NEW YORK STATE WATER RESOURCES INSTITUTE
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ESF State University of New York
College of Environmental Science and Forestry

Mapping needed and existing vegetative buffers to reduce nutrient loads

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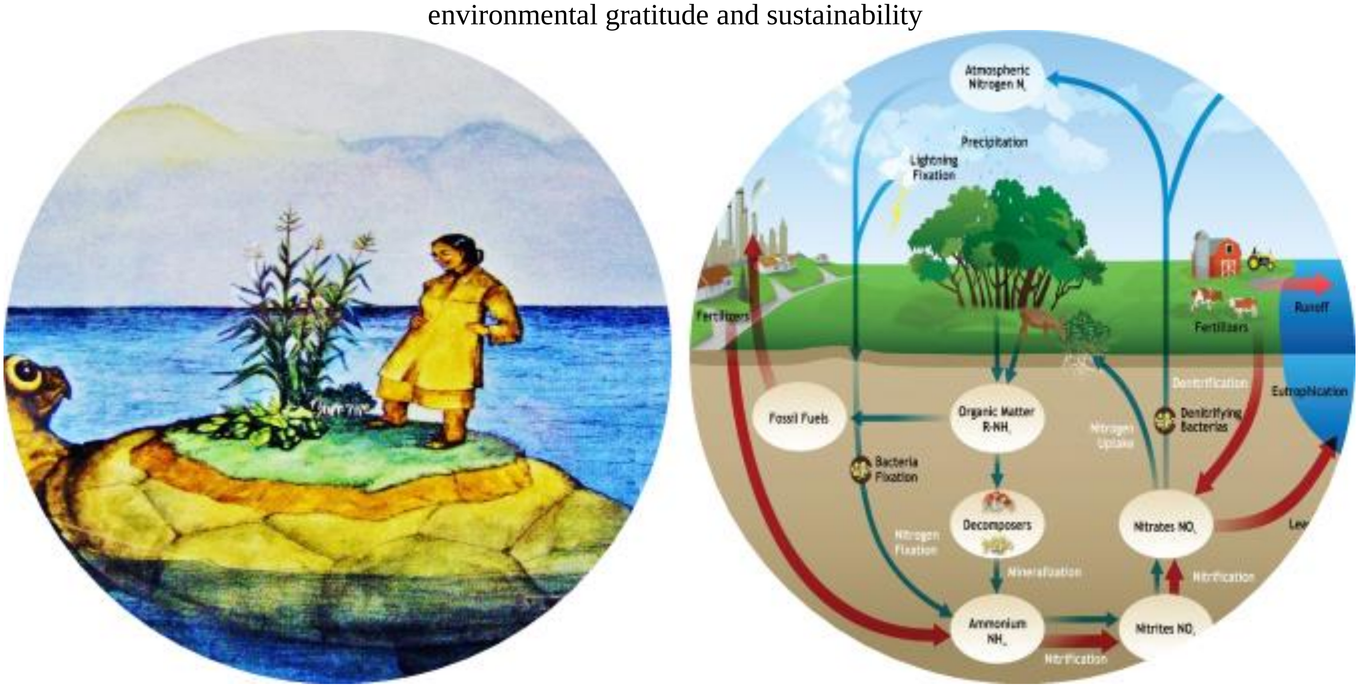
Seeing with indigenous and scientific knowledge to achieve environmental gratitude and sustainability



Abstract
The Hudson River Estuary and its Wallkill River tributary suffer from pollution due to excess inputs of nutrients from nonpoint source runoff. This study aimed to create outreach materials to engage land owners as advocates for riparian vegetative buffers to improve basin sustainability. The i-Tree Buffer tool was used to generate flow path derived maps of nitrogen and phosphorus loading hotspots to identify priority vegetative buffer planting sites. The study established a collaborative partnership with the Center of Native Peoples and the Environment to construct story-based outreach materials that combine traditional ecological knowledge with scientific ecological knowledge, and thereby connect more widely and deeply to help improve basin stewardship. Such stories might build on ideas expressed in the Haudenosaunee Thanksgiving Address, the duties of water, and the animacy of nature. The study initiated via letters consultation with active and potential stewards, including five Indigenous Nations, on valuation of local water resources and design of outreach materials.

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Respondents stated the ecological to spiritual value of Wallkill River basin waters and riverside forests, and encouraged story-based outreach materials that resonate with local residents, as well as high visibility buffers to attract more attention.

Three Summary Points of Interest

- Nutrient loading hotspot maps were created for the Wallkill River basin and Trees for Tribs riparian planting sites
- Stewardship partnerships were built with Centers for Native Peoples and the Environment and other groups
- Outreach stories were envisioned to combine indigenous and scientific knowledge to achieve basin sustainability

Keywords
i-Tree Tools, Trees for Tribs, non-point source runoff, outreach materials and stories, traditional ecological knowledge, scientific ecological knowledge

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Introduction

Nutrient loadings and the resulting accelerated eutrophication is a top ten water quality issue for NY (https://www.dec.ny.gov/chemical/69489.html). Loads of nitrogen and phosphorus from nonpoint sources such as fertilizers, animal waste, and atmospheric nutrient deposition, lead to elevated nutrient concentrations and excessive growth of nuisance algae and aquatic weeds, which can make waters unfit for target uses (such a swimming, fishing, drinking), and then during the decay of this excess growth dissolved oxygen levels are depleted, creating hypoxic dead zones unable to support critical target water uses. Nutrient loads are considered the primary cause for water quality impairment in 23% of NYs 5000+ water bodies, and are a contributing (but not primary) cause for impairment in another 29% of NYs waters.

NY is committed to reaching target water uses, and through its Department of Conservation and the Natural Heritage Program NY developed the Trees for Tribs [Conley et al., 2018] program and the Statewide Riparian Opportunities Assessment. This program was developed to help land owners plant vegetative buffers and reduce nonpoint source runoff of nutrients. Several groups are concerned about water quality in the Wallkill River basin and want to improve outreach materials that help landowners strategically plant vegetative buffers to reduce nutrient loading. Unfortunately, the scientific knowledge developed in these programs is not widely utilized in stewardship by residents, suggesting the potential for improvements in transferring knowledge. This problem was observed by Walter et al [2000] in the Catskill watersheds, who developed innovative ways to use maps of hydrologically sensitive areas to alert landowners to the overlap of runoff and pollutants.

This study builds on the work of Walter et al. [2000] and will address two gaps in watershed management of nonpoint source nutrient loading. The first gap is the Statewide Riparian Opportunities Assessment does not use flow paths connecting pollutant sources to receiving waters when identifying needed and existing vegetative buffers. Outputs of the i-Tree Buffer tool [Stephan and Endreny, 2016], created in partnership with the USDA Forest Service, uses flow path analysis and local nutrient export coefficient values to create maps of nutrient loading hotspots which can help prioritize which nonpoint sources contribute the disproportionate water quality impact and are candidates for riparian vegetative buffers. This second gap is the use of data-driven stories showcasing the benefit of existing and potential vegetative buffers, created through a collaborative process with partners interested in stewardship of the basin. Outputs of this research would be identification of partners, and the start of an iterative process to generate outreach material that educates the public on the water quality value of existing and needed buffers.

This study aimed to create outreach materials to motivate and guide land owners on why and where to plant riparian vegetative buffers and reduce the loading of nonpoint source nutrients. The study focus was the Wallkill River basin, headwaters to the Hudson River Estuary, which is a nutrient impaired water body. Our objectives included: 1) mapping nitrogen and phosphorus nutrient loading hotspots and total nutrient loads in the Wallkill River basin of NY using the i-Tree Buffer tool; 2) collaborating with groups involved in environmental stewardship of the basin to identify how best to present information on outputs from the i-Tree Buffer tool, or similar Trees for Tribs NY Riparian Assessment tools, so it represents economic, social, and environmental interests and tradeoffs; 3) providing to constituents a set of results from i-Tree Buffer, which could include a first set of stories and maps showcasing the benefits of vegetative buffers and identifying priority plantings, as well as a plan for follow-on proposals with the collaborators.

Results & Discussion

A technical achievement from this work was refactoring the i-Tree Buffer tool to utilize the National Hydrography Data Plus (NHDPlus) version 2 flow direction maps to create runoff flow path, and more accurately predict interaction with riparian buffers. The earlier i-Tree Buffer model used a NHD digital elevation model (DEM) to derive flow directions, but the DEM rasters were not forced to align with NHD vector maps of receiving waters and could suggest faulty interactions between runoff and riparian buffers. The new tool is better suited for outreach due to its use of trusted data to connect land cover runoff with its actual section of receiving water.

The i-Tree Buffer tool generated maps of nutrient loading hotspots for nitrogen (Figure 1) and phosphorus (Figure 2) in the Wallkill River basin. These maps can guide vegetative plantings by noting each pixel hotspot can be reduced by acting on the: 1) a category of land use on that pixel that exports nutrients; 2) the upslope area that generates runoff; and 3) the downslope area by adding vegetative buffers. Maps are best used in a geographic information system (GIS) with reference layers.

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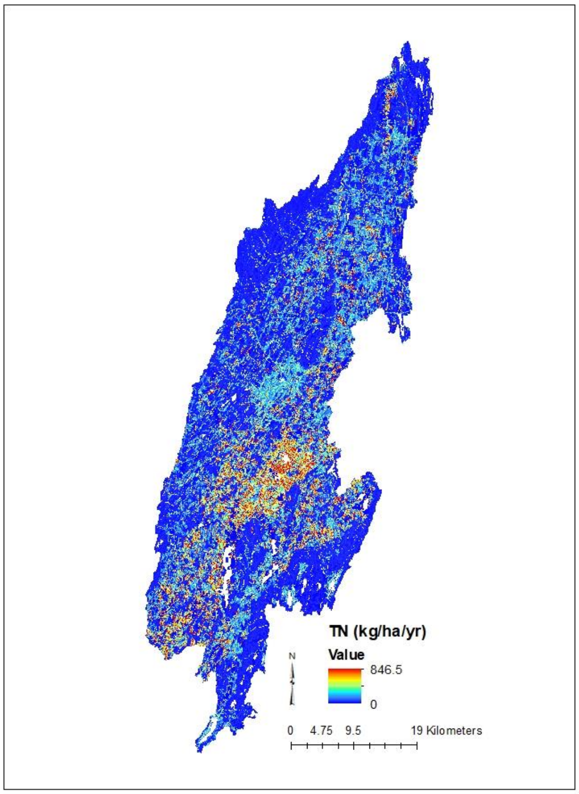

Figure 1. Total nitrogen loading (kg/ha/yr) for the Wallkill River basin, NY. Larger image in Appendix and a digital file for GIS at https://osf.io/4sg5h/.

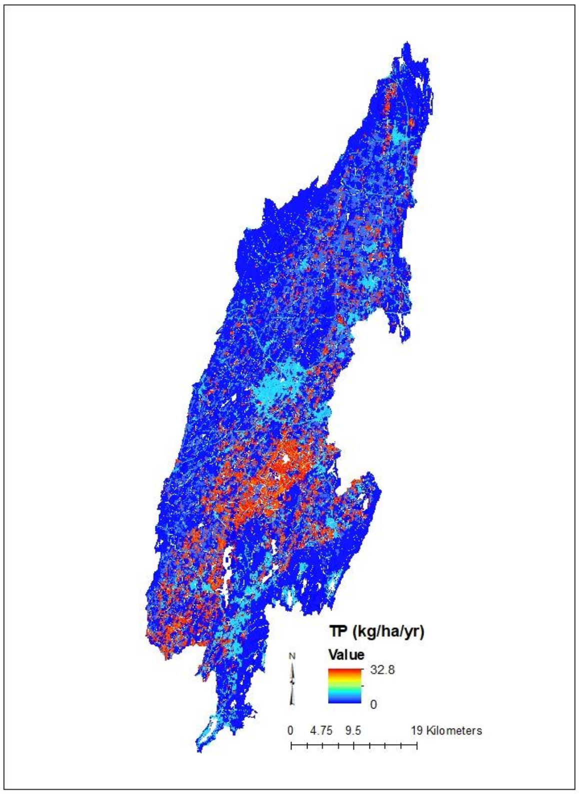

Figure 2. Total phosphorus loading (kg/ha/yr) for the Wallkill River basin, NY. Larger image in Appendix and a digital file for GIS at https://osf.io/4sg5h/.

The study team worked closely to establish a new vision for outreach materials that combine traditional ecological knowledge with scientific ecological knowledge, and thereby connect more deeply and achieve sustainable stewardship for water quality. This vision emerged from the shared vision planning process between the staff of Endreny at State University of New York (SUNY) College of Environmental Science and Forestry (ESF), Kristin Hychka at Cornell University New York State (NYS) Water Resources Institute (WRI) and Beth Roessler at the Department of Environmental Conservation (DEC) Trees for Tribs. This vision emerged from readings by ESF scholar Robin Kimmerer on the Earth origin story involving Sky Woman falling onto Turtle Island, and the animacy of nature enlivening story.

The study established a new partnership between WRI and the ESF Center of Native Peoples and the Environment (CNPE) staff Catherine Landis and Neil Patterson, who work with CNPE director Robin Kimmerer. The CNPE became an informal partner with this study, sharing with us the goal of combining Indigenous and scientific knowledge to improve sustainability, and we have agreed to try and work collaboratively to secure future funding to advance this research. The CNPE staff provided for our study the contact information for the five Indigenous nations with stewardship standing in the Wallkill River basin. Through this partnership the study achieved a greater understanding for Indigenous perspectives on the duties and rights of water, and for the Haudenosaunee how the Thanksgiving Address, which expresses shared gratitude for the benefits of nature, is a mechanism for education and outreach through storytelling [King, 2007]. These are profound concepts that bring positive disruption and can transform outreach in the field of water resources.

The ESF, WRI, DEC, and CNPE partners collaborated to develop a set of questions to solicit consultation on outreach materials. A common set of questions were sent to forty contacts which included three categories of: 1) residents and property owners totaling seven, 2) conservation managers totaling twenty-four, and 3) Indigenous leaders totaling nine. These contacts and affiliations are listed in Table 1 to 3 in the Appendix. We noted managers and leaders could be residents and also sent them questions for residents. Maps and aerial photos of four diverse and high-profile riparian vegetative buffer sites on Monhagen Brook in Middletown, NY, the Muddy Kill in Montgomery, NY, and the main stem in Wallkill, NY were included with the letter seeking consultation. The letter also included material explaining the legacy of Indigenous stewardship in the basin. The initial letters sent to Indigenous leaders explained the project and requested a meeting, and after the meeting the questions were shared. The questions are listed here, with each prefaced by the number of the contact category.

1a. Why do you value or not value the Wallkill River waters and the riverside forests?
1b. What reasons would you want or not want riverside forests in the watershed?
1c. How have you seen or heard of any of these four sites benefiting your community?
1d. Can you share personal stories, reflections, or cultural teachings related to the Wallkill River waters and riverside forests? This could include or not include any of the four sites in our maps.
1e. Is there anyone else we should share these questions with?
2a. From your experience or from what you have heard, what outreach materials have and have not worked to affect the behavioral change needed to improve the watershed?
2b. If you could disseminate new content through outreach, what methods would you use or avoid?
2c. Are you familiar with the Statewide Riparian Opportunities Assessment Tool, aka Trees for Tribs Prioritization Tool, and if so, what improvements might make the Tool inform the decisions to improve the watershed?
3a. How should we engage indigenous and settler communities in the process of building outreach materials to protect river waters and adjacent lands?
3b. Do you have insights into how outreach materials can help educate communities and thereby help these forested riverside places fulfill their duties and responsibilities?
3c. Would you be interested in sharing any outreach materials or educational resources with us, with you defining how we can use them in our effort to support the roles of water, rivers, and riparian areas?
3d. What should we know about managing riparian areas for mutual benefits?
3e. Do you have questions you think we should be asking the local constituents? Below is the current list of questions we have for this group. If you have ideas, we would likely build these into our future studies and meetings.

The letters had nine responses, a rate of 25% when noting four contacts had moved, and included 46 distinct ideas total nearly 3500 words. The Indigenous leaders sent no direct responses to the questions, and the response by the Chief Abram Benedict of the Mohawk Council of Akwesasne led to a meeting for their council to hear directly about the project and explain their many environmental stewardship and education programs. At the close of that meeting, we agreed our future collaboration in outreach material development should be supported by funding for all consultants.

The respondents to the letters valued and wanted the Wallkill River waters and riverside forests for ecological, economic, social, and spiritual reasons. Some had heard of the four riparian sites included in the maps through engagement with plantings, while others who were unaware of these sites suggested planting higher-profile sites. Ideas for outreach materials included strategic use of stories in media campaigns, such as profiles on the site and stewards in community publications (vs agency brochures), high quality social media posts that may spread, personal interaction with experts speaking to the importance of riverside forests, and word of mouth advocacy about positive planting or nature experiences. Respondents suggested outreach via attention grabbers like door hangers, which may succeed where mailings are recycled, and yard signs which celebrate landowners for their stewardship. In two cases, outreach was effective in the brochures of: 1) Life at the Water's Edge by the Lower Hudson Coalition of Conservation Districts; and 2) Stream Processes – A Guide to Living in Harmony with Streams by Chemung County Soil and Water Conservation District. To build on this feedback would be the goal in a follow-on study. The responses are in Table 4a to 4g in the Appendix.

Policy Implications

The policy implications of your research extend to the historical and continuing relationship to these waters and lands on the part of Indigenous peoples are recorded by the NYS Parks, Recreation and Historic Preservation map showing Indian Nation Areas of Interest (please see Appendix). The Indigenous people who have areas of interest in the Wallkill River basin include the: Delaware Nation, Delaware Tribe of Indians, Mohawk Nation, Saint Regis Mohawk Tribe, and Stockbridge-Munsee Community Band of Mohican Indians. The policy implications extend to the NYS DEC Commissioner's Policy 42 honoring ongoing rights of Native peoples to this land.

Methods

Our methods are as follows, each with subtasks:
A) Mapping nutrient loading hotspots and total nutrient loads with the i-Tree Buffer tool for the Wallkill River watershed. The tool will 1) assign ecoregion specific export coefficients (kg/ha/yr) to each National Land Cover Data (NLCD) raster of land cover to represent potential nutrient pollutant loads of nitrogen and phosphorus [White et al., 2015]; 2) process NHDPlus flow direction (FDR) and county soil survey grids (SSURGO) hydraulic conductivity data to determine for each raster grid the upslope contributing area likely to generate runoff using the soil-topographic index wetness index; 3) process reversed NHDPlus FDR data, SSURGO data of soil thickness, and NLCD land cover to calculate the downslope dispersal area for overland and subsurface flow paths where vegetative buffering could occur before nonpoint source runoff reaches a receiving water [Endreny and Wood, 2003; Stephan and Endreny, 2016]; 4) intersect the runoff likelihood and buffer likelihood with the pollutant magnitude to identify and map the nonpoint source nutrient runoff hot spots. The computing methods for this work entitled "Methods for i-Tree Buffer tool" in the Appendix.

B) Collaborating using the shared vision planning process [Palmer et al., 2013] with staff from SUNY ESF, NYS WRI, and DEC Trees for Tribs to: 1) introduce the i-Tree Buffer and Trees for identifying priority vegetated buffers that protect water quality; 2) iteratively engage in structured collaboration to create effective vegetative buffer guidance (one immediate benefit was this resulted in using the NHDPlus in place of DEM); and 3) update i-Tree Buffer tools to make output more user-friendly and represent important cultural and scientific information. This process resulted in creating maps of fourteen Trees for Tribs riparian buffer sites, and then narrowing this list to four sites based on ecological and social features. The technical steps in this work are explained in "Methods for Riparian Maps" in the Appendix.

C) Providing to existing and potential stewards a set of updated model results as outreach products. This could include a first set of data-driven stories and maps for the why and where of priority plantings and plans for follow-on proposals with collaborators. This involved building the collaborative relationship with the CNPE, identifying and reaching out to Indigenous communities with a history of stewardship in the basin, developing questions for consultancy. These questions explored the value of riparian areas, and suggestions for best outreach practices, and included maps of the four riparian sites to help conjure personal stories that can be shared. Consultation was sought from conservation managers, extension agents, property owners, and Indigenous leaders.

Outreach Comments

The list of individuals and organizations contacted in efforts to solicit feedback on outreach materials and stories are appended as a table, along with the example letters sent to these individuals.

Student Training

No students were trained in this study.

Publications/Presentations

The i-Tree Buffer tool, the input data, and the output maps were published on the Open Science Framework https://osf.io/4sg5h/. The questions for consultancy and responses on the value of riparian buffers and stories in outreach materials are appended in Tables 4a to 4g.

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Appendices

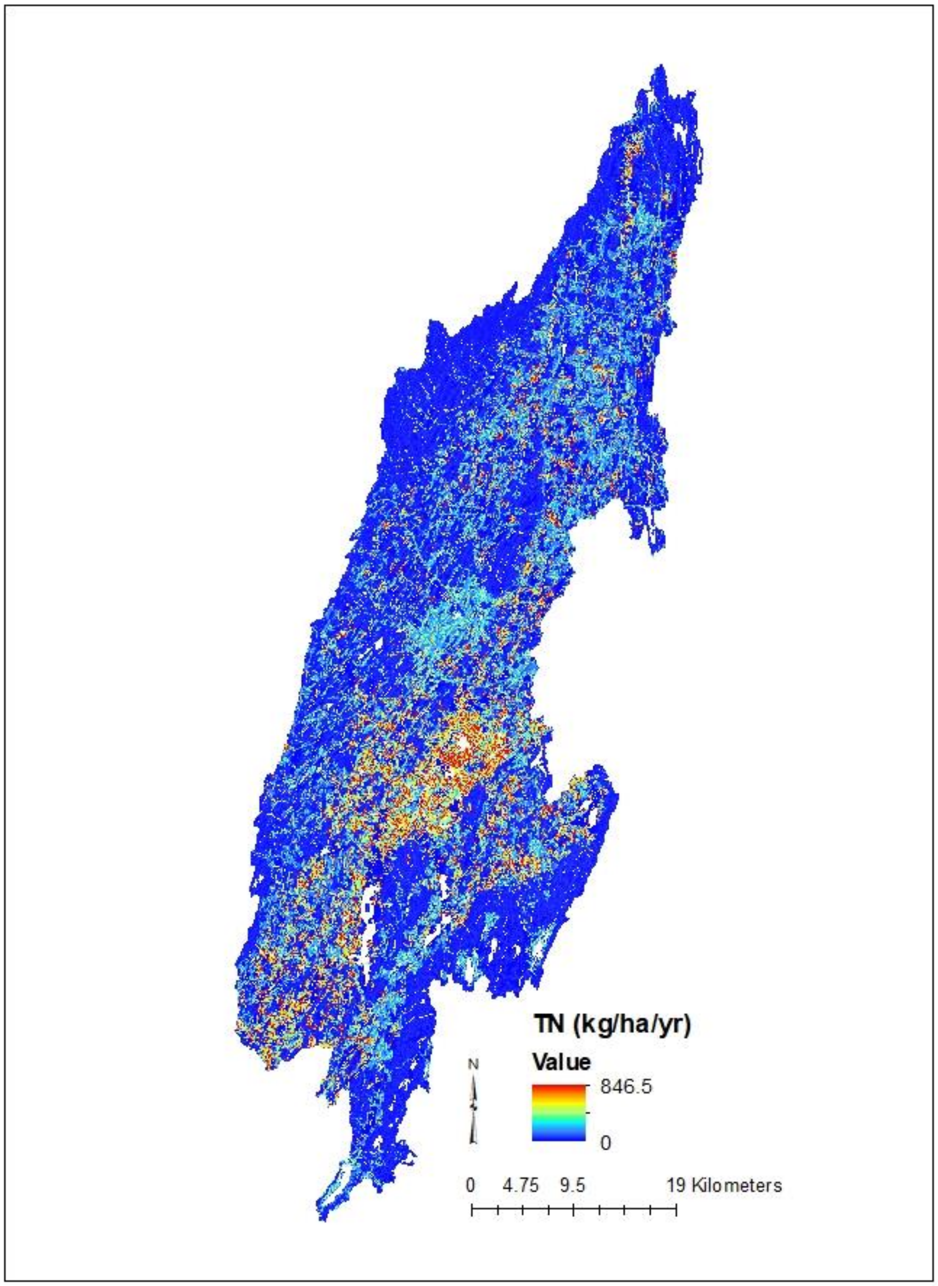

Figure 1. Total nitrogen loading (kg/ha/yr) for the Wallkill River basin, NY. This map is available at https://osf.io/4sg5h/ as a GIS file to explore with reference layers, such as land cover and rivers. The map can guide vegetative plantings by noting each pixel hotspot can be reduced by acting on the: 1) a category of land use on that pixel that exports nutrients; 2) the upslope area that generates runoff; and 3) the downslope area by adding vegetative buffers.

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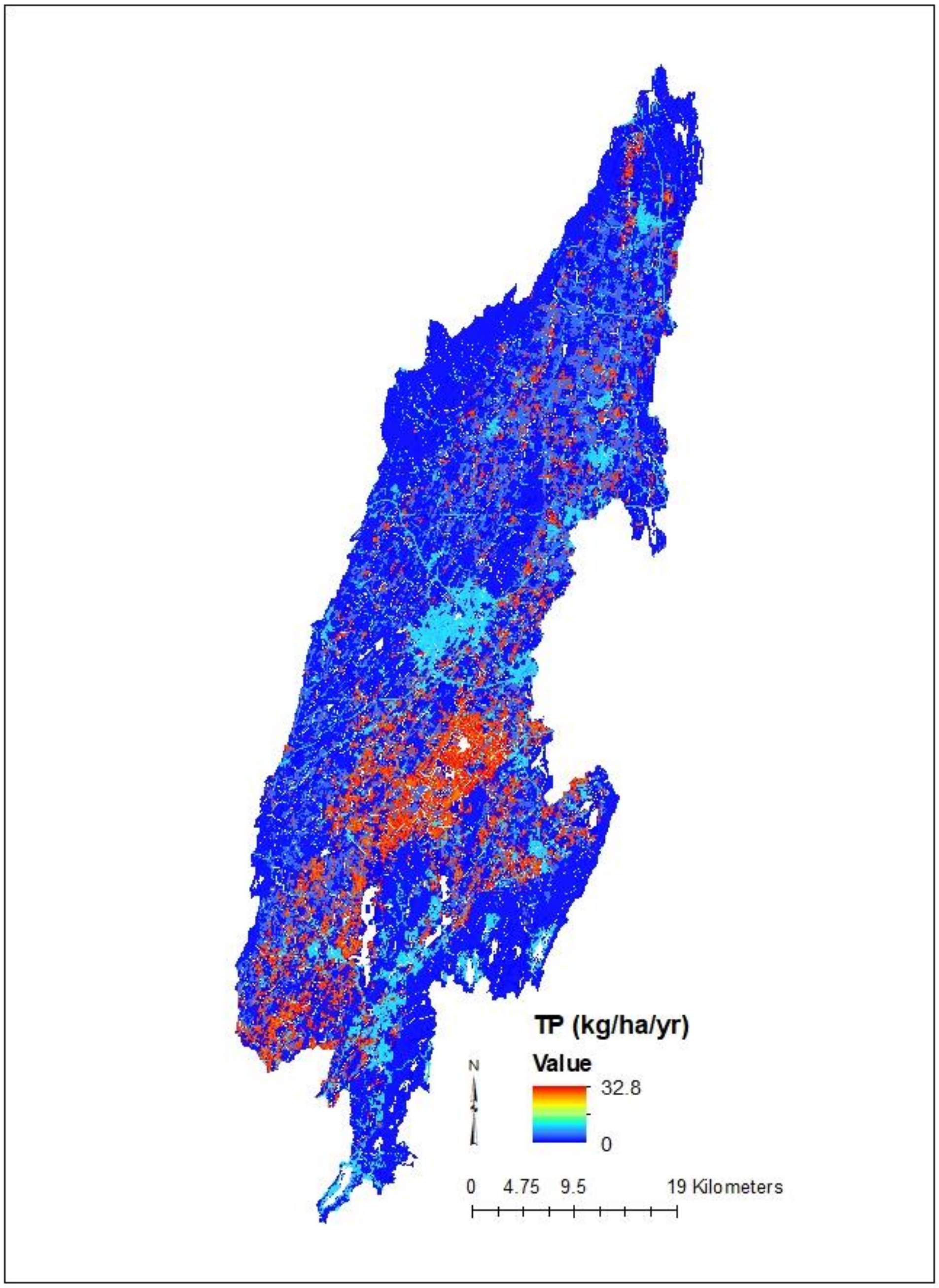

Figure 2. Total phosphorus loading (kg/ha/yr) for the Wallkill River basin, NY. This map is available at https://osf.io/4sg5h/ as a GIS file to explore with reference layers, such as land cover and rivers. The map can guide vegetative plantings by noting each pixel hotspot can be reduced by acting on the: 1) a category of land use on that pixel that exports nutrients; 2) the upslope area that generates runoff; and 3) the downslope area by adding vegetative buffers.

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Table 1. Contact name, affiliation and category of resident who were sent letters requesting consultation on development of stewardship outreach materials for the Wallkill River basin, NY. The response of Received indicates they sent or arranged for feedback to questions.

Name	Affiliation	Category	Response
Susanne Driscoll	Maple Hill Elementary Principal	Resident	
Dave Haldeman	CAC for Town of Shawangunk	Resident	Received
Patricia Henighan	Town of Montgomery CAC	Resident	Received
Cathy Kennedy	Wallkill Valley Savings and Loan	Resident	
Arif Khan	Wallkill River Watershed Alliance, Business Owner in Watershed	Resident	
Gary Leather	Town of Montgomery CAC	Resident	
Dominick Radogna	Monhagen Middle School Principal	Resident	

Table 2. Contact name, affiliation and category of manager who were sent letters requesting consultation on development of stewardship outreach materials for the Wallkill River basin, NY. The response of Received indicates they sent or arranged for feedback to questions.

Name	Affiliation	Category	Response
Jared Buono	Ulster County CCE - Executive Director	Manager	
Brenda Cemelli	Wallkill River Watershed Alliance member	Manager	Received
Dave Church	Orange County Water Authority?	Manager	
Martha Cheo	Wallkill River Watershed Alliance member	Manager	
Matt Decker	Orange County Land Trust	Manager	
Joseph M. DeStefano	City of Middeltown Mayor	Manager	
Adam Doan	Executive Directory of Ulster Soil & Water Conservation District	Manager	
Brian Duffy	DEC Monitoring	Manager	
Brent Gosh	Ulster County CCE watershed educator - Ashokan Watershed	Manager	
Melinda Herzog	Cornell Cooperative Extension of Ulster County	Manager	
Sarah Hoskinson	Catskill Stream Buffer Initiative	Manager	Received
Tim Koch	Ulster County CCE stream educator - Ashokan Watershed	Manager	Received
Amanda LaValle	Ulster County Dept of Environment	Manager	
Jeff Mapes	Acting Coordinator of Trees for Tribs	Manager	
Kelly Morris	Orange County Water Authority / Orange County Planning	Manager	
Archie Morris	Wallkill River Watershed Alliance member	Manager	Received
Erik Schellenberg	CCE Orange County Commercial Horticulture & Natural Resources Educator	Manager	
Dan Shapley	Riverkeeper	Manager	
Kyle Sitzman	Wallkill River Watershed Alliance	Manager	Received
Angela Sisson	Shawangunk-Gardiner habitat map	Manager	
Kevin Sumner	Orange County Soil and Water Conservation District	Manager	Received

Jacob Tawil	City of Middletown Commissioner of Public Works	Manager	
Bobby Taylor	Coordinator of Catskills Stream Buffer Initiative	Manager	
Emily Vail	Hudson River Watershed Alliance	Manager	

Table 3. Contact name, affiliation and category of Indigenous Nation who were sent letters requesting consultation on development of stewardship outreach materials for the Wallkill River basin, NY. The response of Received indicates they sent or arranged for feedback to questions.

Name	**Affiliation**	**Category**	**Response**
Nathan Allison	Stockbridge-Munsee Community, Historic Preservation, Band of Mohican Indians	Nation	
Director David Arquette	Mohawk Nation Council of Chiefs, Haudenosaunee Environmental Task Force	Nation	
Chief Abram Benedict	Mohawk Council of Akwesasne	Nation	Received
Chief Chester Brooks	Delaware Tribe of Indians	Nation	
Chief Beverly Cook	Saint Regis Mohawk Tribe	Nation	
Tony David	Saint Regis Mohawk Tribe, Environment Division	Nation	
President Deborah Dotson	Delaware Nation	Nation	
President Shannon Holsey	Stockbridge-Munsee Community, Band of Mohican Indians, President	Nation	
Erin Paden	Delaware Nation, Director Historic Preservation	Nation	

Table 4a. Responses to question, Why do you value or not value the Wallkill River waters and the riverside forests?

Count	Response
1	I value the Wallkill River waters and riverside forests for their role in providing healthy ecosystems, water quality, flood control, recreation, and species conservation.
2	I value the Wallkill River waters and riverside forests for their sacredness. I value these resources for providing spiritual and emotional replenishment.
3	I value the Wallkill River waters and riverside forests for the aesthetic beauty they bring, with pleasant sounds and reflection of light, and the comfort I get from seeing vegetation.
4	I value the Wallkill River riverside forests for the shade they provide which makes it comfortable to visit the river and creates a thermal refuge in sections of the river where temperature-sensitive organisms find habitat.
5	I value rivers in general for their presence in many positive experiences in my life.
6	I do not value the polluted condition of the Wallkill River, which the Wallkill River Watershed Alliance has reported the water is heavily polluted by bacteria, overloaded by nutrients, and incredibly abused by garbage and tires.
7	I do not value the Wallkill River being one of the most polluted tributaries of the Hudson River Estuary, particularly given how many local residents spend time considering this resource.
8	I value the Wallkill River waters and riverside forests for geese, herons, egrets, eagles and other wildlife, the mamals and other species filling with life the wooded shores, the fishermen pulling bass and other fish out of the river, those choosing to kayak or canoe the long navigable sections, the hydroelectric power gained from its flow, and how it all enhances this community.

Table 4b. Responses to question, What reasons would you want or not want riverside forests in the watershed?

Count	Response
1	I want river side forests for the reasons that I value the Wallkill River waters and forests.
2	I want riverside forests because they are an integral way to protect water quality and ecological integrity.
3	I want riverside forests to trap pollutants (such as excess nutrients) that would go into the water, and to absorb CO2, produce oxygen and reduce problems from stormwater runoff.
4	I want riverside forests to provide bank stability, clean water, recreation, and scenic beauty.
5	I want riverside forests to encourage a change of attitude toward the Wallkill River, from treating it as a polluted site to treating it with appreciation for its healthy waters and trees.
6	I want riverside forests to filter polluted runoff, reduce bank erosion and maintain stable stream channels, provide unique habitat for aquatic and riparian species, and for offering local sites where people can comfortably spend time near the river

Table 4c. Responses to question, How have you seen or heard of any of these four sites benefiting your community?

Count	Response
1	Yes, through DEC emails about Trees for Tribs benefits.
2	Yes, and so has the Middletown Highway Department when a planting was advertised, and that led to their understanding the importance of vegetation and the curtailment of mowing riparian vegetation.
3	Yes, and others have heard through volunteers involved in plantings who went out as stewards for sustainability and told others.
4	Yes, and I am concerned the Benedict Farms Park site is suffering due to land use mismanagement by neighboring land owners and Town of Montgomery projects.
5	Yes, three years ago at the Wallkill Valley Federal Savings and Loan site I helped plant trees on a barren bank to reduce channel erosion, and now I occasionally spend time there clearing weeds from around the trees; it seems 75 to 80% of the trees have survived, and it remains to be seen if they reduce erosion

Table 4d. Responses to question, Can you share personal stories, reflections, or cultural teachings related to the Wallkill River waters and riverside forests? This could include or not include any of the four sites in our maps.

Count	Response
1	Trees for Tribs has been exciting way to engage in watershed and make a difference.
2	Sadly, on a field trip to a safe (not harmfully polluted) section of Wallkill River to collect water samples, the teacher wrongly told students not to put their hand in the water because the pollution would harm them.
3	Fortunately, a flood mitigation project in a meadow required tree planting to address conservation needs for an endangered bat, which resulted in the community learning the trees brought multiple benefits while not constraining flood conveyance.
4	A few years back I asked my town officials to participate with Trees for Tribs, but they declined, and I am happy to see on the map that the town did participate.
5	I became involved with the Wallkill River Task Force and later the Wallkill River Watershed Alliance when I moved to the area, and then became involved with Trees for Tribs and have continued this for more than 10 years.
6	I have enjoyed recreation on the Wallkill River with my family, separate from the four sites included with the maps.
7	I had wanted to fish and enjoy the Wallkill River waters, but found pollution and am incensed by the degree of neglect for the Wallkill River basin waters and riverside forests.
8	I have paddled the Wallkill River in efforts to remove trash, and while our group has removed >150 tires, we have had to leave > 300 submerged tires, and some of these are restricting riparian tree growth.
9	I believe that all of us living in this community feel the Wallkill River waters and riverside forests are a part of who we are and that we are willing to advocate for its conservation to make it clean again and to preserve the natural beauty it offers.

Table 4e. Responses to question, From your experience or from what you have heard, what outreach materials have and have not worked to affect the behavioral change needed to improve the watershed?

Count	Response
1	Press about poor water quality can motivate actions by people and government.
2	Two publications that generated positive feedback were: 1) Life at the Water's Edge (Lower Hudson Coalition of Conservation Districts); and 2) Stream Processes – A Guide to Living in Harmony with Streams (Chemung County Soil and Water Conservation District).
3	Word of mouth advice from conservation experts about the importance of riverside forests and vulnerability of water quality has guided our engagement in local riparian plantings, joining the Trees for Tribs events.
4	Involving Boy Scouts and family groups in plantings has worked to get trees planted and spread the word through their connections.
5	Having visual access to a planting, and then visiting and seeing the health status of a prior planting is motivating, and encourages the investment in caring for those trees and planting new trees.
6	Outreach programs advertising financial and technical assistance get attention and responses of interest in joining the program.
7	Lawn sign programs in the Housatonic watershed have been successful, where landowners receive a lawn sign to advertise what they have done for conservation.
8	The Trees for Tribs sites should be more visible and accessible so people are aware of the plantings and can then support their maintenance and new plantings.
9	In-person and on-site programming that attracts citizens will build a sense of place and a connection that has a beneficial and lasting impact. draw people to events
10	Providing people who participate in riverside plantings with unique tokens or items they can use helps generate engagement.
11	Riverside forests seem to be protected by designation of wild and scenic river for the Shawangun Kill, tributary to the Wallkill River, while in the Town of Shawangunk on the banks of the Wallkill River a new landowner cut down all the trees and shrubs along his section of the bank, destroying wildlife habitat and scenic beauty.

Table 4f. Responses to question, If you could disseminate new content through outreach, what methods would you use or avoid?

Count	Response
1	Have a publication write a story about the Trees for Tribs program rather than sending out flyers.
2	Social media posts (photos, videos) featuring local citizens planting trees (as news or as fun) can have significant dissemination across and into the community via sharing, bringing a positive image of conservation.
3	Door hangings might be a method to ensure that people see the content, rather than a letter that they may dispose of before reading
4	Short, educational and/or inspirational videos seem to be the most effective method of outreach, and this even works with the constraints of social-distancing measures during a pandemic.

Table 4f. Responses to question, Are you familiar with the Statewide Riparian Opportunities Assessment Tool, aka Trees for Tribs Prioritization Tool, and if so, what improvements might make the Tool inform the decisions to improve the watershed?

Count	Response
1	Outreach to land owners would be useful, rather than depending on people to apply.
2	One idea for this tool is to ensure it can prioritize riparian areas at several scales, at the state-wide scale to prioritize resources across watersheds, to the within-town scale so municipalities can incorporate it into their conservation planning
3	Not enough to make suggestions for improvements.

Modeling and GIS notes

Methods for i-Tree Buffer tool

The i-Tree Buffer model was run using a set of raster data containing elevation, land cover, soil information, as well as look-up tables containing nutrient data. In consultation with the project collaborators, the choice was made to run the i-Tree Buffer model with the National Hydrography Database (NHD) Plus Version 2, a 30 m spatial resolution dataset that has forced elevation flow direction data to align with maps of receiving waters. This choice was made to use the most accurate publicly available flow path raster data in order to have the best chance of representing actual interactions between nutrient runoff and buffers. The more advanced NHDPlus High Resolution data, which are at 10 m, were not available for the mid-Atlantic region which contains the Wallkill River basin[1].

This project was the first in which i-Tree Buffer was run using the NHDPlus flow directions and ensure the flow direction files, typically derived from elevation data, align with the national hydrography maps. The NHDPlus data use the NAD 83 Albers projection, and this determined the projection used for i-Tree Buffer, which traditionally had used UTM projection. Converting NHDPlus data to UTM projection shifts the raster grid alignment and breaks the flow direction raster map, disrupt the flow paths networks needed for simulating the transport of nutrients from field to receiving waters. While the project used NHDPlus elevation data in addition to the flow direction data, the elevation data would not generate the hydrography corrected flow direction maps. The NHDPlus elevation data were only used for computing slopes, not for routing runoff.

The NHDPlus elevation data, and associated riverine flowpaths and lakes, were obtained for NHDPlusV2 Mid-Atlantic 02b[2], from which the files of NHDSnapshot for Hydrography[3], with NHDFlowline, NHDWaterbody, the NEDSnapshot for DEM[4] for slope and Flow Direction[5] data were obtained. These data are described in the NHDPlusV2 user guide[6]. In addition, the i-Tree Buffer model used 2016 National Land Cover Data (NLCD), gridded soil survey data (SSURGO), and as described by Stephan and Endreny [2016] tables of export coefficients for the NLCD cover types, specific to the 8-digit HUC from White et al. [2015].

To obtain the Wallkill River basin boundary polygon area, the US Geological Survey (USGS) Streamstats tool was used for watershed delineation, making the outlet where the Wallkill River enters Roundout Creek at 41.854 ° latitude and -74.050 ° longitude. The Streamstats delineation uses the NHD flow direction standards forcing the elevation derived watershed boundary to comply with the national hydrography. With this boundary polygon file, the raster data were processed. The data preparation required to run i-Tree Buffer model are presented below in outline form. In the cases when a Python script was used for data preparation, it is noted and the script is named.

1. Prepare NHD data
    a. Use NHD Flow Accumulation (fac) within StreamStats watershed for Wallkill River HUC 02020007 to find pour point at outlet confluence.
        i. In directory: C:\data\gis\nhdplusv2\NHDPlusMA2b
        ii. Remaining in native projection of NAD_83_Albers.
    b. Use ArcMap to create new shapefile point layer and edit to add a point at the pour point called prpt_wk_albers.shp.
    c. Use ArcMap p_wri_a01_WallkillRiver_wshd.py watershed command with NHD Flow Direction (fdr) and prpt_wk_albers.shp to create wk_albers.tif watershed

[1] https://www.usgs.gov/core-science-systems/ngp/national-hydrography/nhdplus-high-resolution#WhereAvailable
[2] https://www.epa.gov/waterdata/nhdplus-mid-atlantic-data-vector-processing-unit-02
[3] NHDPlusV21_MA_02_NHDSnapshot_04.7z
[4] NEDPlusV21_MA_02_02b_NEDSnapshot_01.7z
[5] NHDPlusV21_MA_02_02b_FdrFac_01.7z
[6] https://s3.amazonaws.com/edap-nhdplus/NHDPlusV21/Documentation/NHDPlusV2_User_Guide.pdf

i. In directory: C:\iTree\BufferF_git\basin_grids_albers.

d. Use ArcMap p_wri_a02_raster2polygonWallkillRiver.py with maintain edges to convert wk_albers.tif to wk_albers.shp watershed.
e. Use ArcMap p_wri_a03_clip_rasterFDRDEM.py raster clip command with wk_albers.shp to clip fdr and NHD NEDSnapshot (elev_cm) to watershed (fdr_wk.tif, elev_cm_wk.tif), clip to geometry and maintain extent.
f. Use ArcMap p_wri_a04_multiplyDEM.py to convert NHD NEDSnapshot from cm to m.
g. Use ArcMap p_wri_a05_reclassFDR.py to reassign NHD Flow Direction to reverse directions as alternative to negated DEM in Buffer.py.
h. Use ArcMap to project the NHDFlowline and NHDWaterbody data to Albers from WGS

2. Create single raster of NHDFlowline and NHDWaterbody data that is projected to full extent of watershed:
   a. Use ArcMap p_wri_a06_buffer_whsd.py to create wk_albers_buf.shp from wk_albers.shp at 180 m buffer width. This step is likely optional.
   b. Use ArcMap to p_wri_a07_clip_polyNHD.py clip to wk_albers_buf.shp the NHDFlowline and NHDWaterbody and create output wk_flowln.shp and wk_waterbd.shp that extend beyond the basin to ensure when it is converted to grid it has extent that can be clipped by basin. This step is likely optional.
   c. Use ArcMap p_wri_a08_polyNHD2raster.py to convert from polyline to raster for wk_flowln.shp to wk_flowln.tif and polygon to raster for wk_waterbd.shp to wk_waterbd.tif. This generates raster map of receiving waters for intercepting runoff.
      i. Set workspace and extent environments to flow direction raster arcpy.env.extent = C:/iTree/BufferF_git/basin_grids_albers/wk_fdr.tif
      ii. Set Snap Raster environment arcpy.env.snapRaster = wk_fdr.tif
      iii. For Polylines: value_field = "GNIS_NBR", cell_assignment = "MAXIMUM_COMBINED_LENGTH", priority_field = "COMID", and cellsize = "30"
      iv. For Polygons: value_field = "FID", cell_assignment = "CELL_CENTER", priority_field = "NONE", and cellsize = "30"
   d. Use ArcMap p_wri_a09_reclassNHD.py to reclassify wk_flowln.tif from 0 to 1 in wk_flowln1.tif and wk_waterbd.tif from 202 to 1 in wk_waterbd1.tif
   e. Use ArcMap p_wri_a10_clipBufOut_rasterNHD.py to clip wk_flowln1.tif and wk_waterbd1.tif from wk_buf_albers.shp extent to wk_albers.shp, create wk_flowln1wk.tif and wk_waterbd1wk.tif.
   f. Use ArcMap p_wri_a11_ConIsnull_NHD.py to conditionally Isnull convert NoData to 0 for wk_flowln1.tif and wk_waterbd1.tif and create wk_flowln01.tif and wk_waterbd01.tif.
   g. Use ArcMap p_wri_a12_plus_add2NHD.py to combine wk_flowln01.tif and wk_waterbd01.tif and create wk_waters01_0s.tif
   h. Use ArcMap p_wri_a13_clipZero_rasterNHD.py with wk_waters01_0s.tif and wk_albers.shp to clip all 0s from beyond watershed boundary.
3. Collect NHD processed data output as input to Buffer.py from directory 'C:/iTree/BufferF_git/basin_grids_albers/
   a. wk_elev_m.tif
   b. wk_fdr.tif
   c. wk_fdr_r.tif
   d. wk_waters01.tif'
4. Use Buffer.py with the delineated watershed, wk_albers.shp in the basin_shapefiles directory with the HUC ID number within the file name, as in wkbuf_02020007.shp, to clip the NLCD and SSURGO data using iPrepInputs = 1 flag.
   a. SSURGO attributes called ksat_r, ksat_h, ksat_l, hzdepb_r, hzthk_r, wtdepannmin
   b. Run with large constants folder that contains NLCD and SSURGO data, D:\wHD\itree\Buffer_git

5. Collect the following outputs from above Buffer.py run, and then use as input to Buffer.py from directory 'C:/iTree/BufferF_git/basin_grids_albers/:
    a. Outputs: Basin.shp; nlcd; ic; s_depth_est; s_ksat_est; s_ksath_est; s_ksatl_est; s_thick_est; s_wtable_est

With the above data, the i-Tree Buffer model was run a 1st time with the Buffer.py script and the flags iHaveData = 0, iPrepInputs = 1, iSSURGO = 1 and iNLCD = 1 (it is not important which, but one of the flags iDEM or iNHD = 1). These options read the SSURGO and NLCD data from the constants folder, to clip them to the watershed extent. The constants folder contains locally the default databases needed the i-Tree Buffer model. The DEM or NHD data are needed to generate data for flow direction, flow accumulation, slope, and compute topographic indices. In the subsequent model run, NHD data will be read in directly for those computations. This 1st run requires that a watershed polygon file wk_albers.shp in the basin_shapefiles directory, with the HUC ID number embedded within the shapefile name, as in wkbuf_02020007.shp, and the HUC ID number listed in the files basinlist.csv.

The outputs from SSURGO and NLCD processing in the 1st run of i-Tree Buffer were used in the 2nd run and should be stored in the local directory basin_grids_albers. This same directory was used in the above pre-processing steps to store intermediate products. This directory should include: wk_elev_m.tif; wk_fdr.tif; wk_fdr_r.tif; wk_waters01.tif; Basin.shp; nlcd; ic; s_depth_est; s_ksat_est; s_ksath_est; s_ksatl_est; s_thick_est; s_wtable_est.
The i-Tree Buffer model was run a 2nd time with the flags iHaveData = 1, iPrepInputs = 0 to generate the nutrient loading hotspot maps. In the 2nd run, the flags for iDEM, iNHD, iSSURGO, and iNLCD can be set to 1 or 0 due to the condition of iHaveData = 1 causing the code to skip over any decisions with these other flags.

Methods for Riparian Maps

Four riparian vegetative buffer sites were featured in the letters seeking consultation. The team of PI Endreny (ESF) and collaborators Kristen Hychka (NYS WRI) and Beth Roessler (DEC Trees for Tribs) began with thirteen riparian sites within the Wallkill River basin, identified by Roessler as representative of Trees for Tribs projects. These sites ranged from agricultural areas to urban highly developed areas, with parkland and rural developed sites also included. A fourteenth riparian site was included when Kevin Sumner, a colleague of Roessler, recommended the high-profile site off the Middletown Main Street Bridge as a good focus point for potential outreach.

The team then set about identifying sites that should be removed due to issues that may reduce the impact of our messaging, and identifying sites that should be prioritized as exemplary. This process involved an inventory of sites by Roessler that considered: a) the frequency and ease of public access; b) the opinion of planting project colleagues; c) the diversity of plant and associated natural resources. This became an iterative process within the team, with on-site feedback leading to new maps, or with team discussions identifying additional criteria to consider. In the end, the process resulted in four riparian sites of interest, each with a number based on the ordering of the fourteen sites: #6 known located on a site called Gold Mine; #8 located on a site with Bennedict Farm; #12 located on a site with the Wallkill Federal Saving and Loan Bank; and #14 located upstream of the Middletown Main Street Bridge.

The data processing steps for this task involved isolating the riparian sites of interest and their unit drainage areas. Each riparian site had a polygon area delineating the planting zone. The site unit drainage areas were defined by identifying the watershed area that sent flow into the riparian site polygon, using the NHDPlus flow direction to define flow paths. The data preparation completed in this task is presented below in outline form. In the cases when a Python script was used for data preparation, it is noted and the script is named.

1. Create upstream and downstream pour points along the channel where it is bounding each riparian site of interest, using Edit with new feature polypoint.shp,
    a. If a tributary enters the channel, an additional left bank or right bank site can be assigned, for example, creating prpt06d.shp, prpt06u.shp, prpt06lb.shp.
2. Use ArcMap with p_wri_b01_wshd.py to delineate watershed with flow direction, creating
    a. C:/data/gis/nhdplusv2/NHDPlusMA2b/fdr using pour points

   b. C:/data/gis/trees4tribs/walkill/prpt0%s.shp" %id to create watershed
   c. C:/data/gis/trees4tribs/walkill/wk_s_0%s.tif %id as tif output.
3. Use ArcMap with p_wri_b02_raster2polygon.py to convert .tif watershed
   a. "C:/data/gis/trees4tribs/walkill/wk_s_%s.tif" % id to create polygon watershed
   b. "C:/data/gis/trees4tribs/walkill/wk_s_%s.shp" % id.
4. Use ArcMap with p_wri_b03_symdiff.py to find symmetry of the overlapping watersheds
   a. This is implemented after completing above steps for upstream and downstream pourpoints and watersheds along the riparian site of interest.
   b. Take the difference between the larger and smaller watershed areas and extract only the watershed draining to the section of riparian site
   c. In cases when the site of interest had an additional tributary or the NHDPlus suggested drainage areas different from expert knowledge, additional clipping was performed to reduce the drainage area to the known extent.
5. Use ArcMap to remove from riparian sites of interest the opposite bank drainage area if vegetation planting had not included that bank. This process involved:
   a. Select the river polyline segments passing through buffer wk_flowln
   b. Edit > Advanced Edit > Split Polygon > Save and now polygon has line dividing it
   c. Edit > Edit Vertices > Select selection on bank with no vegetative filters > Delete > Save
   d. Edit Vertices > Right Click for Edit Vertices > Select to activate vertices > Right Click to Delete > Save.

Once all four buffers were processed, they were renamed to count from 1 to 4, and stored as wk_s_##_vf.shp, where ## indicates the number.