	CDL	Manual	0%	0-40%	40-60%	60-70%	70-100%
Developed land cover (%)	CDL	Manual	60-100%	25-60%	10-25%	0-10%	0%
Wetland (%)	NWI	Quantile	0-0.3%	0.3-1%	1-2%	2-7%	7-100%
Drainage density	NHDPlusv2	Quantile	0-0.55	0.55-0.71	0.71-0.87	0.87-1.15	1.15-64
Mean slope	USGS	Natural breaks	2-47	47-63	63-72	72-76	76-84
Biodiversity/wildlife habitat	NHP	Quantile	1	1-27	27-91	91-233	233-3296
Drainage accumulation	NHDPlusv2	Quantile	35,577-2,220,166	11,691-35,577	4833-11,691	2255-4833	0-2255

Because the developers of the CDL derive non-cropland values from the most recent NLCD layer at the time (in the case of CDL 2013, NLCD 2006) I performed a separate forest loss analysis comparing NLCD 2011 (Jin et al. 2013) to 2006 (Fry et al. 2011) to take advantage of the newest available data. I calculated forest loss by developing binary maps of forested land covers ("1": classes 41, 42, 43 and 90; "0": all others) for NLCD 2011 and 2006 and subtracting with raster calculator. Resulting cells with a value of 0 underwent no change, whereas values of "1" gained forest and "-1" lost.

Biodiversity Analysis

I used NatureServe Vista™ version 3.0.0.15 conservation planning software (2013), an Esri ArcGIS extension, to 1) import element occurrence (EO) data (NCNHP), 2) develop conservation value and conflict-compatibility layers with current and projected land uses, and 3) create input files for Marxan, a solution optimization software. The conservation value layer is a summary of species distribution and ecological community maps, summed over the study area and weighted for habitat quality (as specified by the EO rank field of the NCNHP data, described below). The conflict-compatibility layer intersects element occurrence locations with current or projected future land uses to assess element compatibility with the mapped uses. Vista compiles a map and report that quantifies what percent of a user-specified goal of compatible element distribution is attained under any particular scenario. In other words, if the user sets a goal of preserving 100% of the EO area, if half of an EO for a forest species overlaps developed land, open space, and half to deciduous forest, Vista will report that 50% of the species goal is met (subject to meeting element minimum viable occurrence size requirement).

Element occurrence data

I obtained EO data from the NCNHP. These data have been collected over the last four decades and are the most exhaustive inventory of rare plant, animal, and ecological community occurrences in the state. As a consequence, these data are invaluable in helping us identify and understand where the most important areas are located from a biodiversity conservation standpoint. In addition to containing spatial information (location, size of occurrence), EO records are given a rank based on their condition and landscape context. A high score "A" signifies a highly viable population or occurrence whereas a "D" score signifies an area of low quality, although it still may be important if it is a very rare species. For our analysis, EO ranks A, B, C, D, and E were included; all others were filtered out. For EO ranks listed as two letters, rank was rounded up to the preceding letter, i.e. BC became B. The NCNHP dataset also contains NatureServe conservation status ranks. Those ranks attempt to identify which species and ecosystems are thriving and which are rare or declining (NatureServe 2015). For species, the ranks are an estimate of extinction risk; for communities they are an estimate of elimination risk. For both element types, ranks range from 1-5 wherein a rank of 1 is critically imperiled and a rank of 5 is secure. Conservation status ranks are reported in the NCNHP dataset at both the global (G) and state (S) spatial extents. I rounded state and global rankings to the higher risk of extinction rank. Finally, I buffered aquatic species occurrence shapefiles 20 m (2/3 the width of a single raster cell) to avoid creation of a discontinuous occurrence during Vista conversion to raster formats. Four elements present in the UNRB, Piedmont boggy streamhead, floodplain pool, Carolina ladle crayfish (*Cambarus davidii*), and Piedmont fameflower (*Phemeranthus piedmontanus*), are excluded from the analysis because of unresolvable processing errors in Vista (I recommend attempting to include these in the newer Vista 3.2 in ArcMap 10.2 or newest versions if this project is updated).

Minimum size for viability (MSV)

The minimum size for viability represents the smallest amount of area (patch or occurrence) that an element needs to be viable (subject to condition/compatibility with intersecting land use or other stressors). In calculating the conflict-compatibility layer, Vista excludes occurrences that are smaller than the minimum size for viability on the grounds they are not viable. For some species, values for MSV can be obtained from the scientific literature. Because this process is labor intensive, whenever possible, I used values from a previous Vista project developed for the Georgia coast by NatureServe and the Georgia Department of Natural Resources (GA DNR) (R. Smyth, pers. comm.). Although there was only one exact species match (Bald eagle, *Haliaeetus leucocephalus*) between the elements from the GA coast to this project, several species matched to the genus level (timber rattle snake vs. pygmy rattlesnake, multiple vascular plants). The Georgia DNR ecologists declined to place an MSV on any aquatic organism on the grounds that they are affected by land use in the watershed well beyond actual "habitat", so I did not specify an MSV for aquatic species. I also did not specify an MSV for the three butterfly species in the dataset. Although I was able to find a home range estimate in NatureServe Explorer for one butterfly of the three species, it was much larger than the occurrence, which would have effectively excluded that species from the analysis. On discussion with the local ecological expert (R. White), I decided not to specify an MSV for any of the three butterflies to keep them in the analysis. We felt that the EO record was intended to represent a viable occurrence, even though it was not collected with a minimum size for viability in mind. I did not specify MSVs for ecological communities as I was not able to find any relevant information. These settings can be updated and the analyses refreshed in Vista if effort is made to collect expert knowledge about these elements. Note that in the case where the element spatial unit is set in Vista to "Occurrence" rather than "Area," the MSV is effectively whatever the mapped occurrence area is since Vista requires that the entire occurrence remain viable/compatible to be counted toward the representation goal.

To calculate the conservation value summary, I gave the rarest species the highest weights (ranks G1, G2 and G3 received a value of 1) and progressively more secure species lower weights (rank G4 S1-3, 0.9; rank G4 S4, 0.7; rank G5 S1, 0.8; and rank G5 S2, 0.7. I set a conservation goal of 95% of the element occurrence area (or 95% of the occurrences themselves) being viable in terms of compatible land uses. I used NLCD 2011 to represent baseline (current) conditions.

Future Threat model

I used an urban growth model developed for the Southeastern U.S. (Belyea and Terando 2011) based on SLEUTH (Chaudhuri and Clarke 2013) to create a development threat scenario for 2030. SLEUTH is a simulation model of urban growth based on topography, land use, urban boundaries and transportation corridors. The model output is expressed as a 60 m resolution grid, whose values represent the upper range of probability the pixel will become developed at the specified year. To estimate growth in the UNRB, I reclassified all pixels with a greater than 50% chance of becoming developed into NLCD class

23 (medium intensity development). Because conservation goals for rare species occurrences were not well met under baseline conditions, I used the threat model to identify species and communities that diminished further in incompatible land uses from the baseline (current situation scenario) to 2030.

Conservation Solution Generation

Marxan is a conservation planning software program that was used to create an efficient spatial conservation solution for the watershed. Marxan assembles groups of planning units to maximize biodiversity conservation value at minimum cost (Ball and Possingham 2000). It works by randomly selecting an initial planning unit (in this case parcels) and calculating the marginal gain in user-specified species habitat goals minus the cost by adding units until the goals are met or budget exhausted. Because heuristic algorithms such as Marxan do not always arrive at optimal solutions, the program is generally run many times (with thousands to millions of iterations). Parcels that are selected in many solutions are likely better conservation choices than those that are only selected in a few. Parcel shapefiles for the 6 relevant counties of the UNRB had been previously collected by L. Hammerbacher. I merged the 6 counties in ArcMap, creating a shapefile with a total of 118,443 parcels. The small portion of the UNRB contained in Franklin County was excluded as there was no cost field in that municipality's parcel database. There also were no areas of high conservation value in the small section of Franklin County within the watershed, so that omission should not affect the results. Parcels less than 1 ha in size were also excluded, leaving 19,985 in the planning unit file for the Marxan runs. Protected areas were assigned artificially low costs to ensure their inclusion in the conservation solution. Species elements and natural communities were included in the "species" file. I used Vista to generate the input files and performed one hundred runs of 100,000 iterations each. Because of the large number of iterations, parcels selected all or most of the time are considered "irreplaceable" for meeting the conservation goals.

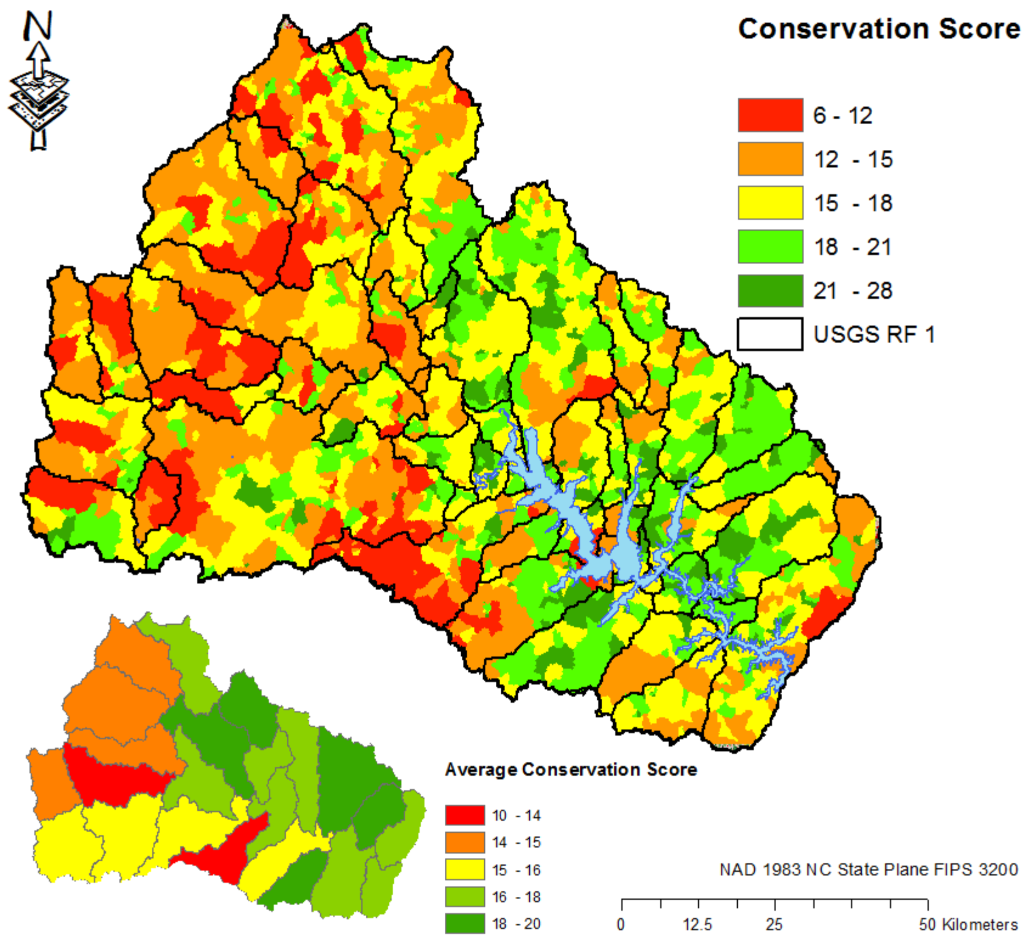
Results

Overall, the UNRB is 58% forested with 68 terrestrial species, 15 aquatic species and 37 natural communities from the NCNHP dataset present. These species and natural community elements represent some of the rarest entities within the watershed. Because of their unique geological, disturbance, or climatic needs, they are not widely distributed on the landscape and are, therefore, highly vulnerable. We hope that in future analyses the excluded elements (Piedmont fameflower, Piedmont boggy streamhead, floodplan pool, and Carolina ladle crayfish) can be brought back in to the analysis as they are all rare elements that may contribute significantly to parcel conservation values.

Watershed Assessment

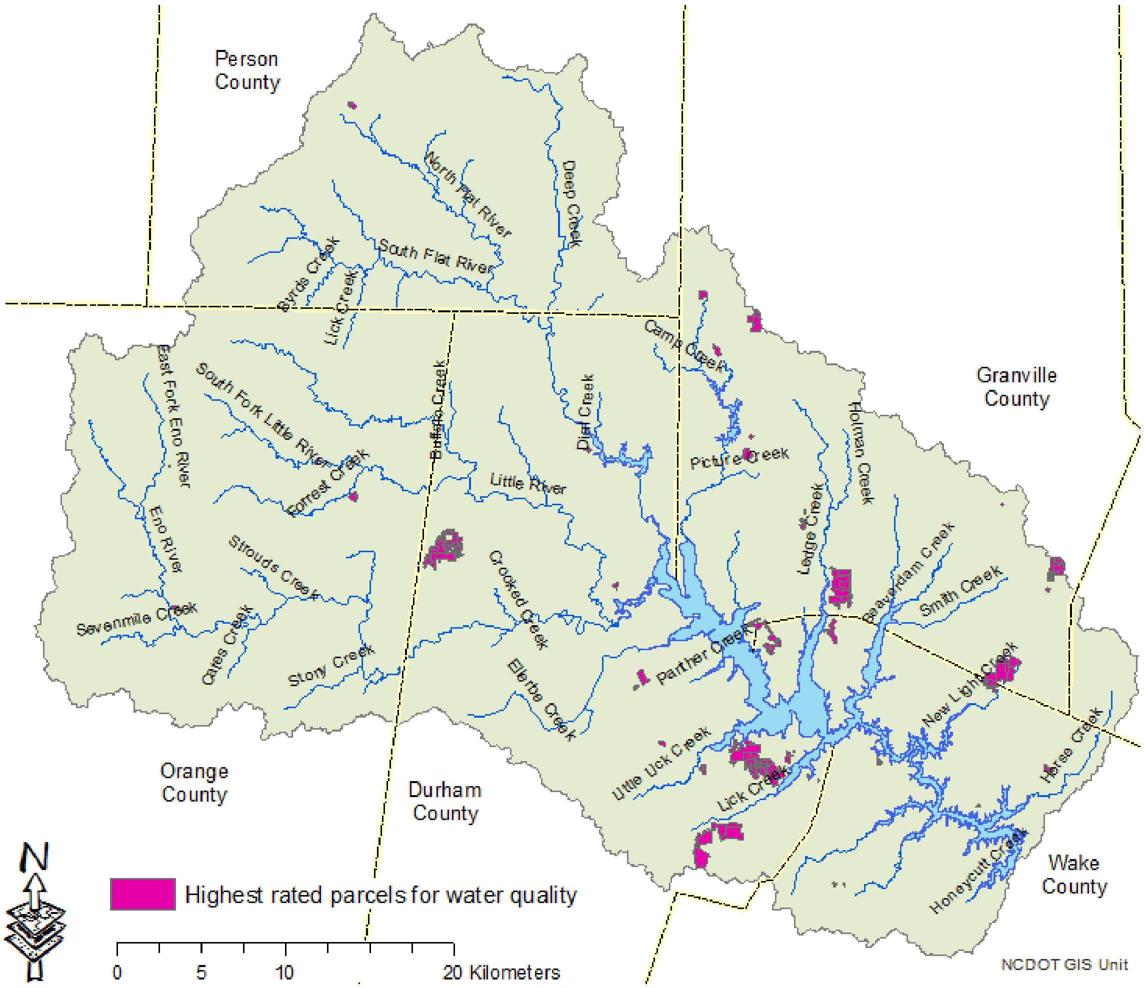
High scoring catchments indicate areas that should be given higher conservation priority if preservation of downstream water quality is the goal (Figure 2). In general, the watershed assessment did not vary grossly from that in the UNCWI Technical Report (TLC and TRC 2010), although the catchment layer used differed slightly in scale. Lacking the data for the original, I was unable to do a quantitative comparison with which I might have been able to quantify loss or gain in water quality potential.

Figure 2. Watershed assessment based on parameters in Table 1.



I also calculated the average water quality assessment value of each unprotected parcel. Durham and Granville counties contain the highest numbers of potentially valuable parcels for water quality in Falls Lake (Figure 3).

Figure 3. Unprotected parcels with the highest average watershed assessment scores (top 1%) are shown in dark pink. Durham and Granville counties have the highest numbers of high value parcels for water quality (not including protected parcels).



Biodiversity

In the UNRB, high conservation value areas for the rare species and communities present are located mostly in protected areas (Figure 4). However, there are scattered areas of high value in the northern portion of the watershed that are not in or near protected areas. Additionally, some of the most valuable areas in the watershed are near developed areas and conflict with current land uses as defined by NLCD 2011 (Figure 5). Only 53% of elements meet conservation goals (95% of their habitat is compatible with species needs) in the baseline scenario (Appendix 1). Twelve species and natural communities have less than half of their occurrence area located in a compatible land use (Table 3).

Figure 4. Conservation value of land in UNRB with protected areas outlined in green. Several areas of relatively high biodiversity conservation value in the northern portion of the study area lie outside protected areas.

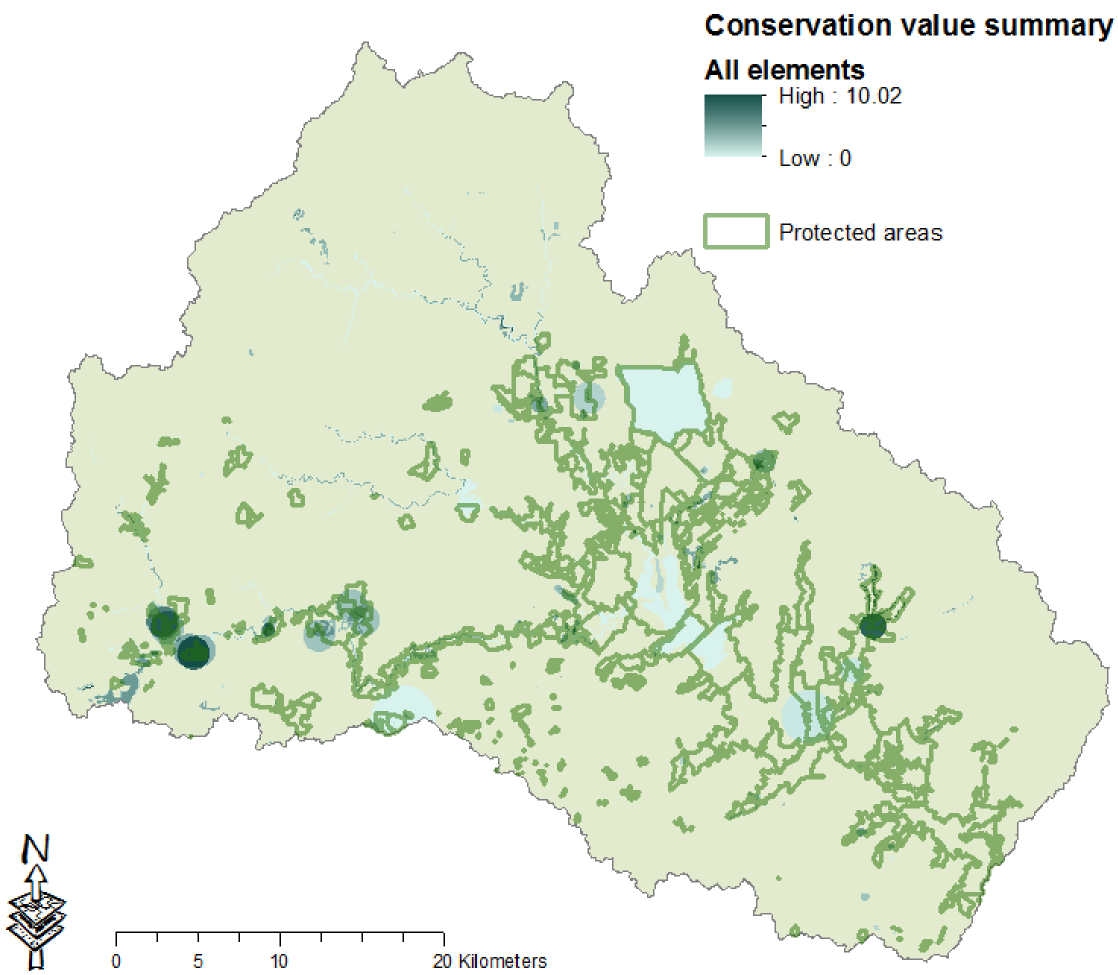
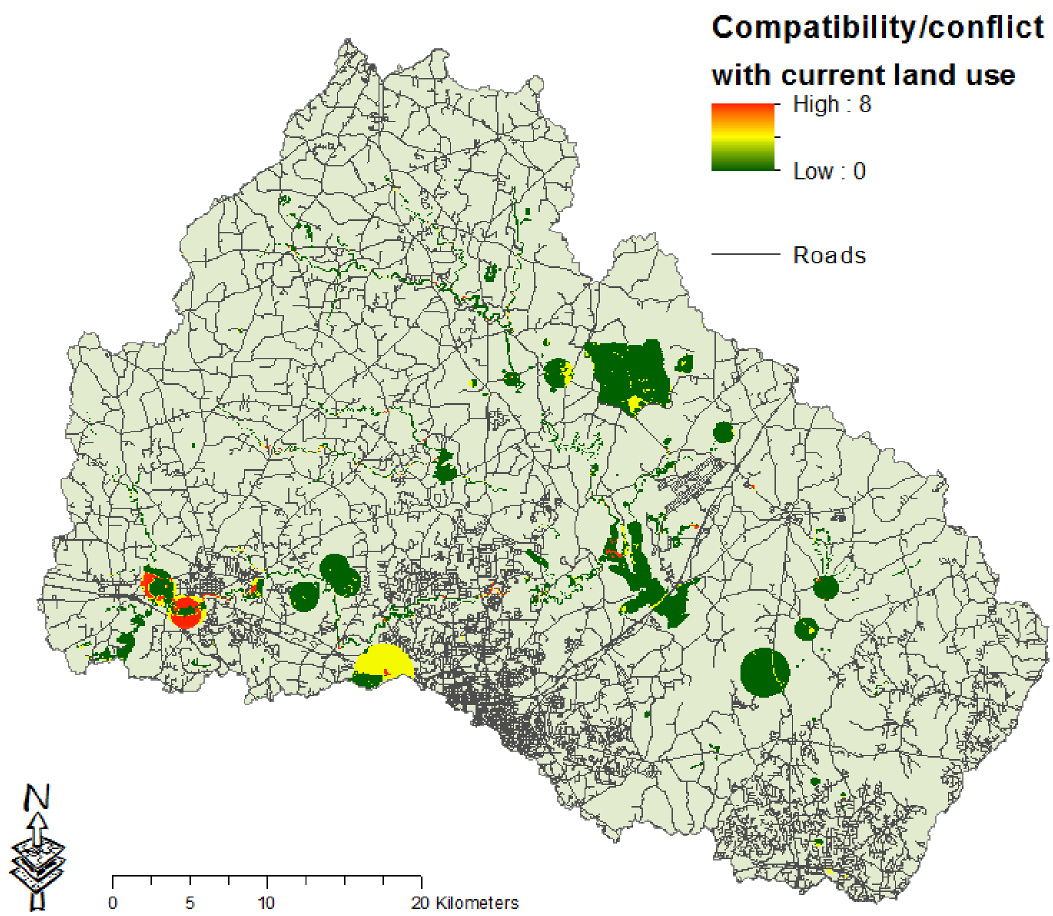


Figure 5. Conflict and compatibility of element occurrences with baseline land use (NLCD 2011). Roads added as a visual representation of development. High conservation value areas in Hillsborough, NC in the western portion of the map have highest conflicts.



When compared to the current conditions scenario (NLCD 2011), the threat analysis for development in the 2030 scenario produced similar results in terms of land use compatibility and conflict with rare species occurrences. However, a small subset of species were disproportionately impacted (Table 4).

Table 3. Species and communities most at risk under from development in 2030, based on an implementation of the urban growth model SLEUTH developed for the Southeastern U.S. (Belyea and Terando 2011).

Element	**Goals met baseline**	**Goals met 2030 scenario**	**Percent Difference**
Carolina bird-foot trefoil (*Acmispon helleri*)	67%	33%	-51%
Piedmont Alluvial Forest	44%	22%	-50%
Upland depression swamp forest	71%	43%	-39%
Glade wild quinine (*Parthenium auriculatum*)	92%	69%	-25%

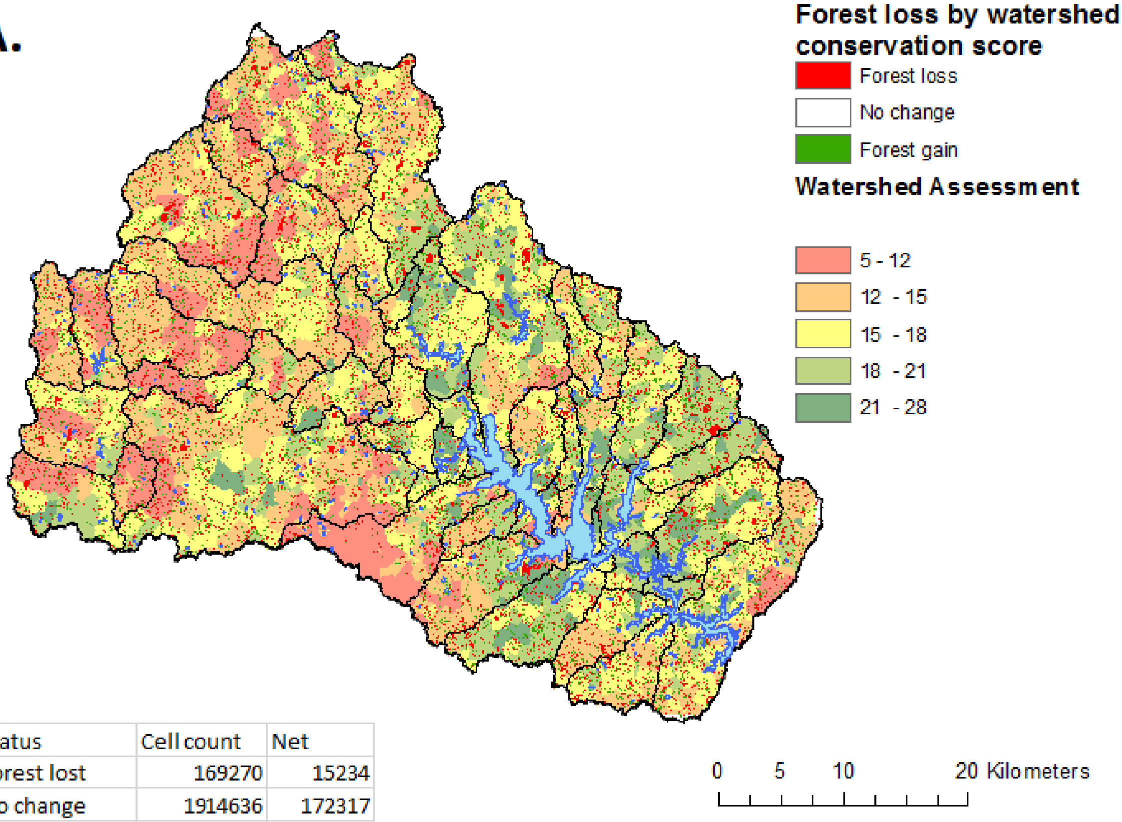
Element	Goals met baseline	Goals met 2030 scenario	Percent Difference
Serpentine aster (*Symphyotrichum depauperatum*)	100%	75%	-25%
Narrow leaf aster (*Symphyotrichum laeve var. concinnum)*	57%	43%	-25%
Smooth coneflower (*Echinacea laevigata*)	83%	67%	-19%
Piedmont coastal plain heath bluff	87%	75%	-14%

Forest Loss

Evaluation of forest cover change showed a net loss of 3,127 ha (2.6%) from the Upper Neuse River Basin (UNRB) between 2006 and 2011. Forest loss was distributed fairly evenly throughout the watershed with the exception of the southwest section of the watershed, which experienced less loss (this area is heavily urbanized already). Based on the watershed assessment, forest was lost from both high and low value areas (Figure 6A). Forest was also lost from high conservation value areas for biodiversity in the western portion of the watershed (Figure 6B).

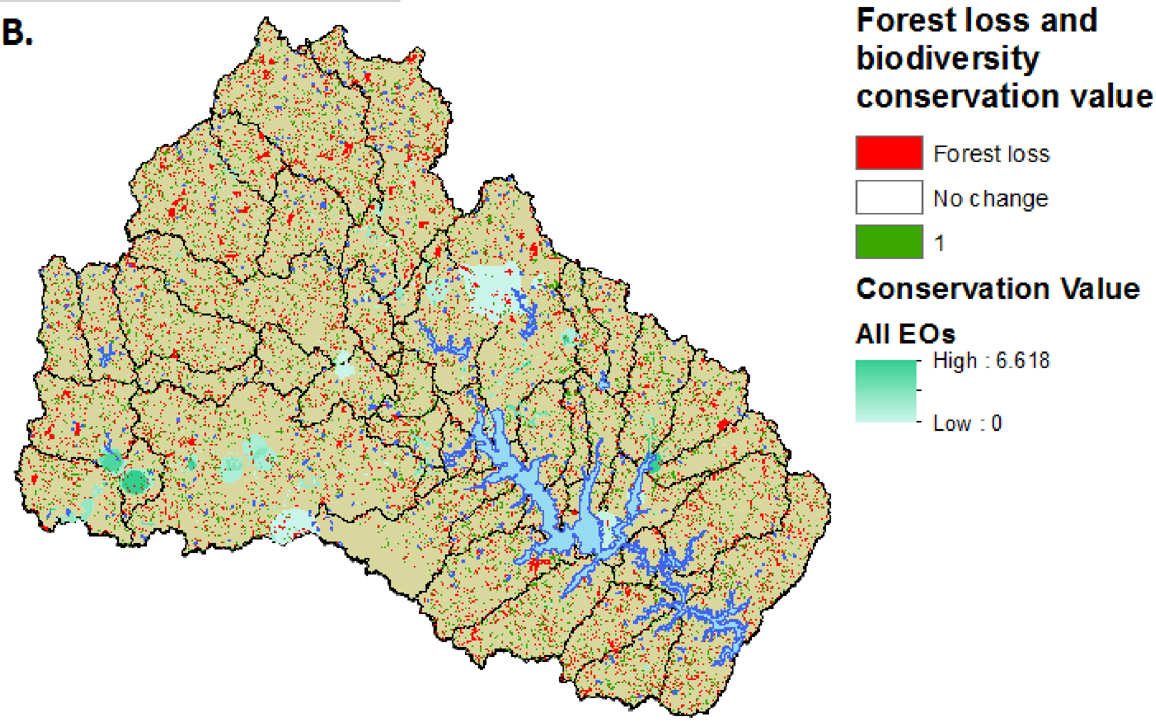
Figure 6A. Forest loss in relation to watershed assessment (which is based primarily on forest cover). Forest loss is diffuse, but is occurring in both low value and high value catchments. B. Forest loss is also ongoing in some of the highest value conservation areas in the western portion of the UNRB.

A.



Status	Cell count	Net
Forest lost	169270	15234
No change	1914636	172317
Forest gained	134526	12107

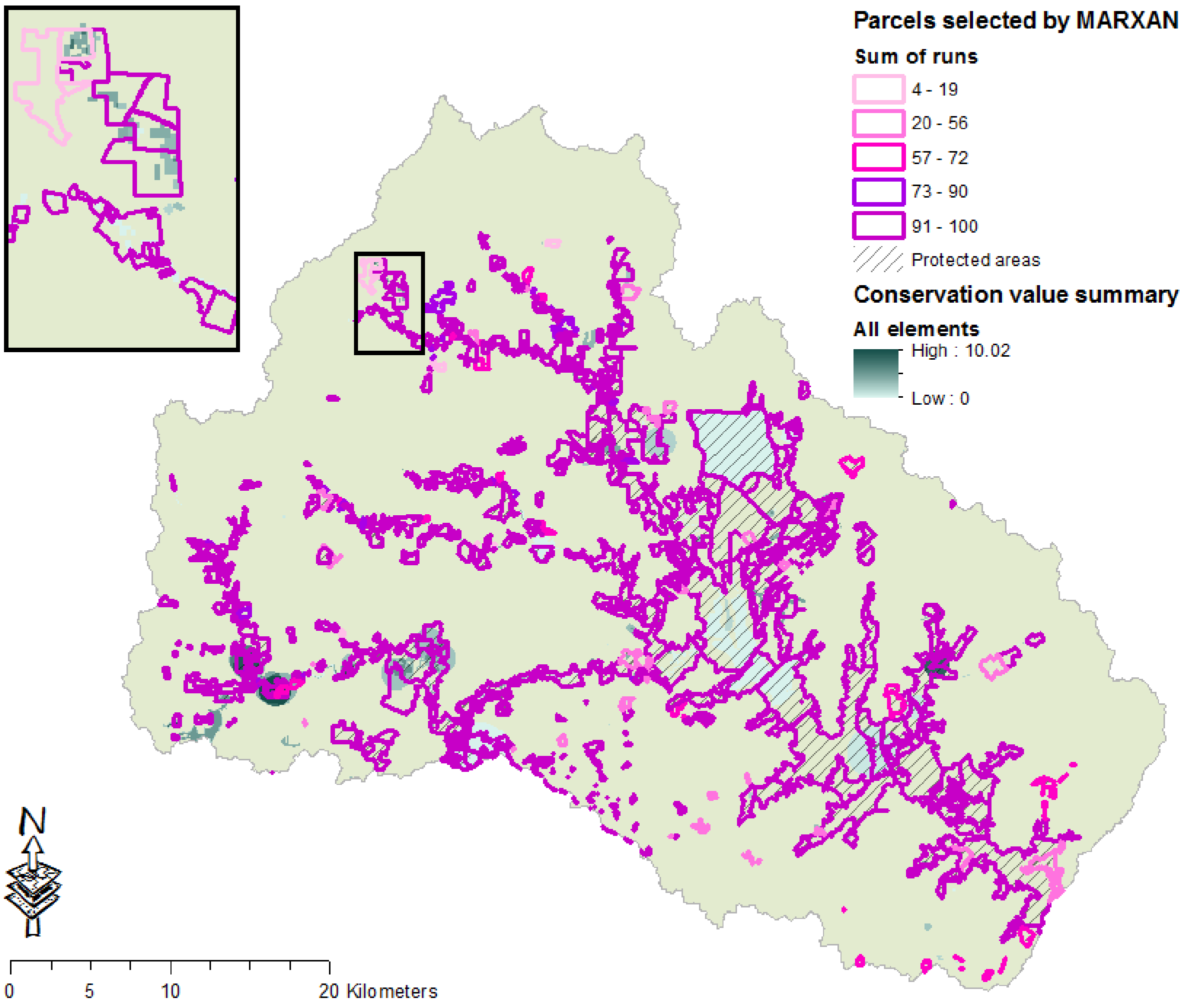
B.



Conservation Solution with Marxan

Perhaps because of the clumped nature of the elements in the UNRB, individual Marxan runs did not vary markedly. Of the total parcels used in the assessment, 520 were selected in one or more of the conservation solutions. Of those 520, 397 were included in every solution making them relatively irreplaceable (or necessary) to meet the conservation goals. Several important parcels included in most solutions contain the areas of high conservation value in the north (Figure 7). Although most of the selected parcels are along stream corridors, at least one group encompasses an upland area (detail, Figure 7).

Figure 7.Marxan conservation solution, using existing parcels as the planning unit. Protected areas were assigned low costs to ensure their inclusion in the solution. The sum of runs indicates how many times out of 100 runs the parcel was selected in the conservation solution. Many frequently selected parcels are in the northern portion of the watershed and are not currently protected. One example is shown in the detail map. Several of those parcels have recently been clear cut since the data was collected, however.



Discussion

The most interesting and potentially informative result of this study is its ability to highlight key areas of conservation opportunity that are both high value and low cost. These areas, based on a combination of factors including biodiversity conservation value and land value are the best opportunities for conservation in the near future. In particular, the high value conservation parcels in the northern portion of the watershed, far from existing protected areas, are clearly great opportunities for stretching conservation dollars as far as possible while making the biggest impact on overall conservation goals.

Conservation efforts to date seem to have focused on areas directly surrounding Falls of the Neuse Reservoir and its tributaries. This makes sense, as those areas are much closer to existing urbanization and thus in more immediate danger of development. However, as urbanization increases throughout the watershed, it may be time to consider a broader approach that examines high conservation value throughout the watershed and further from municipal boundaries. Because water quality in Falls Lake is a large driver of current conservation efforts, headwater stream corridors and parcels valuable for water quality are likely to be of greatest interest to local stakeholders. In fact, because many freshwater species are declining in North Carolina, many of the highest value areas for biodiversity conservation are along stream corridors. However, valuable upland areas should also merit consideration if conservation of biodiversity is a goal as well.

The study also found that the watershed's protected areas are not sufficient to protect a substantial portion of the rare species and ecosystems identified. In our modeled scenario, for instance, conservation goals for almost half of the species and ecosystems we examined were not met. Although more study would be needed on each individual species of concern to confirm that the current protected habitat is not sufficient, this result supports the idea that protection of biodiversity in the watershed is currently insufficient if we want to support sustainability of these species and habitats.

Many people rely on this watershed for drinking water, recreation, nature appreciation, and other valuable "ecosystem services". In addition, this watershed provides a number of intangible benefits such as habitat for key parts of our natural heritage. Unfortunately, forest cover in the watershed is already at a "tipping point" in terms of its positive effect on downstream water quality, and development and logging rates are projected to increase under all current models we have found. In addition to the protection of buffer lands directly adjacent to the reservoirs, conserving several stream corridors in the northern portion of the watershed as well as some of the high value forested areas in Durham and Granville counties should greatly increase conservation outcomes. With regards to biodiversity conservation, we believe efforts could be targeted to those parcels identified by the Marxan prioritization, which incorporates cost as well as conservation value to arrive at recommendations that optimize both of those variables. Furthermore, we believe consideration should also be given to those species and communities that do not currently have sufficient habitat, and to those that lose most under threat from development.

Limitations and Recommendations

The following text was added by NatureServe:

This study was conducted as a volunteer project that provides a reasonable set of analyses for consideration but should not be used solely, or as-is to make final regulator or acquisition decisions. Some specific limitations and recommendations include:

- As noted previously, some species could not be included because of technical issues at the time. As rare and imperiled species, it is recommended that they be included and analyses rerun.
- The assessment of water quality was based on previous methods which do not include the use of hydrologic models of runoff, sedimentation, and nutrient inputs. We recommend that such modeling be conducted to better understand changes in inputs from baseline to potential future situations, which streams and reservoirs may be impacted and to what degree, and where in the watershed such inputs may be generated. This information can provide much more precise targeting of conservation and restoration actions.
- Conservation requirements and responses of the species and habitats were drawn from analogs in a project from the Georgia Coast. We recommend local expert review and revision of those inputs to the Vista model to provide the most accurate results.
- The Marxan assessment is highly sensitive to inputs such as which species/habitats and their quantitative goals. We recommend additional iterations and input from stakeholders to set key parameters for this model.

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Table 3. Elements not meeting 50% of habitat conservation goals in the baseline scenario (NLCD 2011). These elements' occurrences lie on incompatible land uses. Elements that did not meet conservation goals had EO Rank E (verified extant, but sufficient information to assign and A, B, C or D rank) are not included.

Name	**Area (ha) of EO**	**Compatible area of viable habitat (ha)**	**Percent of 95% goal**
Checkered White (*Pontia protodice*)	62.1	0	0%
Mole Salamander (*Ambystoma talpoideum*)	2.7	0	0%
Pale Coneflower (*Echinacea pallida*)	0.2	0	0%
Piedmont Acidic Glade	312.3	0	0%
Piedmont Cliff (Acidic Subtype)	625.5	0	0%
Piedmont Headwater Stream Forest (Hardpan Subtype)	3.6	0	0%
Ultramafic Outcrop Barren (Piedmont Subtype)	10.8	0	0%
Xeric Hardpan Forest (Northern Prairie Barren Subtype)	157.5	0	0%
Dry-Mesic Oak--Hickory Forest (Piedmont Subtype)	1,310.40	43.2	25%
Xeric Hardpan Forest (Basic Hardpan Subtype)	21.6	2.7	25%
Piedmont Monadnock Forest (Typic Subtype)	594.9	27	33.33%
Piedmont Alluvial Forest	741.6	34.2	44.44%

Appendix 1. Conservation goal achievement for EO's under baseline and 2030 development threat scenarios.

Name	Area (ha)	Occs	Viable and compatible area (ha) baseline	Percent of goal	Viable and compatible area (ha) 2030 scenario	Percent of goal	Percent loss 2011-2030
Checkered White	62.1	1	0	0%	0	0%	N/A
Four-toed Salamander	829.8	11	0	0%	0	0%	N/A
Mole Salamander	2.7	2	0	0%	0	0%	N/A
Pale Coneflower	0.2	1	0	0%	0	0%	N/A
Papillose Tortula	0.6	1	0	0%	0	0%	N/A
Piedmont Acidic Glade	312.3	1	0	0%	0	0%	N/A
Piedmont Cliff (Acidic Subtype)	625.5	2	0	0%	0	0%	N/A
Piedmont Headwater Stream Forest (Hardpan Subtype)	3.6	1	0	0%	0	0%	N/A
Pink-fruited Thread-moss	16.2	2	0	0%	0	0%	N/A
Sharp-shinned Hawk	3.6	1	0	0%	0	0%	N/A
Ultramafic Outcrop Barren (Piedmont Subtype)	10.8	1	0	0%	0	0%	N/A
Xeric Hardpan Forest (Northern Prairie Barren Subtype)	157.5	2	0	0%	0	0%	N/A
Dry-Mesic Oak--Hickory Forest (Piedmont Subtype)	1,310.40	12	43.2	25%	31.5	16.67%	33%
Xeric Hardpan Forest (Basic Hardpan Subtype)	21.6	4	2.7	25%	2.7	25%	0%
Piedmont Monadnock Forest (Typic Subtype)	594.9	6	27	33.33%	27	33.33%	0%
Piedmont Alluvial Forest	741.6	9	34.2	44.44%	13.5	22.22%	50%
Piedmont Levee Forest (Typic Subtype)	8.1	2	4.5	50%	4.5	50%	0%
Roanoke Slabshell	12.6	1	6.3	50%	1.8	14.29%	71%
Showy Aster	0.8	2	0.6	50%	0.6	50%	0%
Narrow-leaf Aster	8.8	7	7.4	57.14%	6.8	42.86%	25%

Name	Area (ha)	Occs	Viable and compatible area (ha) baseline	Percent of goal	Viable and compatible area (ha) 2030 scenario	Percent of goal	Percent loss 2011-2030
Basic Mesic Forest (Piedmont Subtype)	75.6	5	43.2	60%	43.2	60%	0%
Diabase Glade	4.5	2	2.7	60%	2.7	60%	0%
Dry Basic Oak--Hickory Forest	98.1	5	36.9	60%	36.9	60%	0%
Dry Oak--Hickory Forest (Piedmont Subtype)	389.7	5	71.1	60%	71.1	60%	0%
Bald Eagle	1,014.30	6	4.5	66.67%	4.5	66.67%	0%
Carolina Birdfoot-trefoil	62.1	3	58.3	66.67%	49.4	33.33%	50%
PiedmontMountain Semipermanent Impoundment (Open Water Subtype)	225	3	11.7	66.67%	11.7	66.67%	0%
PiedmontMountain Semipermanent Impoundment (Shrub Subtype)	232.2	3	18.9	66.67%	18.9	66.67%	0%
Prairie Dock	1,934.30	16	1,837.40	68.75%	1,812.90	56.25%	18%
Mesic Mixed Hardwood Forest (Piedmont Subtype)	558.9	13	125.1	69.23%	72.9	61.54%	11%
Upland Depression Swamp Forest	337.5	7	22.5	71.43%	11.7	42.86%	40%
Colonial Wading Bird Colony	25.2	3	18.9	75%	18.9	75%	0%
Mixed Moisture Hardpan Forest	54.9	4	39.6	75%	39.6	75%	0%

Name	Area (ha)	Occs	Viable and compatible area (ha) baseline	Percent of goal	Viable and compatible area (ha) 2030 scenario	Percent of goal	Percent loss 2011-2030
PiedmontMountain Semipermanent Impoundment (Piedmont Marsh Subtype)	226.8	4	13.5	75%	13.5	75%	0%
Low Elevation Seep (Floodplain Subtype)	48.6	1	36.9	75.93%	35.1	72.22%	5%
Piedmont Monadnock Forest (Pine Subtype)	15.3	1	11.7	76.47%	11.7	76.47%	0%
Earle's Blazing-star	18.2	13	14.5	76.92%	14.1	69.23%	10%
Panhandle Pebblesnail	34.2	1	27	78.95%	24.3	71.05%	10%
a mayfly	5.4	1	4.5	83.33%	4.5	83.33%	0%
Smooth Coneflower	33.9	12	32.2	83.33%	31.8	66.67%	20%
Prairie Blue Wild Indigo	17.6	7	15.2	85.71%	15.2	85.71%	0%
PiedmontCoastal Plain Heath Bluff	80.1	8	28.8	87.50%	21.6	75%	14%
Neuse River Waterdog	508.5	2	458.1	90.09%	444.6	87.43%	3%
Timber Rattlesnake	114.3	1	103.5	90.55%	103.5	90.55%	0%
Notched Rainbow	766.8	7	707.4	92.25%	675.9	88.15%	4%
Glade Wild Quinine	38.7	13	30.7	92.31%	29.1	69.23%	25%
Yellow Lampmussel	517.5	5	485.1	93.74%	461.7	89.22%	5%
Green Floater	166.5	3	156.6	94.05%	144	86.49%	8%
Roanoke Bass	306.9	5	288.9	94.13%	282.6	92.08%	2%
Atlantic Pigtoe	601.2	4	567	94.31%	547.2	91.02%	3%
Creeper	912.6	5	863.1	94.58%	831.6	91.12%	4%
Triangle Floater	288	2	272.7	94.69%	259.2	90%	5%

Name	Area (ha)	Occs	Viable and compatible area (ha) baseline	Percent of goal	Viable and compatible area (ha) 2030 scenario	Percent of goal	Percent loss 2011-2030
Eastern Lampmussel	2,026.80	6	1,927.80	95.12%	1,896.30	93.56%	2%
Chameleon Lampmussel	395.1	4	378	95.67%	374.4	94.76%	1%
A Moss	116.2	1	110.1	100%	108.8	100%	0%
Alabama Grape-fern	0.6	1	0.6	100%	0.6	100%	0%
American Barberry	11.8	3	11.6	100%	11.6	100%	0%
Appalachian Golden-banner	0.8	1	0.8	100%	0.8	100%	0%
Bog Spicebush	3.2	1	1.2	100%	0	0%	100%
Box Huckleberry	0.1	1	0.1	100%	0.1	100%	0%
Bradley's Spleenwort	3	1	3	100%	3	100%	0%
Buffalo Clover	1.3	1	1.3	100%	1.3	100%	0%
Buttercup Phacelia	3.5	1	3.5	100%	3.5	100%	0%
Carolina Darter	9	1	9	100%	9	100%	0%
Carolina Thistle	0.5	1	0.5	100%	0.5	100%	0%
Crested Coralroot	1,920.20	1	1,826.10	100%	1,804.50	100%	0%
Dissected Toothwort	3.2	1	3.2	100%	3.2	100%	0%
Douglass's Bittercress	145.3	13	134.3	100%	131.6	100%	0%
Dry Piedmont Longleaf Pine Forest	9	1	9	100%	0	0%	100%
Dry-Mesic Basic Oak--Hickory Forest (Piedmont Subtype)	26.1	1	26.1	100%	26.1	100%	0%
Eastern Isopyrum	6.5	3	5.4	100%	5.4	100%	0%

Name	Area (ha)	Occs	Viable and compatible area (ha) baseline	Percent of goal	Viable and compatible area (ha) 2030 scenario	Percent of goal	Percent loss 2011-2030
Glade Bluecurls	6.5	2	5.5	100%	5.5	100%	0%
Glade Flax	1,933	1	1,846.10	100%	1,824.50	100%	0%
Glade Milkvine	13	5	10.4	100%	10.4	100%	0%
Granite Flatsedge	3.2	1	2.2	100%	2.2	100%	0%
Granitic Flatrock (Perennial Herb Subtype)	1.8	1	1.8	100%	1.8	100%	0%
Heller's Rabbit-Tobacco	3.2	1	2.6	100%	2.6	100%	0%
Hoary Puccoon	28.5	12	21.6	100%	17.9	83.33%	17%
Indian Physic	9.6	3	9.6	100%	9.4	100%	0%
James's Sedge	3.4	2	2.9	100%	2.9	100%	0%
Large Witch-alder	3.2	1	3.2	100%	3.2	100%	0%
Low Elevation Seep (Typic Subtype)	0.9	1	0.9	100%	0.9	100%	0%
Low Wild-petunia	1,927.10	5	1,833.70	100%	1,812.10	100%	0%
Mead's Sedge	0.2	1	0.2	100%	0.2	100%	0%
Michaux's Sumac	0.7	1	0.7	100%	0.7	100%	0%
Mottled Duskywing	3.6	1	3.6	100%	3.6	100%	0%
Northern Oak Hairstreak	3.6	1	3.6	100%	0	0%	100%
Northern Witch Grass	2.8	1	2.2	100%	2.2	100%	0%
Oak Barrens Barbara's-buttons	4.7	1	4.7	100%	4.7	100%	0%
Piedmont Basic Glade (Typic Subtype)	0.9	1	0.9	100%	0.9	100%	0%
Piedmont Bottomland Forest (Typic Low	74.7	1	74.7	100%	74.7	100%	0%

Name	Area (ha)	Occs	Viable and compatible area (ha) baseline	Percent of goal	Viable and compatible area (ha) 2030 scenario	Percent of goal	Percent loss 2011-2030
Subtype)							
Piedmont Monadnock Forest (Heath Subtype)	6.3	2	6.3	100%	6.3	100%	0%
Piedmont Quillwort	3.2	1	2.2	100%	2.2	100%	0%
Piedmont Swamp Forest	74.7	1	74.7	100%	74.7	100%	0%
Prairie Goldenrod	3.3	1	3.3	100%	3.3	100%	0%
Purple Fringeless Orchid	5.3	2	5.1	100%	5.1	100%	0%
Purple Milkweed	0.6	1	0.6	100%	0.6	100%	0%
Pursh's Wild-petunia	10	4	9.8	100%	9.8	100%	0%
Rocky Bar and Shore (Alder-Yellowroot Subtype)	2.7	1	2.7	100%	2.7	100%	0%
Rocky Bar and Shore (Water Willow Subtype)	2.7	1	2.7	100%	2.7	100%	0%
Rufous Bulrush	4	2	3.6	100%	3.6	100%	0%
Seneca Snakeroot	3.2	1	3.1	100%	1.2	100%	0%
Serpentine Aster	70.8	4	65.4	100%	53.4	75%	25%
Shale-barren Skullcap	8.8	5	7.2	100%	7.2	100%	0%
Small's Portulaca	3.2	1	2.2	100%	2.2	100%	0%
Southeastern Bold Goldenrod	65.6	3	62.4	100%	55.4	100%	0%
Sweet Pinesap	7.6	2	7.5	100%	6.2	100%	0%
Tall Boneset	2	1	2	100%	2	100%	0%
Tall Larkspur	0.2	1	0.2	100%	0.2	100%	0%

Name	Area (ha)	Occs	Viable and compatible area (ha) baseline	Percent of goal	Viable and compatible area (ha) 2030 scenario	Percent of goal	Percent loss 2011-2030
Upland Pool (Typic Piedmont Subtype)	0.9	1	0.9	100%	0.9	100%	0%
Veined Skullcap	3.2	1	2.8	100%	2.8	100%	0%
Welch's fontinalis moss	12.7	1	12.7	100%	12.7	100%	0%
Wiry Panic Grass	1,927.60	3	1,832.10	100%	1,810.50	100%	0%
Xeric Hardpan Forest (Acidic Hardpan Subtype)	2.7	1	2.7	100%	2.7	100%	0%
Yellow Giant-hyssop	3.7	3	3.2	100%	3.2	100%	0%

Supplementary material.

Evaluation of goal performance at baseline for elements meeting less than 50% of goal in preliminary run.

Failure to meet conservation goals for elements at baseline stems from several circumstances.

1. EO's are smaller than minimum size for viability (mole salamander, Northern oak hairstreak, bald eagle, timber rattlesnake, sharp-shinned hawk).
2. Shapefile maps to incompatible land use (pale coneflower, papillose tortula, checkered white).
3. Single EO has rank E (papillose tortula).
4. Aquatic animals (green floater, eastern lampmussel, panhandle pebblesnail, mayfly, Roanoke slabshell). NOTE: this issue was resolved by buffering these shapefiles 20 m.

Pale coneflower (0%): single small occurrence maps to developed cells in shapefile translation to raster rather than adjacent forest

Eastern lampmussel (20%): Only one occurrence of 5 total has no incompatible cells.

Green floater (0%): NHP shapefile is linear polygon. This translates into scattered raster cells along length. Some of these end up in compatible land uses, some not, but all are assigned conservation value of 0. Did not enter minimum size for viability.

Panhandle pebblesnail (0%): 1 EO rank E, maps to about 1/3 incompatible raster cells.

Mole salamander (0%): Entered minimum size for viability of 200 ha, which I adapted from Georgia DNR value of 500 acres for 3 distinct salamanders. Combined 2 occurrences have 2.6 ha.

Four-toed salamander (0%): Entered minimum size for viability of 200 ha, which I adapted from Georgia DNR value of 500 acres for 3 salamanders. Only occurrence of that size is "0" quality and is half incompatible land use at baseline. Total compatible land use looks like 338 ha to me, but vast majority of that has EO rank E.

Piedmont cliff (acidic subtype) (0%): 2 largish occurrences, some incompatible land use.

Piedmont headwater stream forest (hardpan subtype) (0%): 2 small occurrences, some incompatible land use. 1 occurrence too small to be captured by raster conversion at all.

Pink-fruited thread-moss (0%): Not sure about this one. 2 small occurrences. Did not enter an MSV. One on incompatible land use, the other okay. Both EO rank E.

Xeric hardpan forest (basic hardpan subtype)(25%):

Xeric hardpan forest (Northern prairie barren subtype)(0%):

Dry-mesic oak-hickory forest (Piedmont subtype) (25%):

Piedmont acidic glade (0%): Only half of single occurrence lies on compatible land use.

Bald eagle (33.33%): Only 2/7 occurrences large enough (40 ha). Not sure how Vista calculated 33.33%.

Northern oak hairstreak (0%): Single occurrence 3.13 ha. I entered 50 ha as a minimum size for viability which I based on inferred minimum extent of habitat use of 1 km from checkered white on NatureServe explorer. There was no information to directly arrive at a value.

Timber rattlesnake (0%): Occurrence too small. Needs 700 ha per GA DNR rattlesnake.

Papillose tortula (0%): Tiny (but larger than stated MSV) single EO has rank E and maps to incompatible land use.

Creeper (40%): EO rank E. 2/5 "linear" polygons on compatible land uses.

Triangle floater (0%):

Checkered white (0%): Single occurrence, (although large enough, 60 ha) is half incompatible land uses.

Piedmont monadnock forest (typic subtype) (33.33%):

Mottled duskywing (0%): Single 3 ha EO too small to meet MSV of 50 ha. Also, EO rank E.

Mayfly (0%): Single 3 ha occurrence, EO rank E. Maps to 3 raster cells, one of which is compatible.

Sharp-shinned hawk (0%): Single occurrence too small (3 ha) for MSV (1000 ha).

Ultramafic outcrop barren (Piedmont subtype) (0%): 8 ha single occurrence 25% incompatible land use. No MSV entered.

Roanoke slabshell (0%): Single stream-shaped polygon, EO rank E, so conservation value "0". Translates to 4-5 raster cells, only one on compatible land use.