A TRADE-OFF ANALYSIS FOR PRIORITIZING LAND CONSERVATION IN THE CATAWBA-WATEREE BASIN

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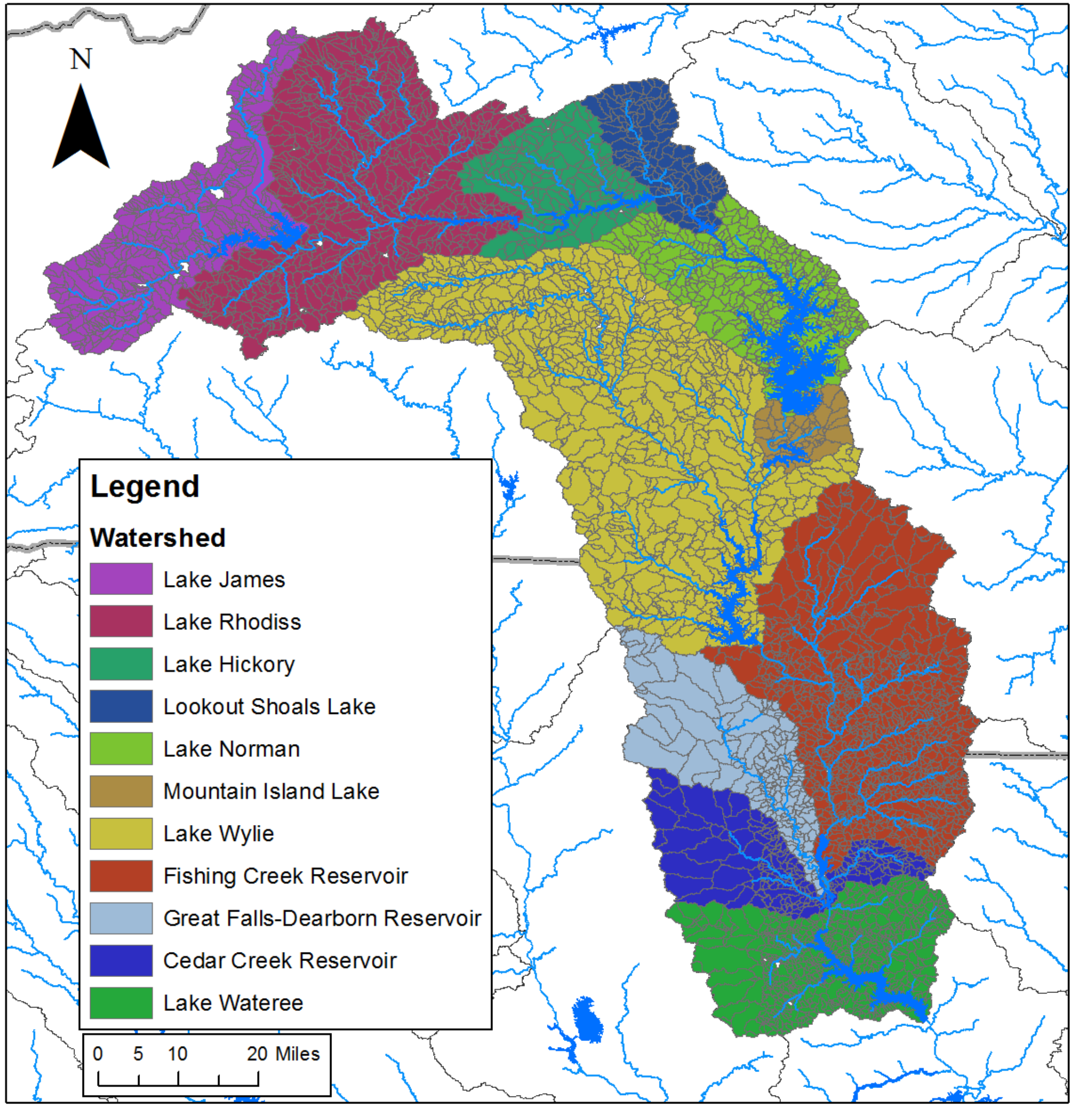
Project Goals

1. Estimate potential changes in flow and sediment delivery in the watershed as a result of future change in climate, land use, and water use
   - Where and how large the changes in the watershed?
2. Find areas in the watershed where the impact relative to other areas is disproportionately large (“hot spots”)
   - What metrics best capture impacts that are important to this group? Are hot spots different for different metrics?
3. Determine if and to what extent land conservation of “hot spot” could mitigate some portion of the total downstream impact to water supply
   - What percent of the impact is mitigated?
4. Prioritize land conservation by assessing economic tradeoffs
   - How do costs and benefits of conservation vary across watershed?

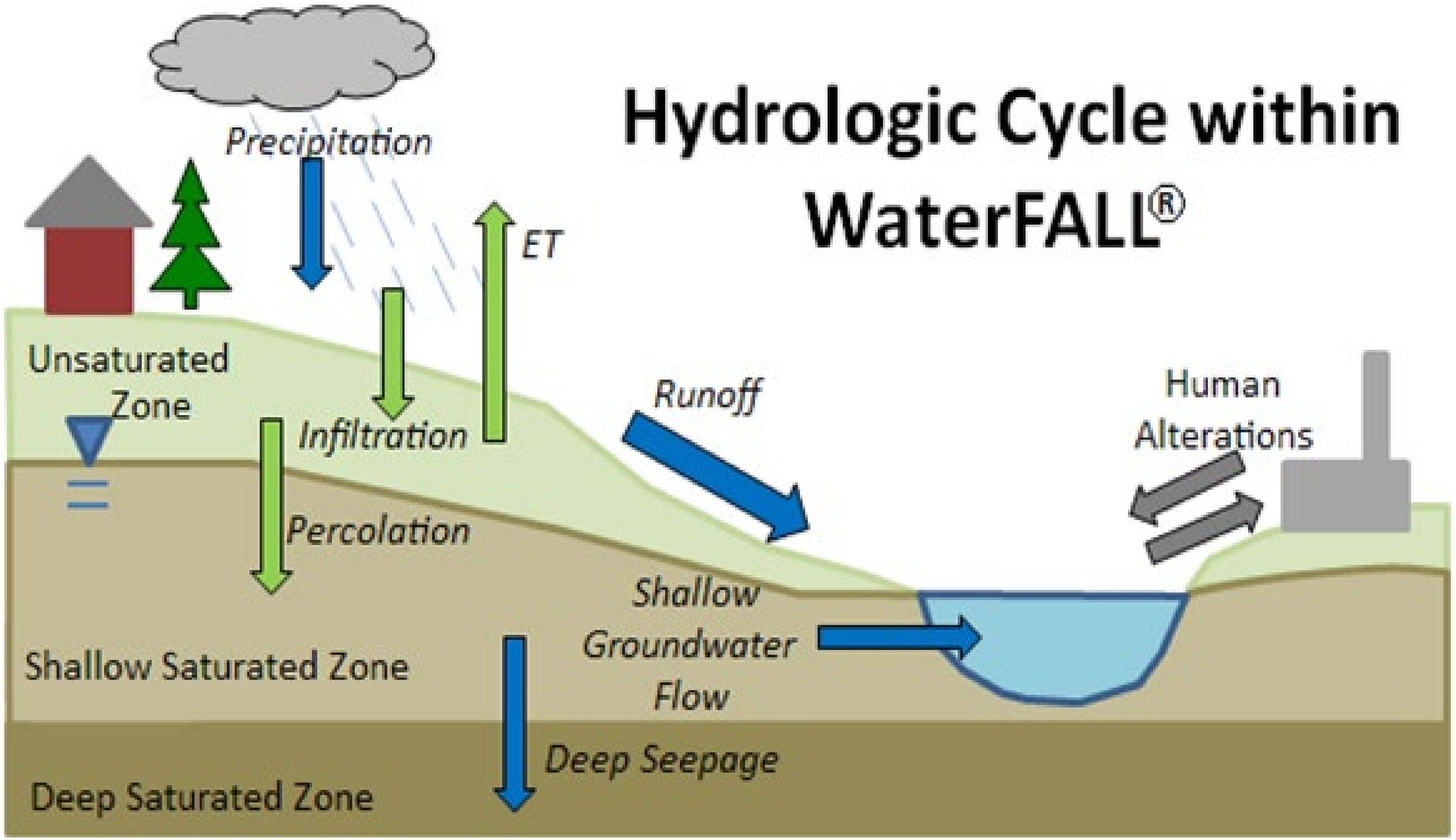
Hydrologic Model + Sediment Simulation (WaterFALL) → Land Use, Climate, & Water Use Future projections → Change Metric Spatial Analysis for Hot Spots → Mitigation Assessment using Model → Hydrologic and Sediment Benefit Calculations → Economic Valuation of Benefits

Catawba-Wateree Watershed in NHDPlus



Watershed	# NHDPlus Catchments	Area (mi^2)
Lake James	467	383
Lake Rhodiss	848	703
Lake Hickory	242	220
Lookout Shoals Lake	155	139
Lake Norman	428	338
Mountain Island Lake	51	74
Lake Wylie	872	1,157
Fishing Creek Reservoir	1,337	788
Fishing Creek	191	289
Great Falls Reservoir	13	2
Cedar Creek Reservoir	362	251
Lake Wateree	801	384
Grand Total	**5,767**	**4,729**

WaterFALL Depiction



Eddy et al., 2017. JAWRA 53(1)

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Selected Hydrologic and Water Quality Metrics

Code	Name	Category	Units	Description
7Q10	Mean 7-day low flow	Magnitude	cfs	Lowest 7-day average flow with a 10% chance of occurring each year
MIN	Median Annual Minimum	Magnitude	cfs	50th percentile of the minimum annual daily flow series
MAV	Mean Annual Volume	Volume	acre- feet	Average total annual streamflow volume
MAX	Mean Annual Maximum	Magnitude	cfs	Average of the maximum annual daily flows
P25	25th Percentile	Frequency	cfs	Daily flow which 25% of the mean daily flow rates are less than.
LFP25	Low flow pulse count	Frequency	days	Average number of flow events with flows below the 25th percentile of current conditions
LFPD25	Low flow pulse duration	Duration	days	Average duration of an event per year below a threshold for the entire flow record.
P75	75th Percentile	Frequency	cfs	Daily flow which 75% of the mean daily flow rates are less than.
HFP75	High flow pulse count	Frequency	days	Average number of flow events with flows above the 75th percentile of current conditions
HFPD75	High flow pulse duration	Duration	days	Average duration of an event per year below a threshold for the entire flow record.
RBI	Flashiness Index	Rate	NA	Daily change in flow relative to long-term flow
SED	Sediment load	Sediment	ton/ year	Average annual sediment loading per unit area

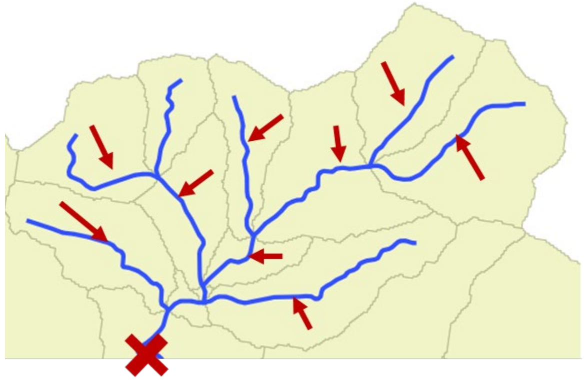
Key Considerations of This Study

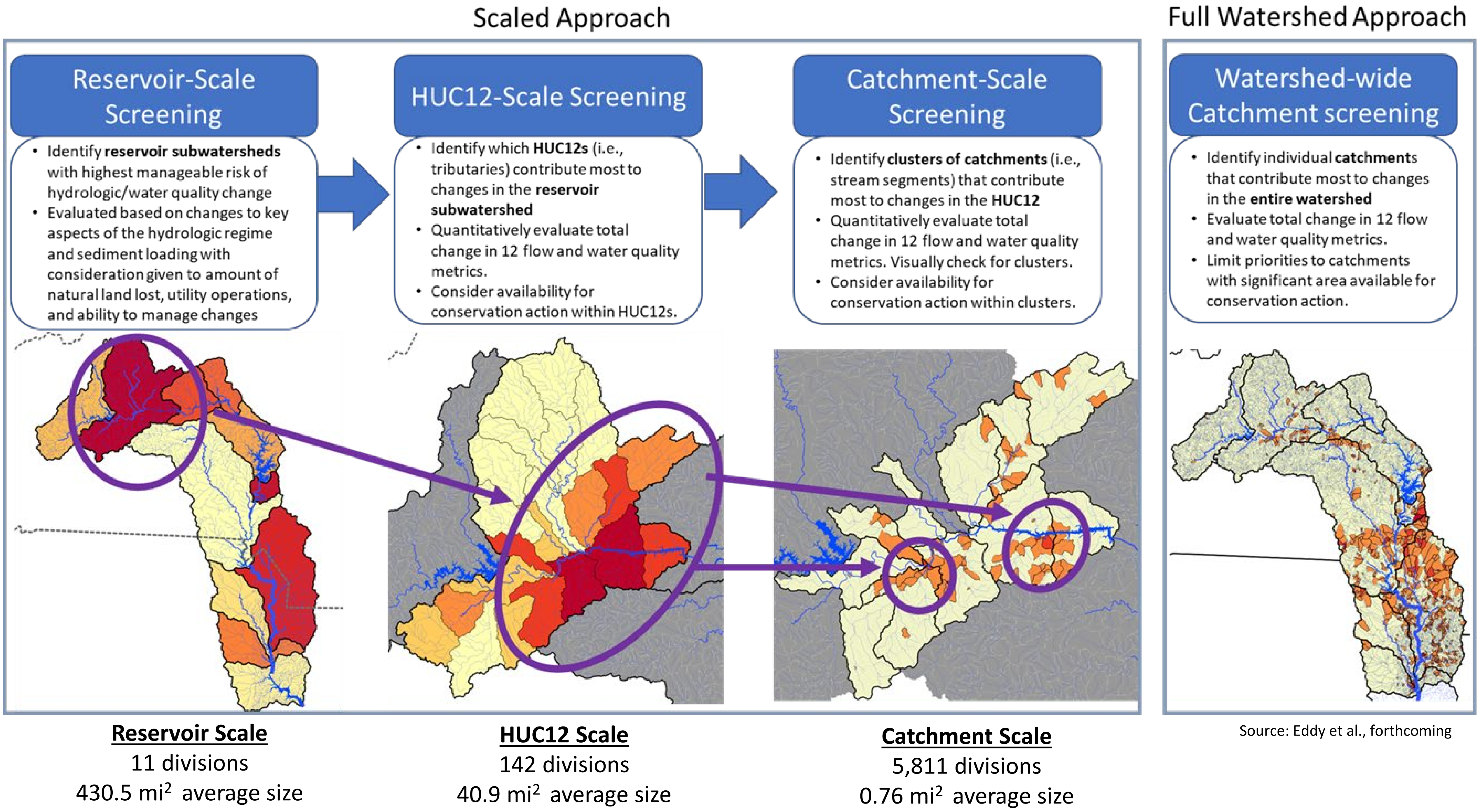
- **<u>Hot Spot</u>: a drainage area within the watershed in which**
  1. future projected changes in land use, climate, or water use have been determined to cause concerning levels of hydrologic or water quality change
  2. there is an opportunity for conservation action to mitigate the projected changes.

- Developed hydrologic and water quality scores (Q) that are
  - evaluated as a change between baseline and future conditions
  - calculated at a catchment level and at a cumulative aggregate level

Percent Change

$$Q_{change}\,\% = \frac{Q_{future} - Q_{current}}{Q_{current}}$$

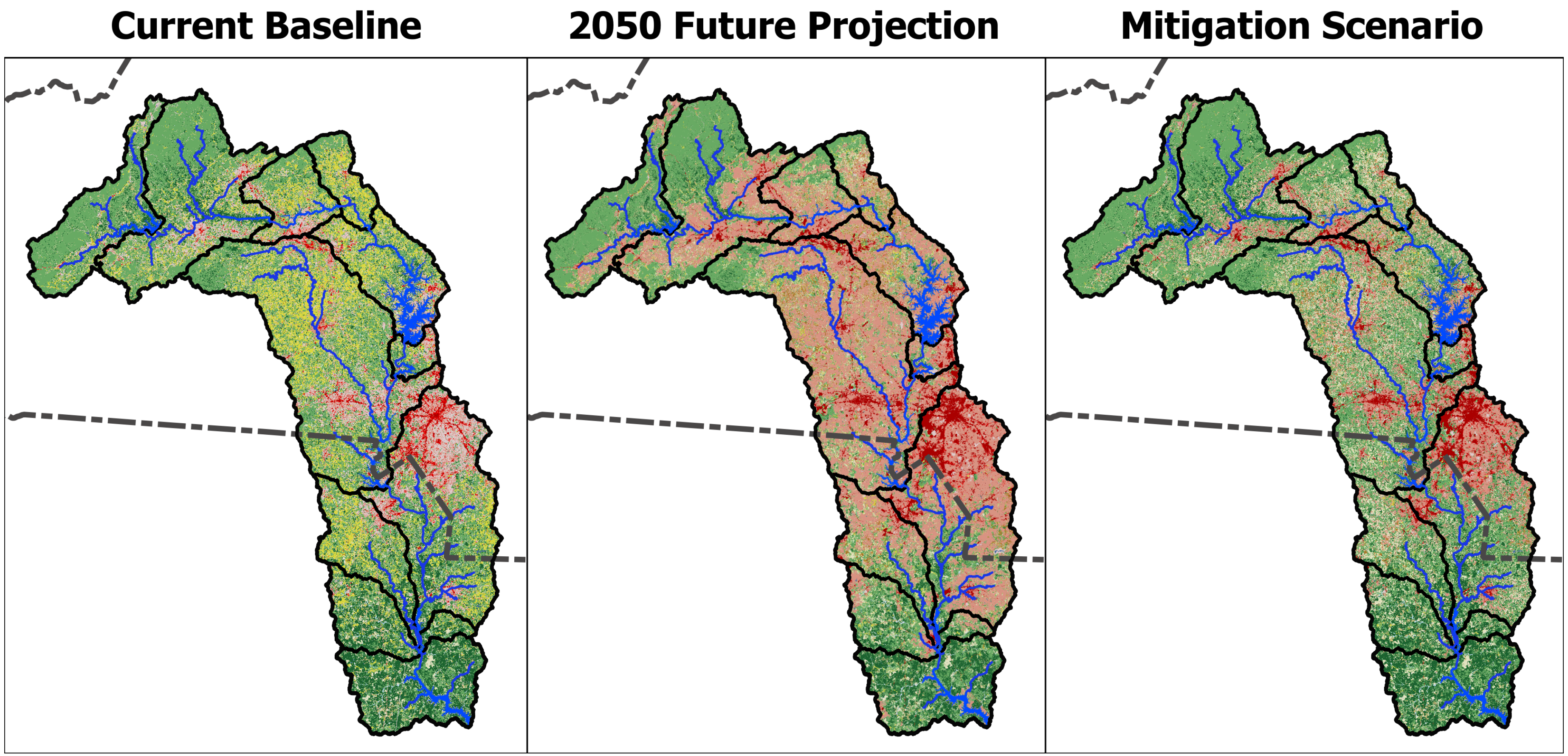




Source: Eddy et al., forthcoming

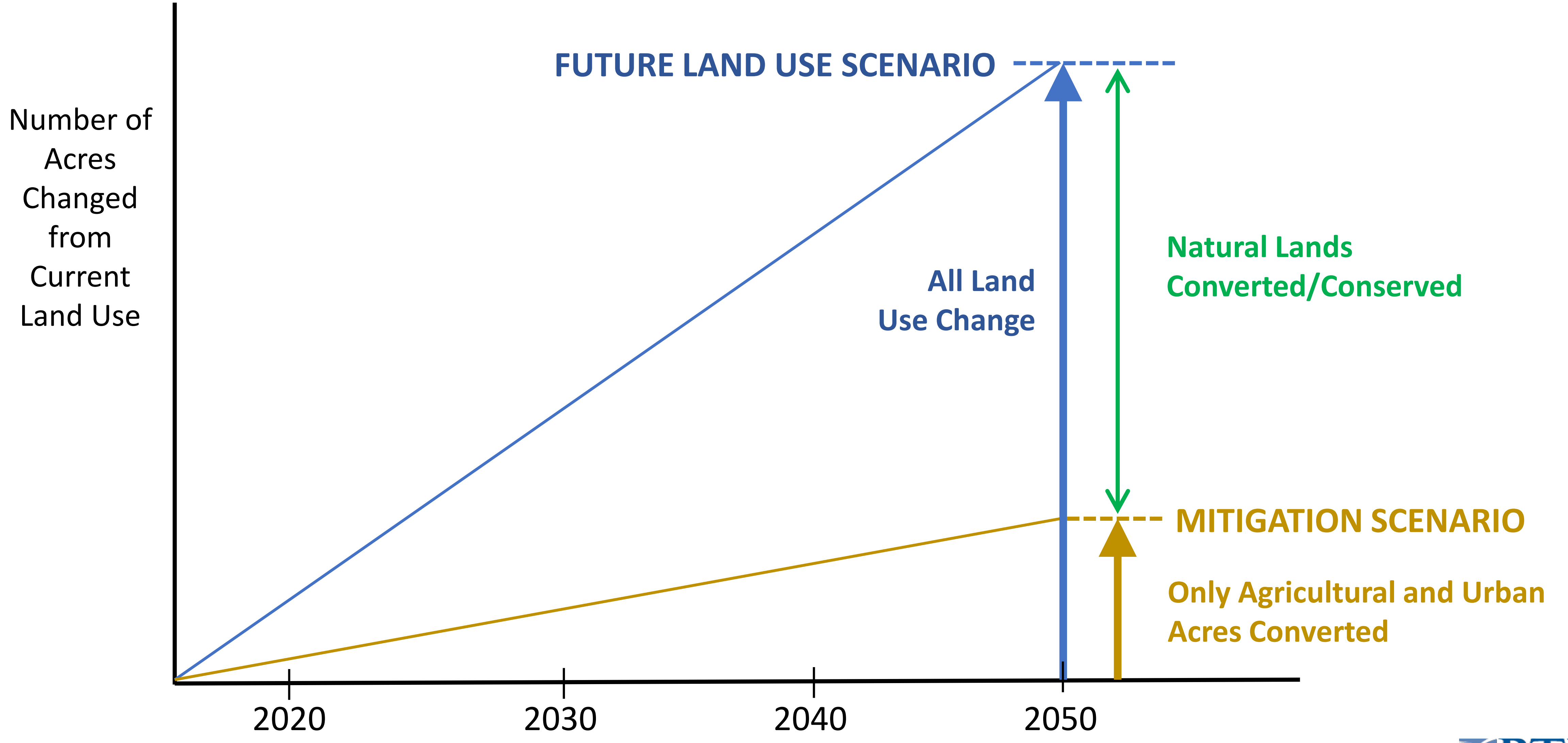
Isolating the Effect of Natural Land Conversion

- **Mitigation Scenario** holds natural lands constant, but allows for conversion of agricultural land and for increase in development intensity
- **Natural lands** are forests, grass/shrub, and wetlands



Source: Eddy et al., forthcoming

Separating Out the Effects of Natural Land Conservation/Conversion



Source: Eddy et al., forthcoming

Estimated Economic Benefits of Land Conservation

- Benefits of land conservation

  = Value of losses due to development of natural lands

- Benefits from avoided sediment loads to reservoirs
  - recreational visitors to lakes benefit from higher water quality
  - lakeshore residents benefit from higher water clarity
  - drinking water treatment systems and customers benefit from cleaner source water

- Benefits from maintaining tree cover
  - Carbon sequestration benefits through reduced climate change damages
  - Human health benefits via air filtration by trees

Three Main Catchment-level Benefit-Cost Indicators

1. **Average (per acre) Net Benefits** of Land Conservation in Catchment *i* (ANB_i) = Total Present Value of Land Conservation Benefits (2018-2050) (B_i) / Total Number of Natural Acres Projected to be Developed by 2050 (N_i) − Average (per acre) Cost of Natural Land in Catchment *i* (AC_i)

$$ANB_i = \frac{B_i}{N_i} - AC_i$$

2. **Total Net Benefits** of Land Conservation in Catchment *i* $= ANB_i * N_i$

3. Hydrologic **Benefit-Cost Ratio** for Land Conservation in Catchment *i* = Hydrologic Benefit Score ($HydAAPC_i$) / AC_i

$$\frac{HydAAPC_i}{AC_i}$$

Source: Eddy et al., forthcoming

Benefits from Reduced Sediment Loads to Main Stem Reservoirs

Modeled Changes in Total Suspended Solid (TSS) Concentrations by Reservoir

Reservoir	% Change in Average TSS Concentrations from Current Levels: Mitigation Scenario	% Change in Average TSS Concentrations from Current Levels: Future Land Use Scenario	Difference Between Scenarios (Effect of Natural Land Development)
Lake James	-3.4%	17.7%	21.1%
Lake Rhodhiss	-8.3%	23.3%	31.6%
Lake Hickory	-5.6%	37.1%	42.7%
Lookout Shoals	-9.9%	15.1%	25.0%
Lake Norman	-13.8%	16.7%	30.5%
Mountain Island Lake	-3.7%	43.8%	47.5%
Lake Wylie	-20.3%	17.1%	37.4%
Fishing Creek Reservoir	-73.3%	-35.9%	37.4%
Great Falls Reservoir	-29.1%	2.9%	32.0%
Cedar Creek Reservoir	-54.4%	0.7%	55.1%
Lake Wateree	-58.6%	1.0%	59.6%

Source: Eddy et al., forthcoming

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Effects of Projected Land Use Change in the Watershed

- Economic Losses from Sediment Loads to Reservoirs due to Development of Natural Lands

Reservoir	Converted Acres	Change in Sediment Load (tons/year)	Value of Lake Recreation			Lakeshore Property Values			Drinking Water Treatment Costs		
			Present Value of Change in Water Quality	Present Value per Converted Acre	Present Value per Ton of Sediment	Present Value of Change in Water Clarity	Present Value per Converted Acre	Present Value per Ton of Sediment	Present Value of Increased Costs	Present Value per Converted Acre	Present Value per Ton of Sediment
Lake James	29,777	69,037	$75,876,041	$2,548	$1,099	$5,748,488	$193	$83			
Lake Rhodhiss	99,307	70,238	$59,154,552	$596	$842	$362,088	$4	$5	$384,404	$645	$456
Lake Hickory	45,286	12,700	$247,304,780	$5,461	$19,473	$10,597,057	$234	$834	$691,771	$127	$36
Lookout Shoals Lake	23,352	7,052	$18,800,140	$805	$2,666	$810,696	$35	$115	$101,191	$126	$38
Lake Norman	69,096	14,912	$579,531,427	$8,387	$38,863	$106,205,544	$1,537	$7,122	$3,131,678	$373	$81
Mountain Island	14,767	2,111	$120,231,425	$8,142	$56,962	$2,557,405	$173	$1,212	$4,029,408	$495	$71
Lake Wylie	288,244	100,650	$566,680,345	$1,966	$5,630	$17,837,889	$62	$177	$899,403	$457	$160
Fishing Creek Lake	152,062	162,412	$42,739,616	$281	$263	$1,753,970	$12	$11	$54,436	$194	$207
Great Falls & Cedar Crk	89,057	23,183	$10,750,393	$121	$464	$3,891	$0	$0			
Lake Wateree	11,745	105,698	$230,748,666	$19,647	$2,183	$5,244,845	$447	$50	$379,165	$19	$174

Source: Eddy et al., forthcoming

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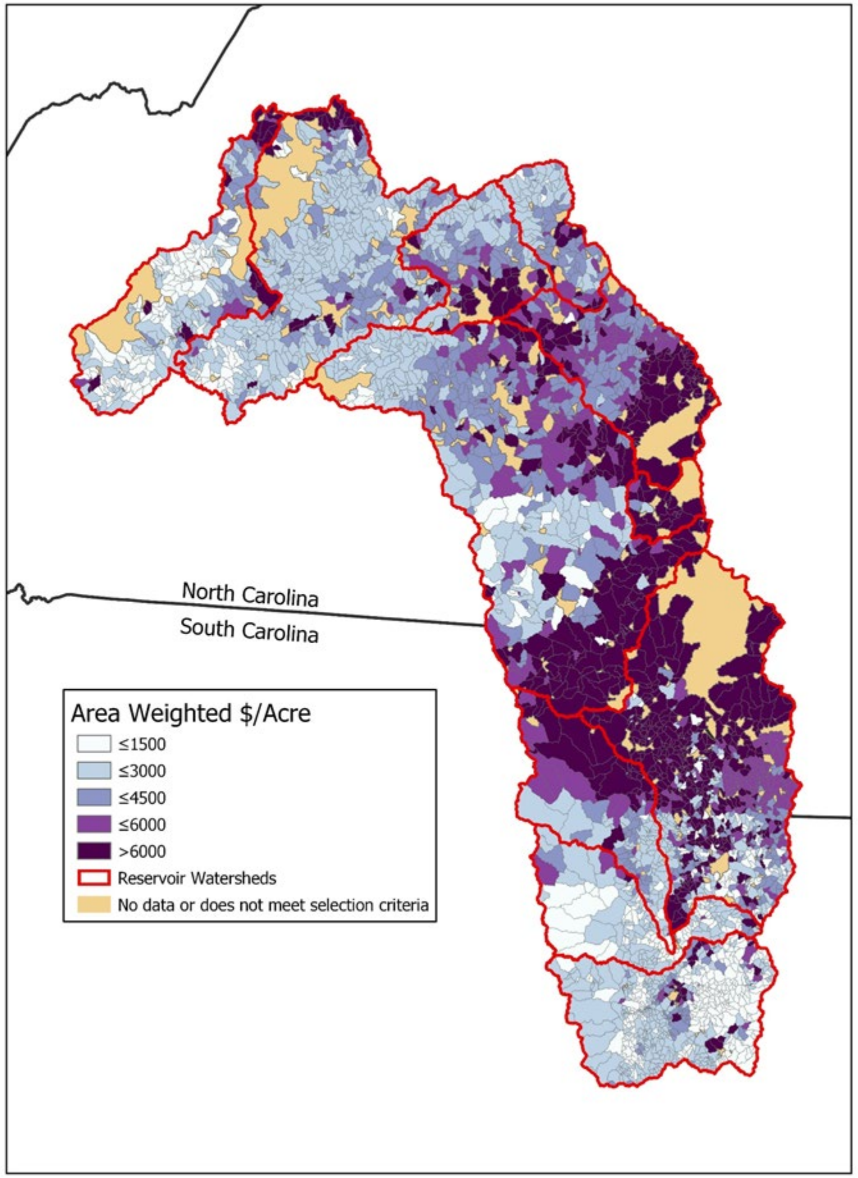
Effects of Projected Land Use Change in the Watershed

- Other Economic Losses due to Development of Natural Lands
  - Carbon releases due deforestation
    - Across all catchments in the watershed, the average present value loss due to carbon releases varies $2,300 (12 metric tons C) per developed forest acre to $6,000 (42 metric tons C) per acre
  - Air quality-related human health effects of deforestation
    - The annual value of increased health impacts from developing forested land vary from less than $18/acre (Avery County) to $2,500/acre (Mecklenburg County), with a mean of $212/acre

Costs of Natural Land Conservation

- Estimated the average cost of conserving natural land in each catchment using land values reported in parcel-level tax assessment data
  - Provides present value estimate for each land unit
  - Approximates the cost of purchasing land
- Selected parcels that would be representative of lands that are potential candidates for conservation using the following criteria:
  - Greater than 20 acres in land area
  - More than 80% of the parcel land area falls under an NLCD natural land category
  - Less than 10% of parcel land area is already protected.
- For each catchment with multiple parcels, calculated an area-weighted average value per acre



Source: Eddy et al., forthcoming

Additional Considerations for Economic Analysis

- Water treatment costs for power plants
  - EPRI (2012): reducing TSS is one of many objectives for cooling water treatment
  - One Duke power plant reports $275,000 in annual spending on dispersants for condenser circulating system, but not just for TSS
- Sediment removal (dredging costs)
  - Average costs of $20.43 per ton of sediment (based on USEPA and USGS reports)
- Other recreation-related economic impacts
  - Increased local spending by recreational visitors to reservoirs (~$400 million in present value) and other nature areas
- Off-stream water storage
  - One study (Coates, 2012) provides an average estimate of $6,720 per acre-foot, but average costs are very sensitive to design specifications
- Cost adjustments for purchase of easements rather than land acquisition
  - Casey et al. (2008) estimate that easement costs (including transaction costs) are roughly 42-43% of fee-simple land acquisition costs

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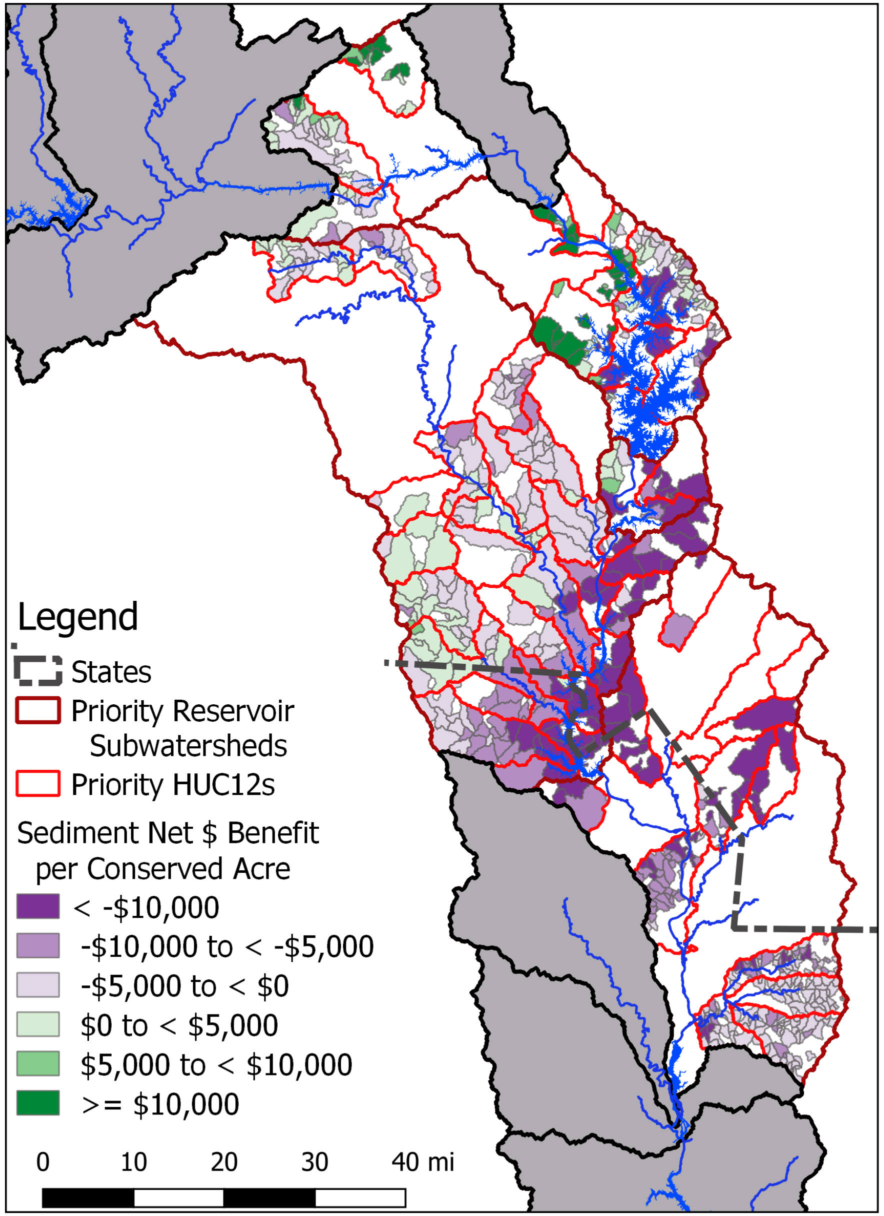
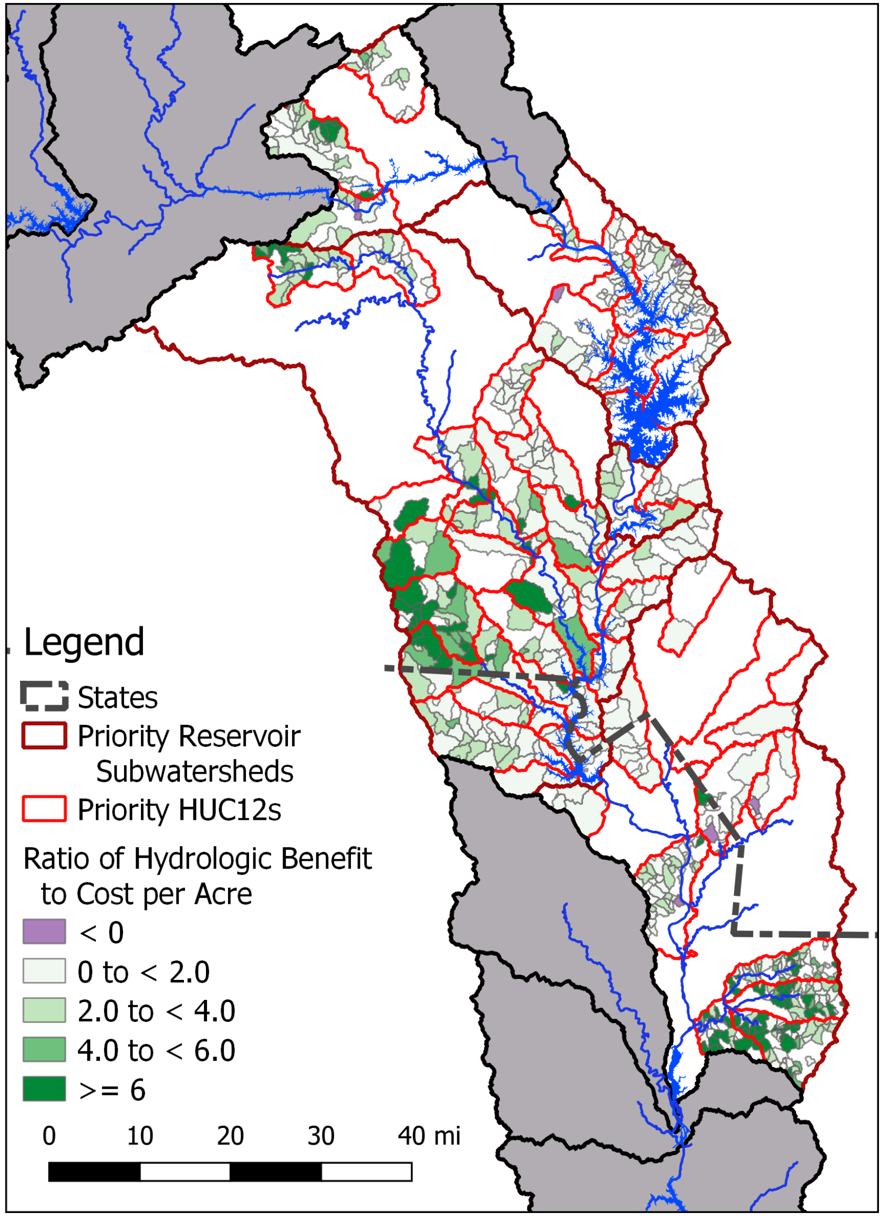
Benefit-Cost Ratings and Comparisons of Hot Spot Catchments

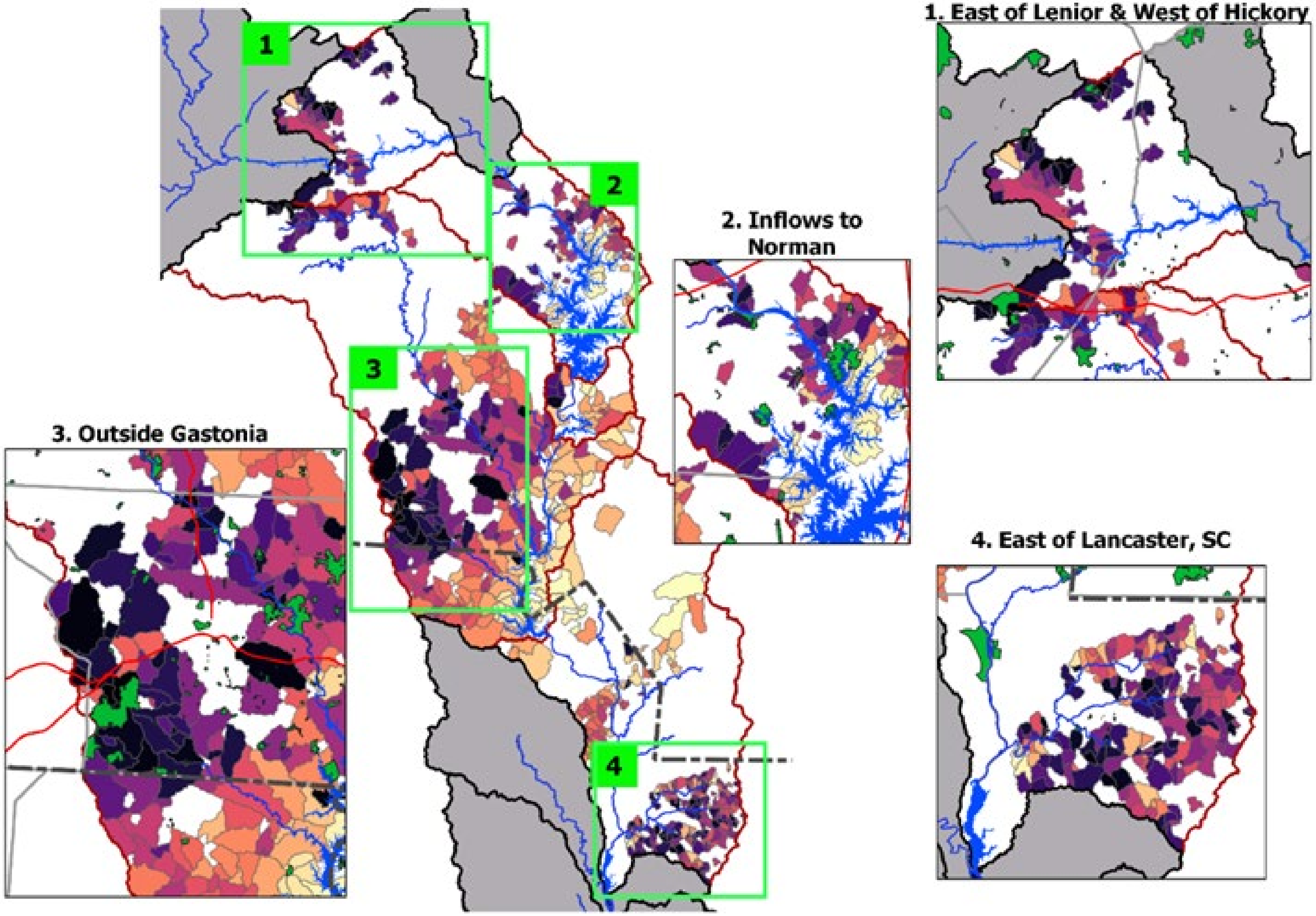




Source: Eddy et al., forthcoming

Recommendations

- #1: Priorities for Smart Development within the Basin



#	Specific Area	# of catchments	Conserved Acres[a]	Total Cost, $[b]
1	Northern Hickory	15	1,815 (3,719)	4,402,072
1	Inflows to Hickory	14	1,694 (3,864)	5,033,790
1	Wylie/Hickory Border	10	1,959 (5,270)	5,085,882
2	West of Lake Norman Shoreline	11	1,714 (4,775)	8,450,982
2	Inflow to Lake Norman	5	508 (1,228)	2,585,112
3	Outside Gastonia	26	7,928 (24,610)	15,877,968
4	East of Lancaster, SC	0		

Source: Eddy et al., forthcoming

Recommendations (cont'd)

- **#2: Combine the numeric and spatial findings with YOUR local knowledge**
  - Study recommendations do not include local knowledge on, for example, parcel ownership, local regulations, or existing planning efforts underway
  - Necessary to gather the "on the ground" knowledge to take these priorities from the assessment to implementation planning stages
- **#3: Plan for the Big Picture**
  - Conservation and smart development plans throughout the Basin can be informed at a Basin-wide scale through this analysis
  - Implementation may be carried out by one municipality/group or another → information and relative comparisons of costs and benefits across the Basin to formulate a "big picture" approach
- **#4: Develop a Centralized Fund or Bank for the Basin**
  - Water funds are institutions that connect downstream beneficiaries with upstream providers of watershed protection activities
  - Establishes a collective funding mechanism to incentivize those upstream activities
  - Institutes governance and watershed management mechanisms to ensure that the funds are collected, managed, and dispersed to achieve the stakeholders' objectives in a cost-effective, sustainable, and scientifically-grounded manner
  - Relevant example: City of Raleigh's Upper Neuse Clean Water Initiative

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Reference:

Eddy, M., K. van Werkhoven, B. Lord, S. Kovach, J. Serago, and G. Van Houtven. Forthcoming. Quantifying the Potential Benefits of Land Conservation on Water Supply to Optimize Return on Investments. **Project #4702**. Denver, CO: The Water Research Foundation.

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