Quote for Mapping Wetland Restoration and Preservation Targets in Pennsylvania Using a Geospatial Modeling Approach

Prepared by:
The Upper Susquehanna Coalition

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Brief budget justification and background:

Budgeting includes salary support for Upper Susquehanna Coalition (USC) Staff to compile data necessary to model and prioritize wetland restoration and preservation opportunities in Pennsylvania and portions of the Chesapeake Bay Drainage. USC is a collection of Soil and Water Conservation Districts 16 in NY and 3 in Pennsylvania organized under a memorandum of understanding to work toward improving natural resources and water quality in New York and Pennsylvania. The coalition has its own specialized GIS databases for wetland resources, in house support to model the distribution of wetland restoration opportunities, rare and underrepresented wetland types (both extant and restorable), and prior experience setting regional level wetland restoration and preservation priorities. USC developed the capacity to identify and set regional wetland restoration priorities under a joint partnership with research scientists at SUNY-ESF under an EPA Wetland Program Development Grant. In 2015 USC's wetland team earned the EPA's highest honor for their work preserving and restoring wetland resources – Environmental Champion.

We provide a quote for mapping wetland restoration and preservation targets with varying levels of detail and for different geographic areas - running sequentially from more basic toward more detailed targeting for sequentially larger areas. All approaches require base data processing, and assembly of relevant GIS layers (e.g., slope, elevation, soils), coding.

Explanation of components included in a wetland resource mapping and prioritization approach:

A) Compiling base data layers (e.g., slope, soils, elevation), compiling wetland training sites for model run(s), coding and running of models (drained wetlands, rare wetland communities)

B) Performing QA/QC on model results

C) Converting predicted wetland results from 0-1 scale into mapped habitat – setting a threshold for suitable habitat

D) Processing to combine wetland "coverages" to produce wetland polygons – existing and restorable wetlands.

E) Validation of predicted areas using high-resolution aerial imagery, and rates of omission, commission for known sites.

F) Prioritization of Wetland Resources

    a. Commonly focus on area metrics, rarity of wetland types, proximity of wetland restoration opportunities to existing wetland complexes, etc

G) Validation of Prioritization Measures Using Known reference sites

Wetland Conservation Targeting Budget by Geographic Focal Region

Focal Region	**Square Miles**	**Phase I:** Mapping high restoration potential wetlands	**Phase II:** Mapping rare wetland types and restoration opportunities	**Phase III:** Prioritization of Phase II	**Total all phases**
Chesapeake Drainage - PA portion	22526	$20,000	$6,000	$25,000	**$51,000**
Pennsylvania - Whole	45406	$40,000	$12,000	$50,000	**$102,000**
Chesapeake Drainage - All	68784	$60,000	$18,000	$75,000	**$153,000**
Chesapeake Drainage & Pennsylvania - Whole	91577	$80,000	$24,000	$100,000	**$204,000**

Sample Budget for the Pennsylvania Portion of the Chesapeake Bay Drainage

	Budget item	**Subtotal**
Phase I	A) Compiling base data layers (e.g., slope, elevation, soils, wetland training sites). 8 weeks @ $50/hr	$16,000
	B) Model high restoration potential & add to NWI, perform QA/QC. 2 weeks @ 50/hr	$4,000
Phase II	C) Model rare wetland types and restoration potential & add to NWI, perform QA/QC. 3 weeks @ 50/hr	$6,000
Phase III	D) Prioritize wetland restoration and protection targets from Phase II, perform QA/QC. 12.5 weeks @ 50$/hr	$25,000
	Total	**$51,000**

**Phase II prices are based on data layers already being prepared in Phase I; Phase III requires Phase I & II to be completed.*

Appendix A: Showing a Phase III Assessment performed by Upper Susquehanna Coalition Staff for The Wetland Trust in New York State.

Reproduced with permission from The Wetland Trust's: Susquehanna Basin Headwater and Adjacent Basins In-Lieu Fee Program Instrument, Developed Under Part 332.8, Federal Register Volume 73, Number 70.

"Computer modeling protocols for site selection in the Susquehanna Basin Headwaters and Adjacent Basins"

A) Executive Summary:

We have implemented a comprehensive site selection protocol that remotely identifies and sets wetland mitigation priorities within the Susquehanna Basin Headwaters and Adjacent Basins. A more technical account of our mitigation site identification tools and their performance was published in the peer-reviewed Journal *Wetlands* as described in Hunter et al. (2012). Here we provide an overview of the methodology, but encourage readers interested in reviewing a detailed assessment of the procedure's performance to review Hunter et al. (2012). These tools help find sites in areas with the best potential to support high quality wetlands for establishment, reestablishment, rehabilitation, enhancement, and/or preservation. They complement and focus the more informative field assessments on the best potential mitigation sites, thus improving their quality compared to those found in the more traditional approaches.

Our site selection approach has three main components:

1) identify and map wetland occurrences and community types (extant and previously impacted) using geo-statistical modeling and available data describing wetland locations;
2) augment databases from step 1 with other available datasets describing wetland quality (e.g., presence of rare and endangered species and communities, site assessments); and
3) rank wetlands (extant and drained) from step 2 according to the best available information related to wetland quality and function.

Using extensive validation measures, our approach outperforms existing computer selection methods for detection of areas suitable for mitigation, and does so for all ILF Program service areas. This approach identifies biologically rare communities (e.g., inland salt marsh, bogs, poor, medium, rich, and marl fens) that either provide, or could provide refuge for rare and underrepresented species – an endeavor that furthers organizational objectives for many governmental agencies in our focal region (e.g., US Fish and Wildlife, NYS-Dept. of Environmental Conservation). In the following sections, we describe the general methods utilized for the modeling procedure, and provide an overview of the "patch" ranking system for targeting restoration and protection of large landscapes containing rare communities with high capacity to support biodiversity. Using the procedures described below to develop this database, we will target the top 20% highest ranked priorities in the Susquehanna Basin Headwaters and

Adjacent Basins for establishment, reestablishment, rehabilitation, enhancement and/or preservation. The overall goal of this approach is to: identify priority locations for wetland restoration activities that improve watershed functioning, habitat connectivity, and biodiversity value. ***We note that this ranking system was explicitly designed to be flexible and to meet watershed specific functional and biological needs. The approach may be updated over time as better site-level information becomes available, or altered with different criteria better meet certain objectives.***

B) The need for improved site selection protocol

Compensatory mitigation frameworks many times lack the scientific rigor required to develop biologically sound watershed-level restoration plans required to identify mitigation priorities. Particularly the identification of focal areas for mitigation has been haphazard, often relying on a combination of parcels that are for sale at the time of mitigation need and an ensuing review of soils maps and aerial photographs. This approach fails to identify and prioritize mitigation projects that maximize hydrological functionality and biodiversity conservation because it does not consider the entire watershed. To overcome these limitations, we collaborated with researchers at SUNY-ESF, to implement an improved site selection protocol that remotely identifies and sets comprehensive wetland mitigation priorities within many basins in New York and northern Pennsylvania.

C) Model Development and Validation

We used GIS layers in the program Maxent (maximum-entropy modeling) to systematically identify features of interest (previously drained wetland areas and rare community types) for protection and restoration efforts. It was chosen due to its superior prediction capabilities compared to other approaches (Elith et al. 2006). We used seven background environmental variables: elevation, slope, aspect, geology (rock types), topographic wetness index, vegetation height, and soil type to predict locations for features of interest (Table 1). SSURGO soils were reclassified into general soil classes more useful for prediction as described in Hunter et al. (2012) and Raney (2014), provided in Table 2. Together, these variables are used to train the model to find additional "features of interest" such as poorly drained forested wetlands or rare, rich fen wetland communities (Figure 1). Occurrence records to model rare communities were taken from acidic designations in existing National Wetlands Inventory and data from the New York Natural Heritage Program element occurrence database (bogs, poor fens, medium fens, rich fens, marl fens, and inland salt marsh) (NYNHP 2013).

We combined features identified by validated models with known wetland occurrences from NWI to create a comprehensive database of potential mitigation sites, hereafter "patches". Using this database we developed a flexible "patch" ranking system that can be utilized to meet a range of wetland mitigation goals depending on specific needs in a given watershed. This large database can be updated over time as more site-level information becomes available.

Model output produced goodness-of-fit statistics, and models were validated using the correct classification rate for known wetland areas. The rationale for statistical model validation using known wetlands to test model precision and accuracy is as follows: the same underlying

environmental conditions that produced extant wetlands also produced the original wetlands that are now drained (e.g., geology, low slopes, hydric soils), thus as a comprehensive statistical model validation measure, modeled "wet" areas should include extant wetlands (here, National Wetlands Inventory) if the procedure is viable. This type of remote statistical model validation is common in the peer reviewed scientific literature, and allows for more robust "Verification" than would be feasible based on field visitation alone. Dozens of predicted sites have been visited by Upper Susquehanna Coalition staff, and generally conform to wetland areas or impacted wetlands.

For comparison with the Maxent modeling procedure, we also created a *hydric soils, low slope model*, which we called the "*Expert Model*". The expert model was designed to mimic the search procedure wetland planners use to select mitigation sites: *typically planners sift through hydric soils and topographic maps to identify areas with appropriate soils and hydrology for wetland restoration.* Expert model patches were created using areas with low slopes (< 1%) and soils high in organic content (muck, silt loam, and loam), which largely represent designated hydric soils (NRCS 2010) for the area.

Maxent outperformed the expert model in a test using an independent sample of known wetlands, predicting wetland locations with a 91% correct classification rate versus 62% for the expert model. Furthermore, compared to simple aerial photo interpretation, site visitation, and NWI comparison, Maxent could consistently and clearly locate quality sites. We demonstrate this ability for mitigation site selection in Figures 2A, B, C, and D. Furthermore, this procedure allowed us to perform a thorough analysis of our ILF Program region.

Table 1 Source of environmental variables used in Maxent analyses. All datum units were converted to UTM. (Table reproduced with Permission from Raney 2014).

Variable	Source	Scale or Resolution	Original Datum	Original Units
Elevation (DEM)	National Elevation Dataset (Gesch 2007)	30 m^2	NAD 83	Meters
Slope	Calculated from DEM in ArcGIS	30 m^2	NAD 83	Percent
Bedrock Types	USGS (Nicholson et al. 2006, updated from Fisher 1970)	1:2,500,000	WGS 84	Categorical
Aspect	Calculated from DEM in ArcGIS	30 m^2	NAD 83	Degrees
Vegetation Height	National Biomass and Carbon Dataset for the Year 2000 (Kellendorfer et al. 2004)	30 m^2	NAD 83	Meters
Soils	SSURGO (NRCS 2010)	Various, typically 1:24,000	NAD 83	Meters
Topographic Wetness Index	Derived following (Beven and Kirkby 1979)	30 m^2	NAD 83	Index

Table 2 Description of soil categories used to model rare wetland community locations and poorly drained areas in the USRB and adjacent watersheds. Each row contains an individual soil classification. Data were reclassified following techniques described by Hunter et al. (2012), and is described in further detail by Raney (2014).

Soil Classes
Alluvial
Boulders
Clay
Cobbly loam
Dam
Gravelly sand & loam
Loams: loam, sandy loam, silty loam
Marl
Marl pits
Marsh
Muck: muck, mucky silt loam, mucky peat
Peat
Poorly drained
Rock outcrop
Salt dumps
Sand beach
Sandy gravelly loam
Silty clay loam, silty clay
Steep
Stony
Rocky loams: Stony silt loam, shaly silt loam, stony loam
Urban: rubble-land, made land, quarries
Water

Acknowledgements: Elizabeth A. Hunter performed the initial model development for the Upper Susquehanna River Basin (USRB) and she contributed Figure 1. Dr. Patrick A. Raney contributed several data layers and modeled the USRB and adjacent watersheds as a single region. We thank Drs. James. P. Gibbs and Donald J. Leopold for their contributions to an earlier portion of this work.

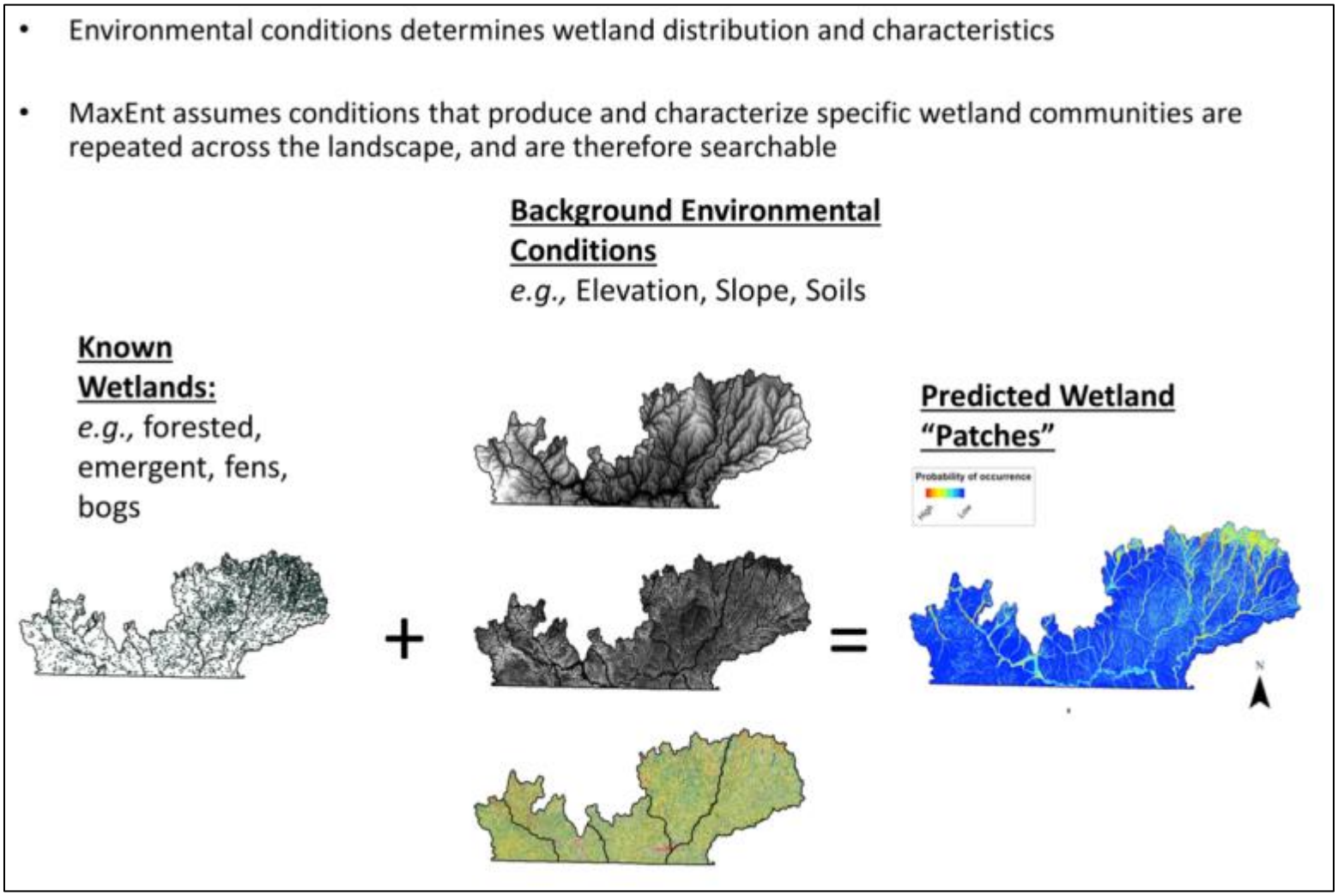


Figure 1: Description of how spatial modeling works when using Maxent, and other models types.

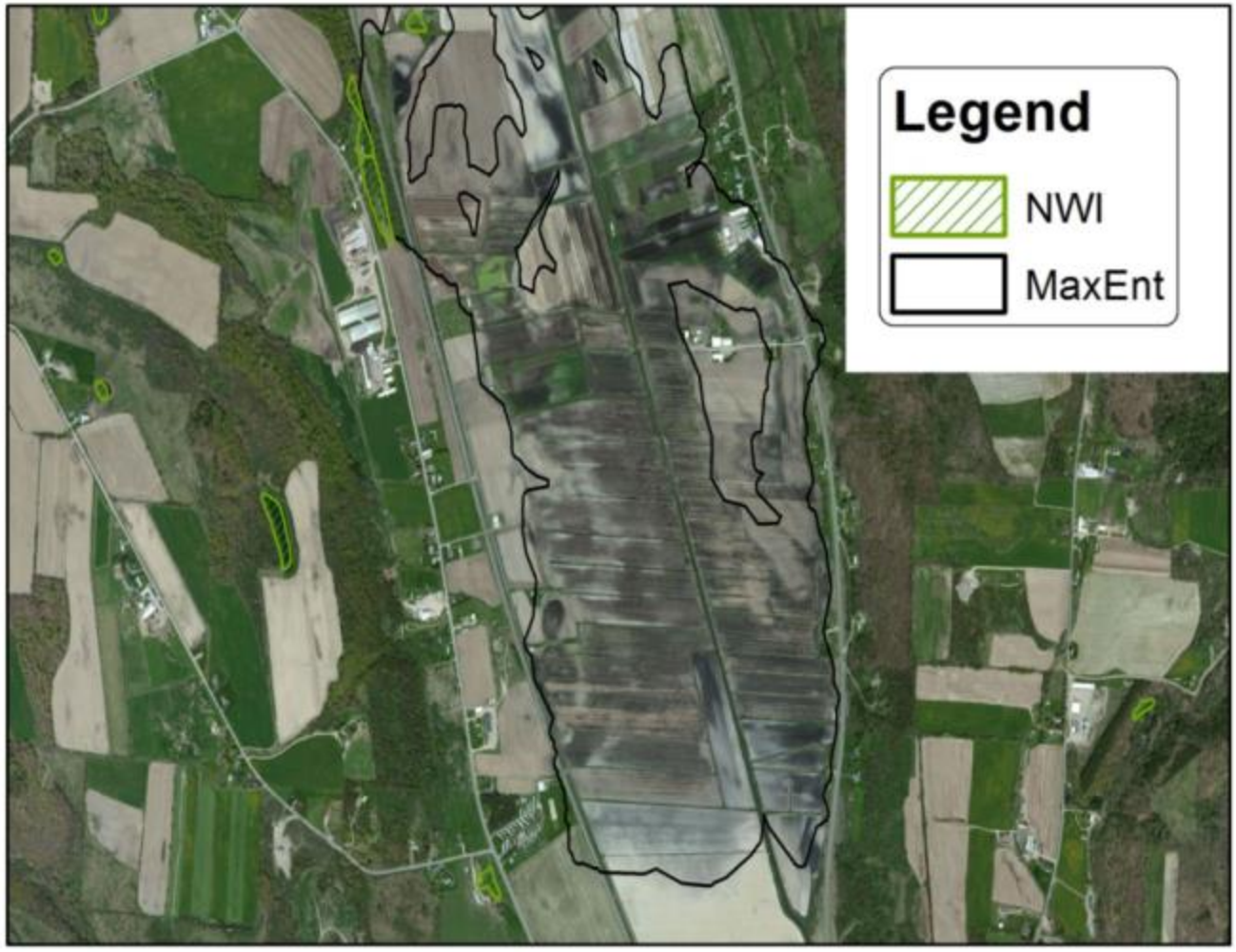


Figure 2-A: Maxent (black outline) clearly identifies more area than NWI (dashed green). Example includes a large drained muckland with visible ditching.

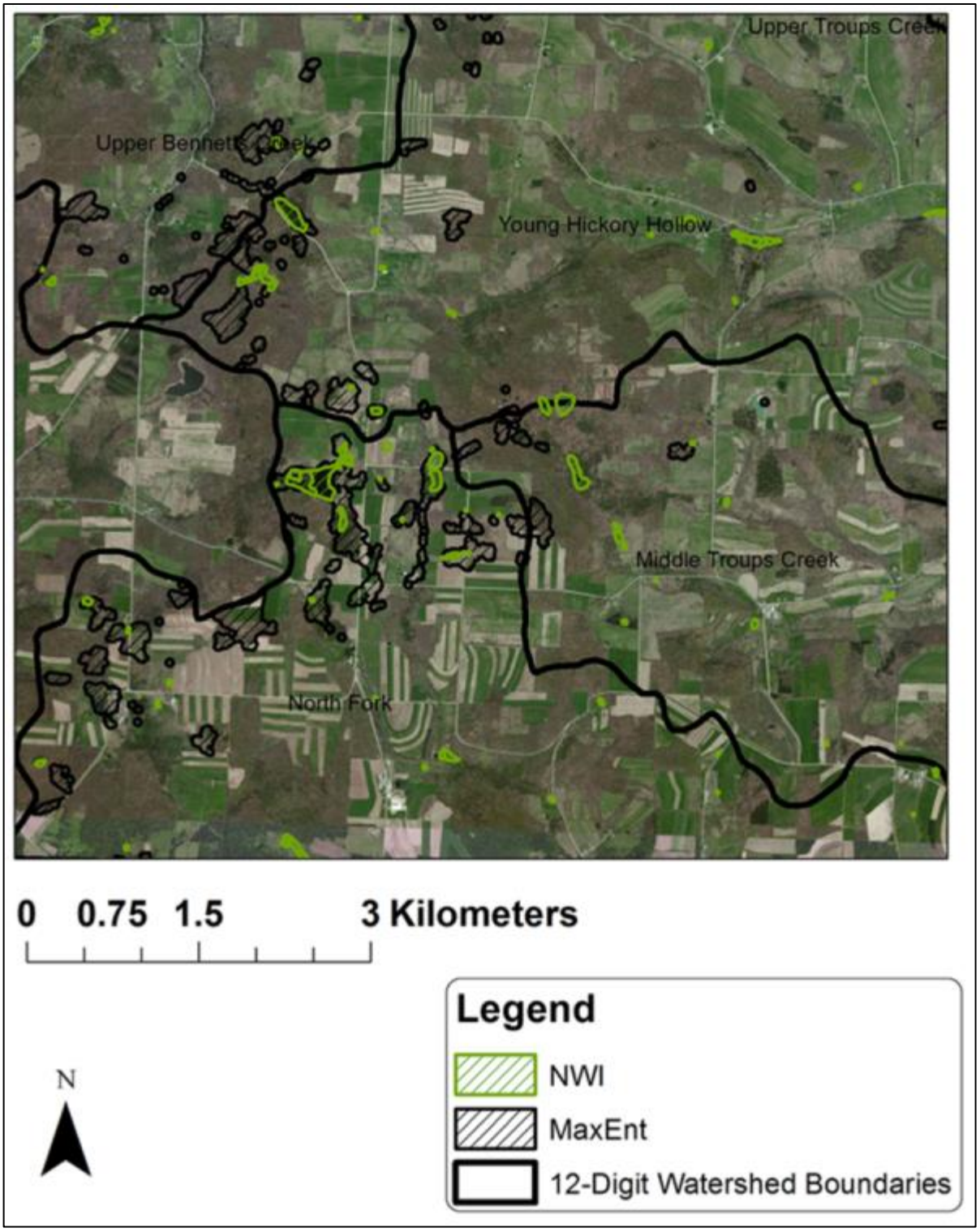


Figure 2-B: Maxent identifies restoration targets in areas lacking many wetlands.

Figure 2-C: Maxent identifies rare communities. Here a medium fen historically supporting rare species is shown.

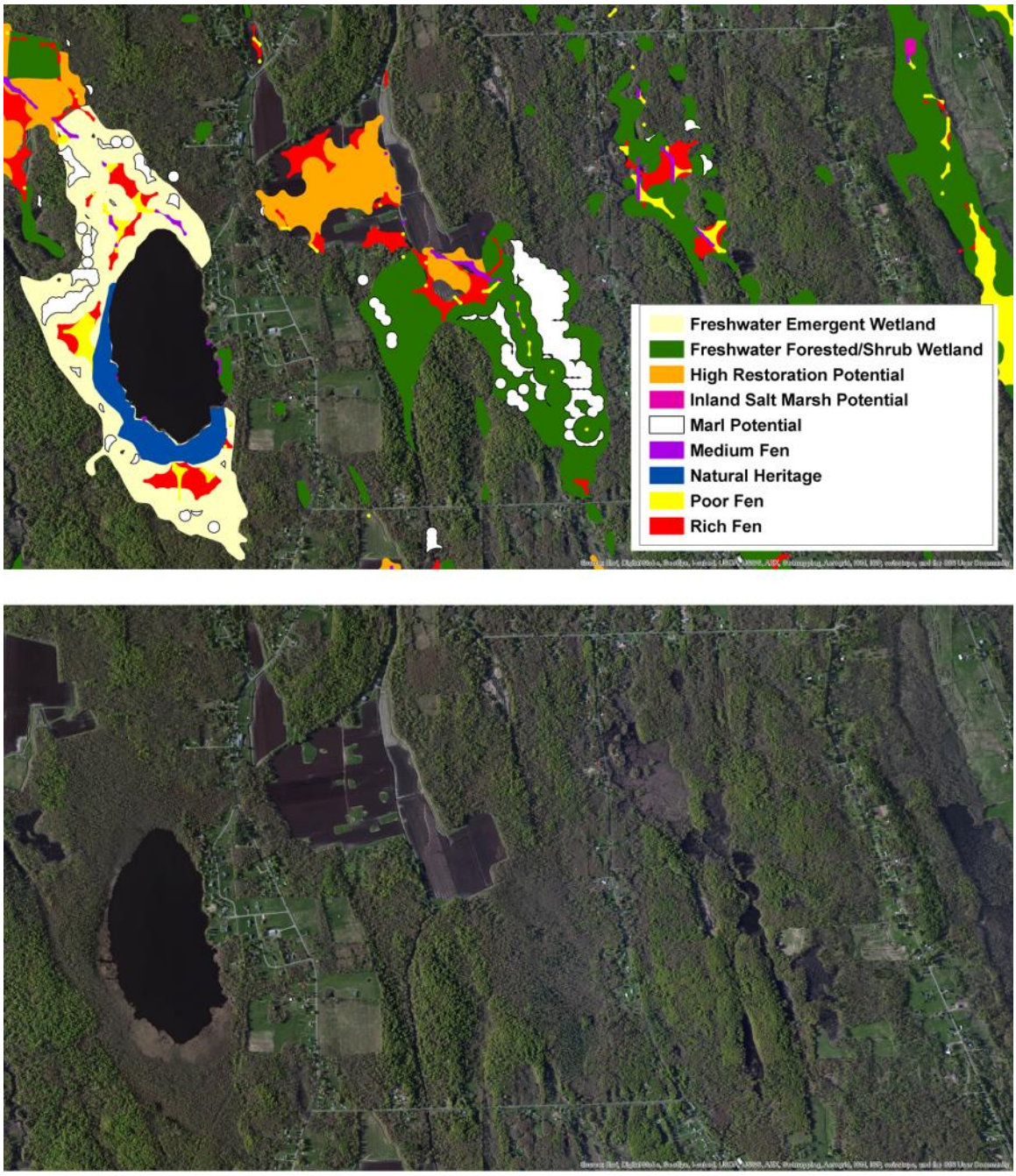


Figure 2-D: Maxent identifies rare communities for protection and adjacent areas suitable for reestablishment, rehabilitation, and enhancement. Here, Silver Lake bog (a medium fen) is shown with nearby mucklands offering excellent reestablishment opportunities. This region has been a previous target for conservation acquisition. Maxent models identified potential for marl and inland salt marsh in this vicinity – two of New York States rarest ecological communities. Areas in orange show locations identified by a model focusing on the identification of human impacted wetlands.

D) Ranking Procedure for Potential Mitigation Sites

For the purpose of prioritizing potential mitigation areas, we combined model outputs with NWI wetland occurrences and Natural Heritage community occurrence records to produce comprehensive coverages of wetland resources for the region. This approach effectively augmented NWI databases with wetland occurrences omitted by NWI, previously drained wetlands, and rare community designations (inland salt marsh, bogs, poor, medium, rich, and marl fens). This approach advantageously allowed for potential mitigation areas to be systematically compared and ranked in terms of potential to support biodiversity and watershed functioning using simple parameters with strong ecological underpinnings.

Our ranking approach is tailored to the varying needs in specific watersheds, and will be modified through time as more information becomes available, or as priorities shift. Below we provide an overview of our patch ranking, which favors a combination of establishment, reestablishment, rehabilitation, enhancement, and/or preservation of large areas with a diversity of wetland communities under a variety of cover types (emergent, scrub-shrub, forested wetlands). These quantitative patch ranking can be tailored to meet project and watershed specific goals and comprehensively identify the best places to work to meet certain objectives.

Patches were ranked according to the following criteria:

- normalized wetland area (A)
- normalized wetland complex area (B)
- designation as significant natural community(C), and
- presence of endangered species (D)

These criteria were chosen due to their direct connection to biodiversity and ecological functioning (e.g., MacArthur and Wilson 1963, Edinger et al. 2002). Variables were normalized and divided by respective maximum values to produce indices on 0-1 scales for summation. Normalization accounted for differences in maximum wetland size by service area. *Rare communities received a *C* value of 0.75 (all other wetlands received 0). The following formula was used for patch ranking:

$$= A+B+C+D/ \text{Max}(A+B+C+D)$$

**As modeling focused on hydrogeologic settings (unique soil conditions) fens in this scheme encompassed a variety of successional stages (from emergent to scrub shrub to forested), therefore not biasing mitigation towards a single successional type. Plant ecologists are increasingly expressing wetland communities in terms of source hydrology, and are less focused on the form of vegetation (forested vs. emergent) thus North American wetlands with mineral rich groundwater discharge are referred to as fens regardless of presence of a tree canopy cover (Bedford and Godwin 2003).*

E) Potential Mitigation Site Ranking Procedure Results

To test the efficacy of the patch based ranking, we calculated the average ranking for all patches, and for the seventy New York Natural Heritage Program wetland occurrences falling within the entire ILF Program region (NYNHP 2013). On a scale of

0 to 1 all patches averaged 0.31 (± 0.30 SD) while Heritage sites were averaged 0.74 (± 0.38 SD), a dramatic difference (Figure 3). Eighty-six percent of the NYNHP sites larger than ten acres in size ranked in the top 20% of sites over the entire ILF Program region, indicating this method possesses the ability to identify biologically important sites, see also (Hunter et al. 2012). Sites in the upper 20% of sites also included those with endangered species, large wetlands >200 acres, rare community types, and related reestablishment opportunities.

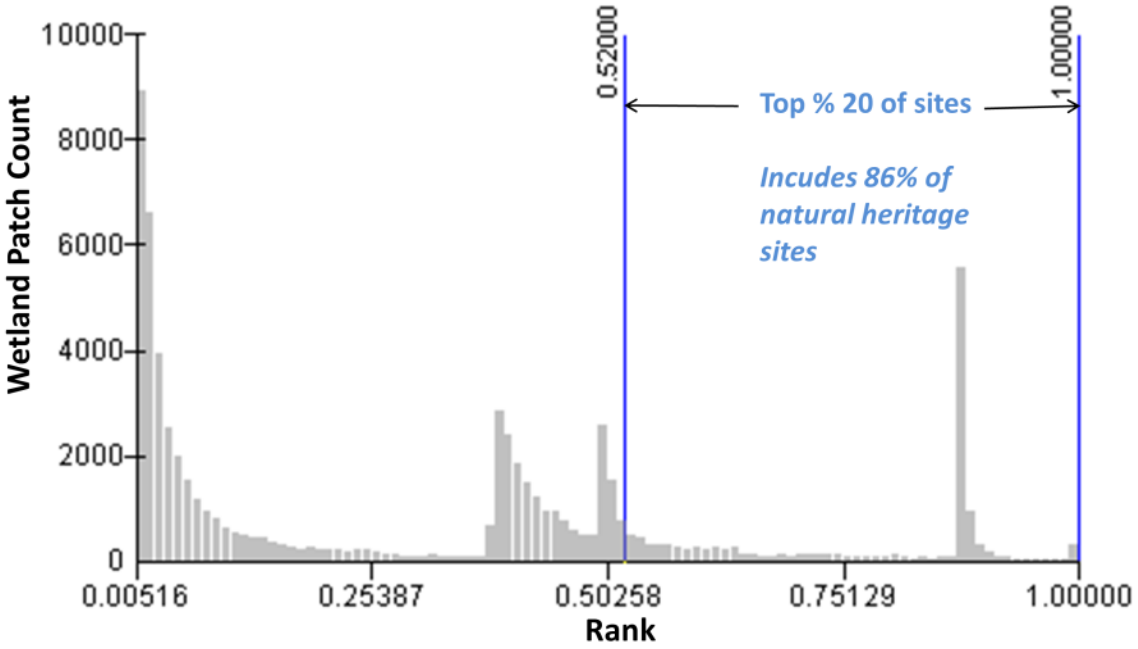
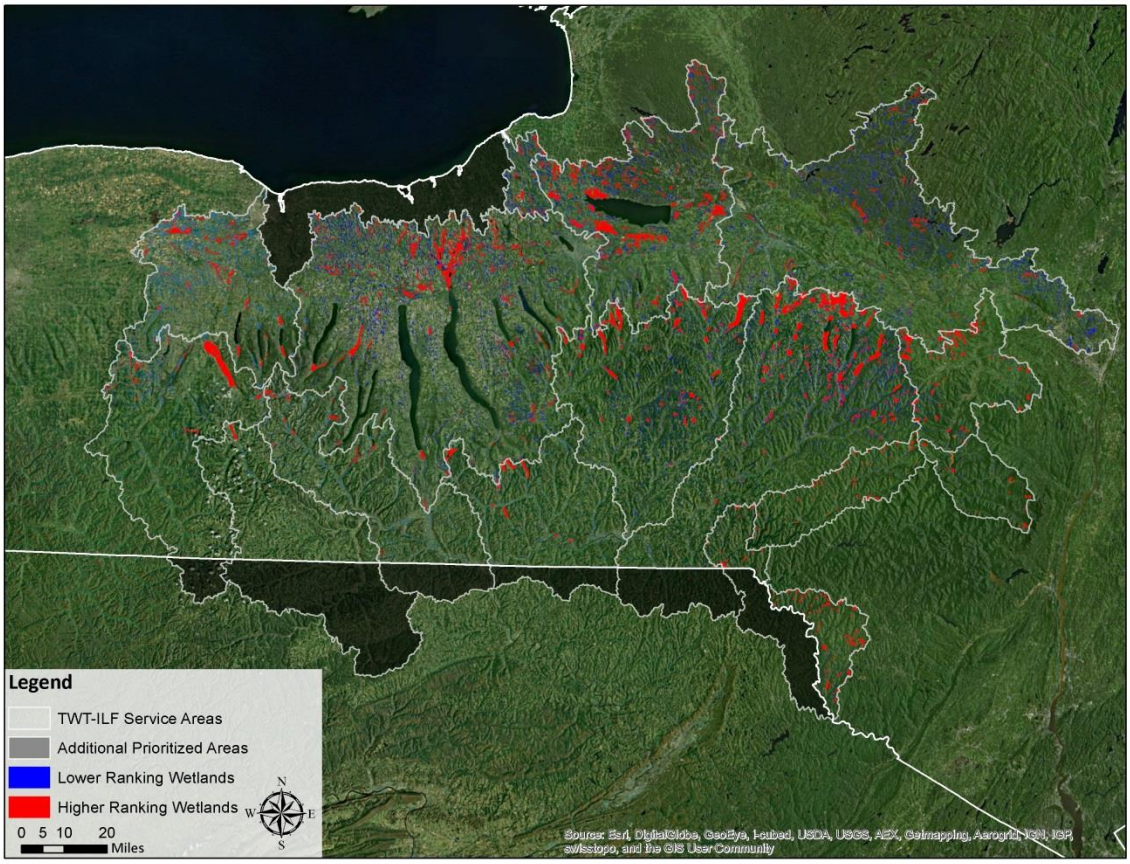


Figure 3: Histogram of patch ranks for the Susquehanna Basin Headwaters and Adjacent Basins (N=68,547).

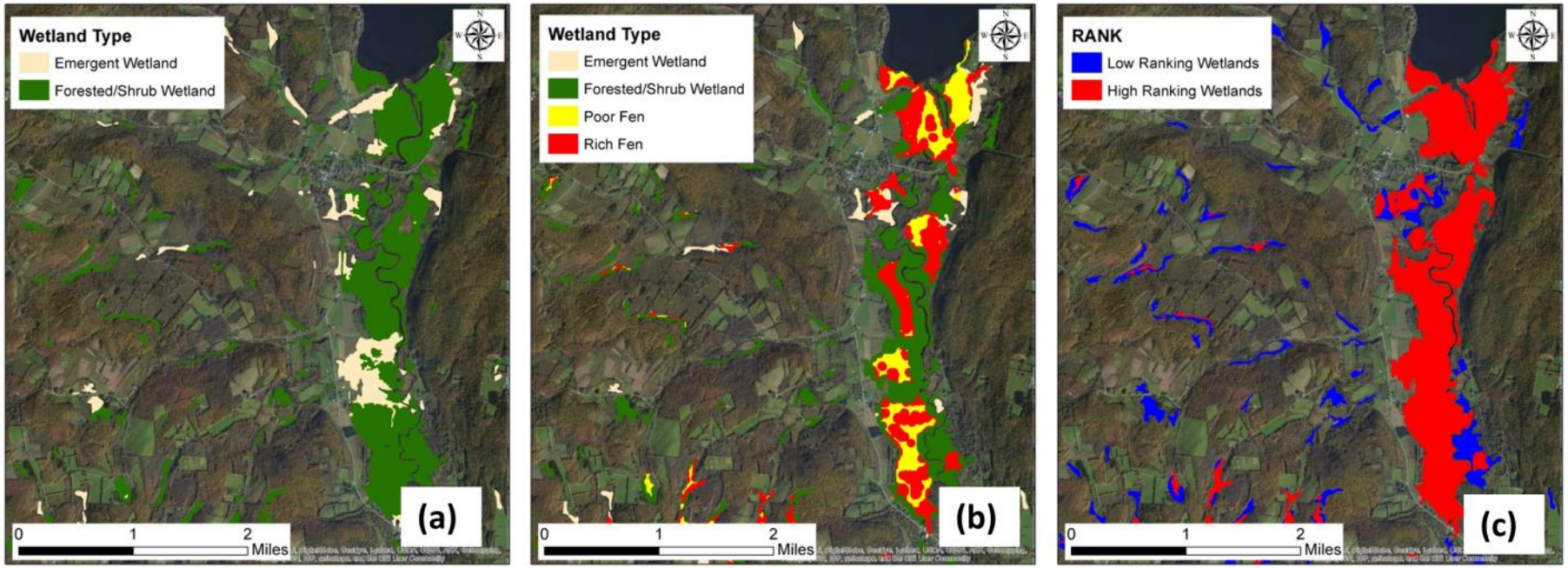
F) Mapping: Upper Susquehanna River and Adjacent Basins Priority Mitigation Areas

In this section, we provide overview maps of our target areas for the Susquehanna Basin Headwaters and Adjacent Basins including highlighting differences between TWT databases and National Wetlands Inventory (NWI). We provide examples of potential sites within individual service areas (8-Digit HUAs). Maps depict the top 20% of potential mitigation sites within that Service Area and examples of specific sites for the ILF program.

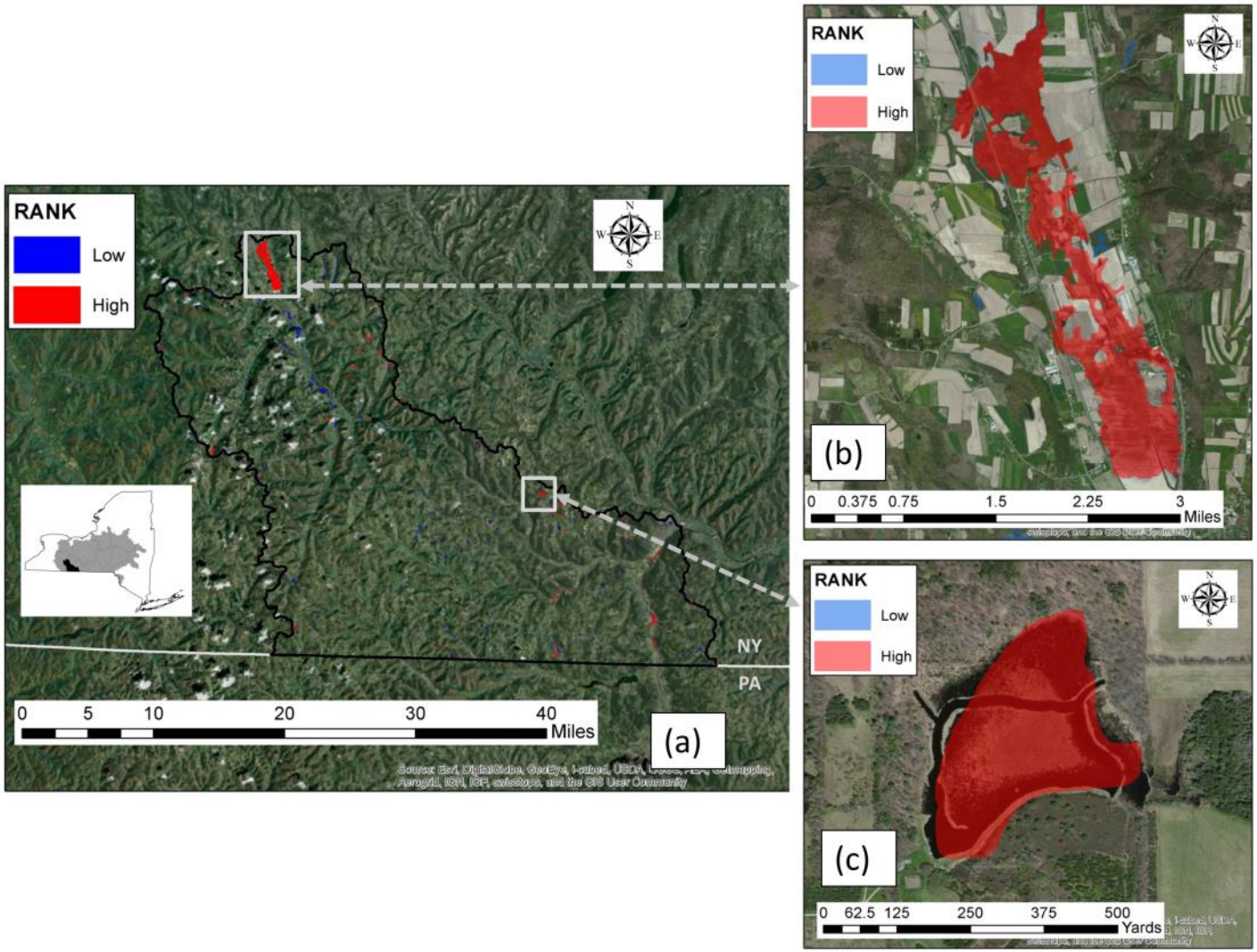
Potential Mitigation Targets in the Upper Susquehanna River Basin and Adjacent Basins In Lieu Fee Program.



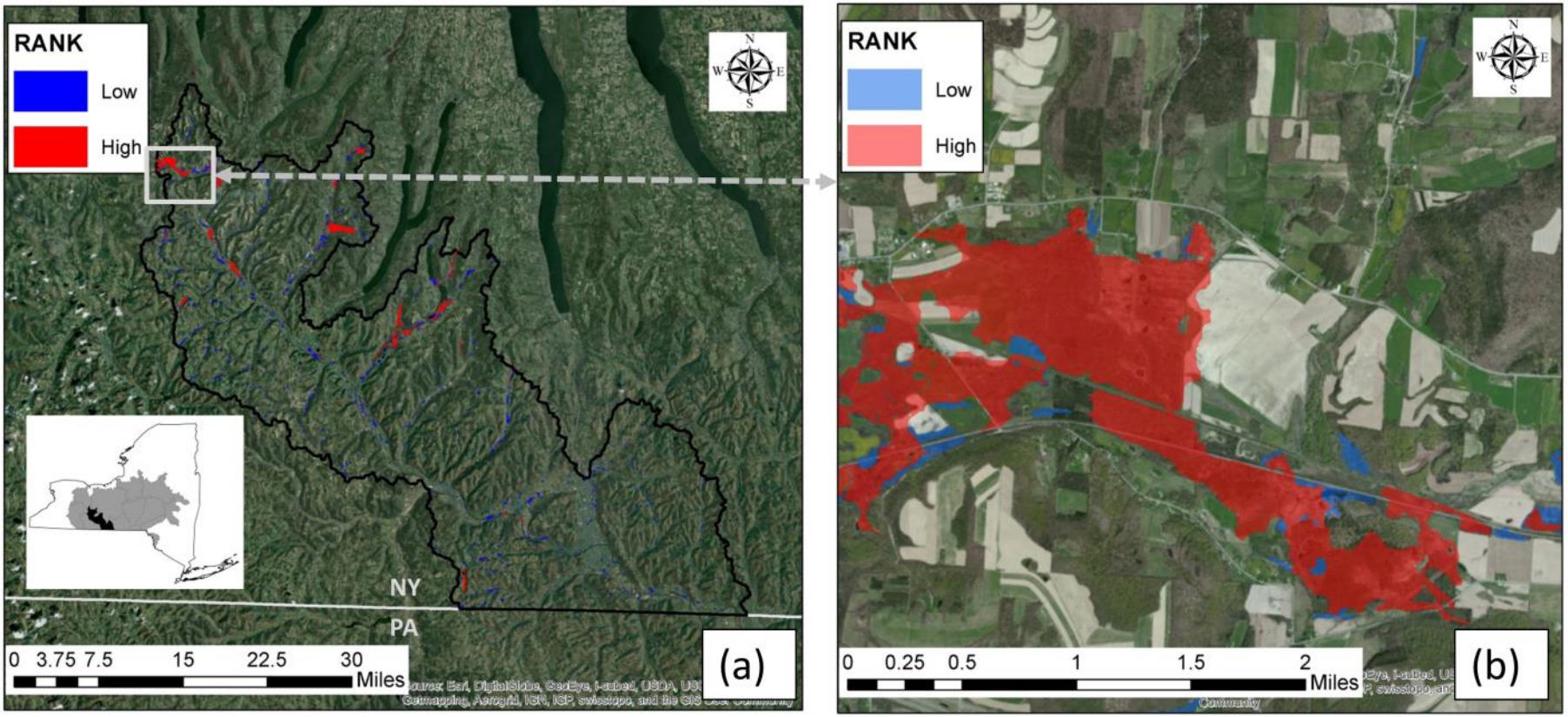
Areas in black have also been prioritized but fall outside of scope of The Wetland Trust's In Lieu Fee Program. Red areas are the top 20% of wetlands for the overall region. Note that priorities within individual service areas are specific to that service area.



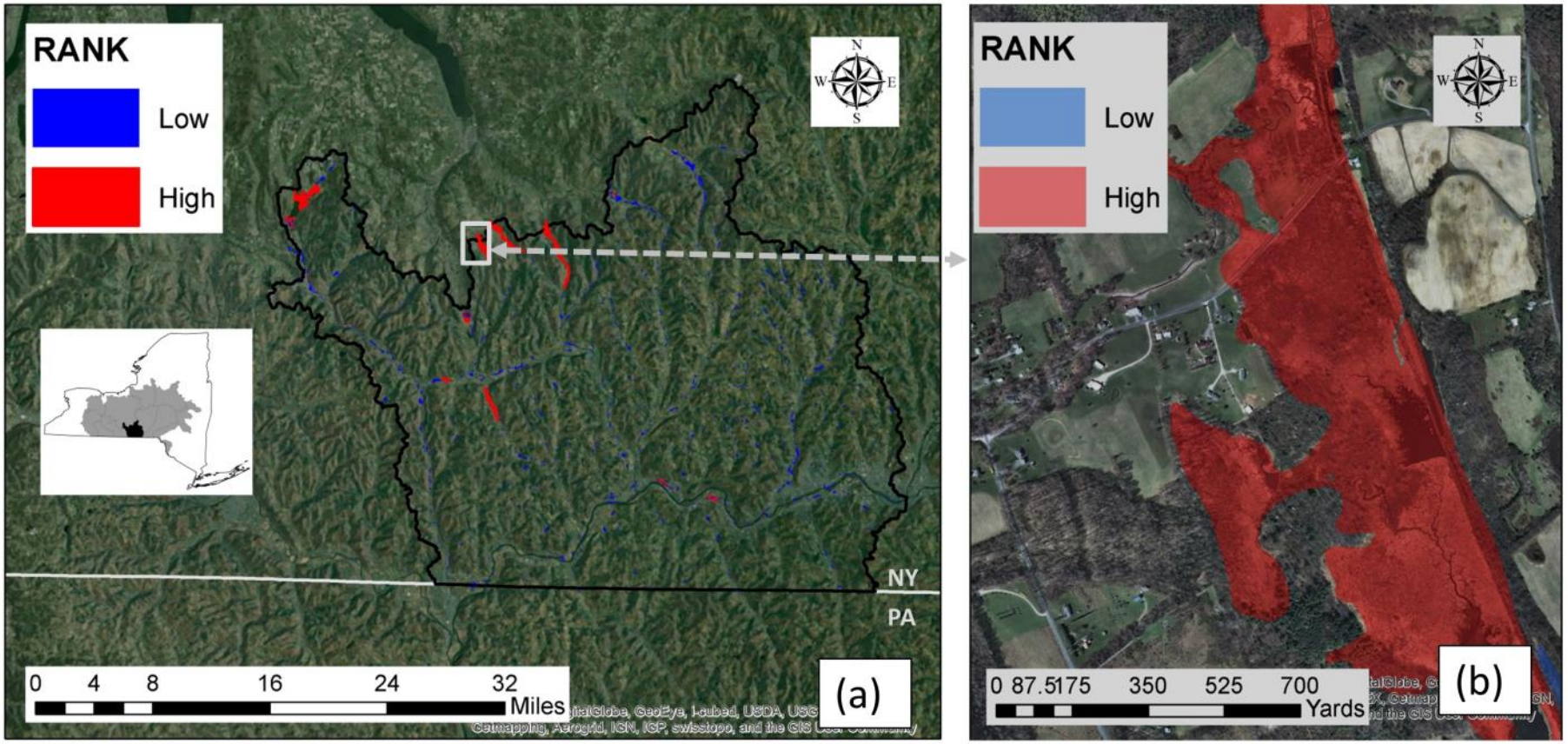
Example of differences between NWI ecological communities (**a**) and, those identified by the Maxent Models (**b**) shown in (**c**) is an example of the wetland complex symbolized by the ranking procedure. Rare community types were given higher weighting, as are larger wetlands including a range of types (e.g., forested, emergent). Oaks Creek Swamp (shown) lies to the south of and Canadarago Lake in the Unadilla/Susquehanna 8-digit HUA in the Upper Susquehanna River Basin. In 2014 TWT established a 101.23 acre preserve within the larger wetland complex within the highly ranking wetland areas. This added to existing conservation holdings (Oswego Co. Land Trust) in this high conservation priority area. The wetlands acquired by TWT include populations of Nodding Trillium (*Trillium cernuum*), an S3 species in NY (identified by Upper Susquehanna Coalition biologists in 2014). A pair of nesting bald eagles were also observed nearby in 2014.



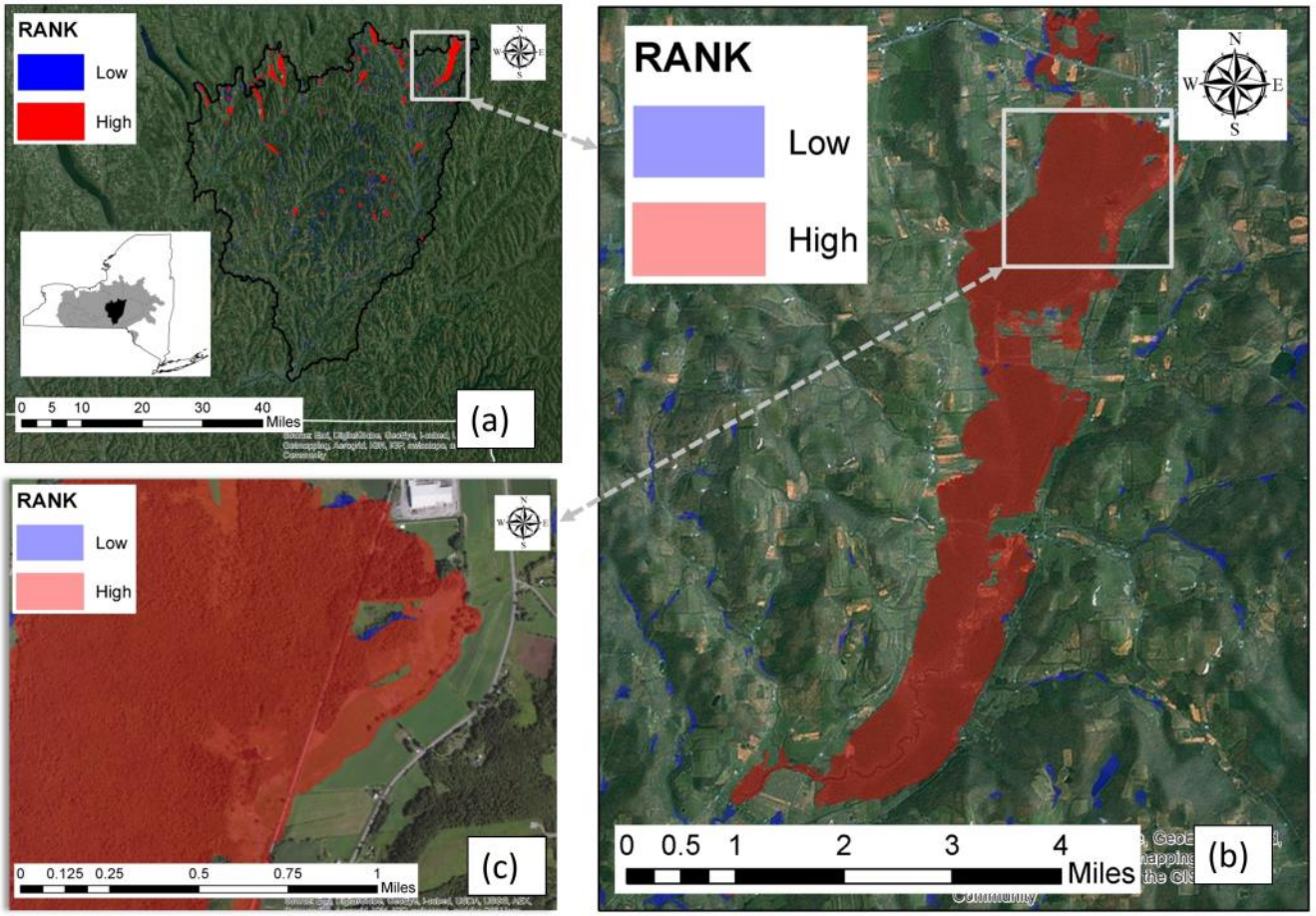
Canisteo Service Area: **(a)** NY - portion of 8-digit HUA in ILF Service Area **(b)** shows a highly ranking area with excellent wetland reestablishment potential and a large block of remnant wetlands to the north **(c)** shows a floating bog mat (poor fen) likely to support rare species near Addison, New York. The site appears to have been managed for bass fishing by cutting boat lanes into the floating vegetation mat.



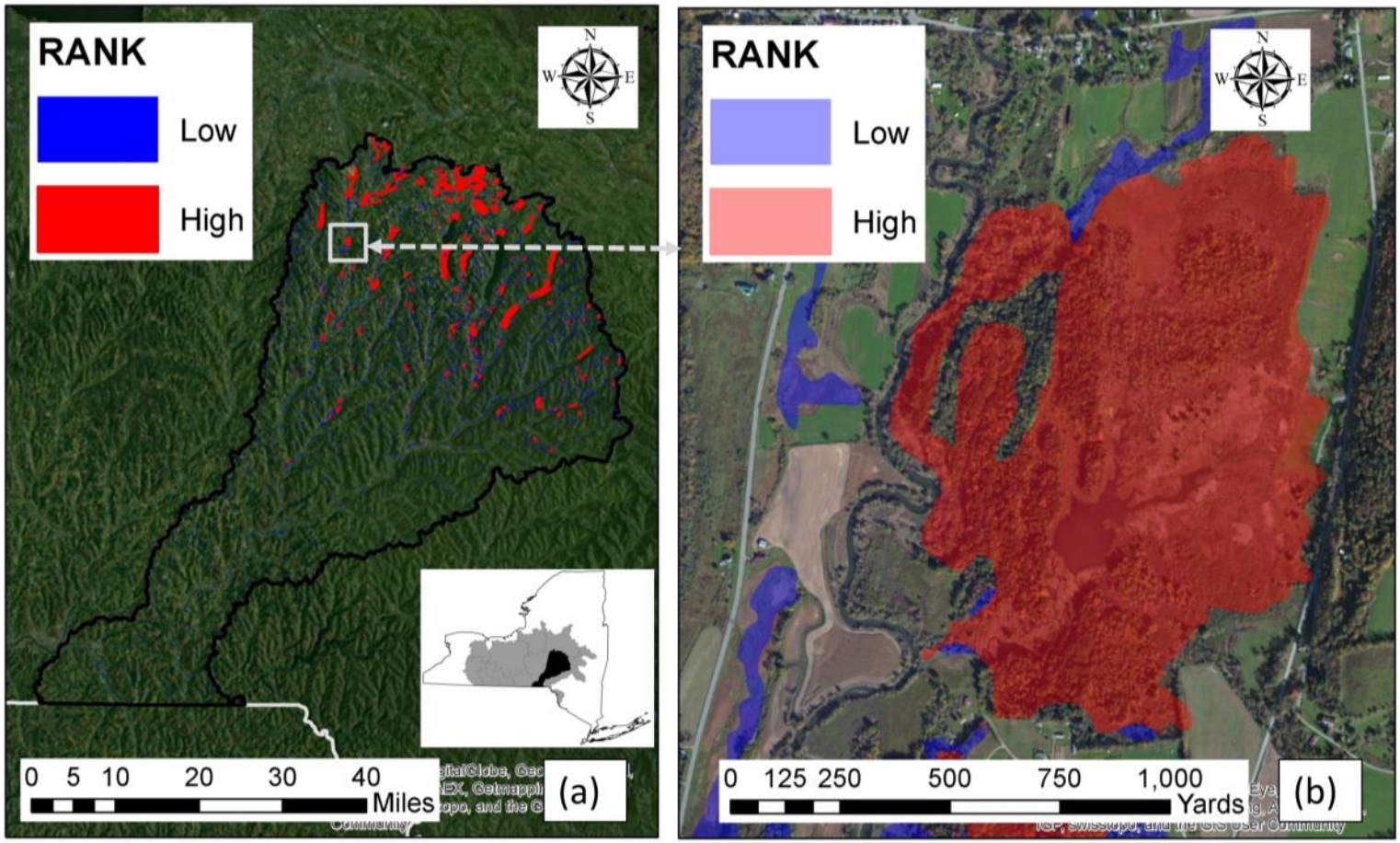
Cohocton/Chemung Service Area: (a) NY - portion of 8-digit HUA in ILF Service Area **(b)** shows a highly ranking area in Wayland, NY with excellent wetland reestablishment potential in and surrounding areas shown in red; TWT has existing conservation holdings in the wetland complex shown; a dwarf shrub bog is known to the east of this wetland complex.



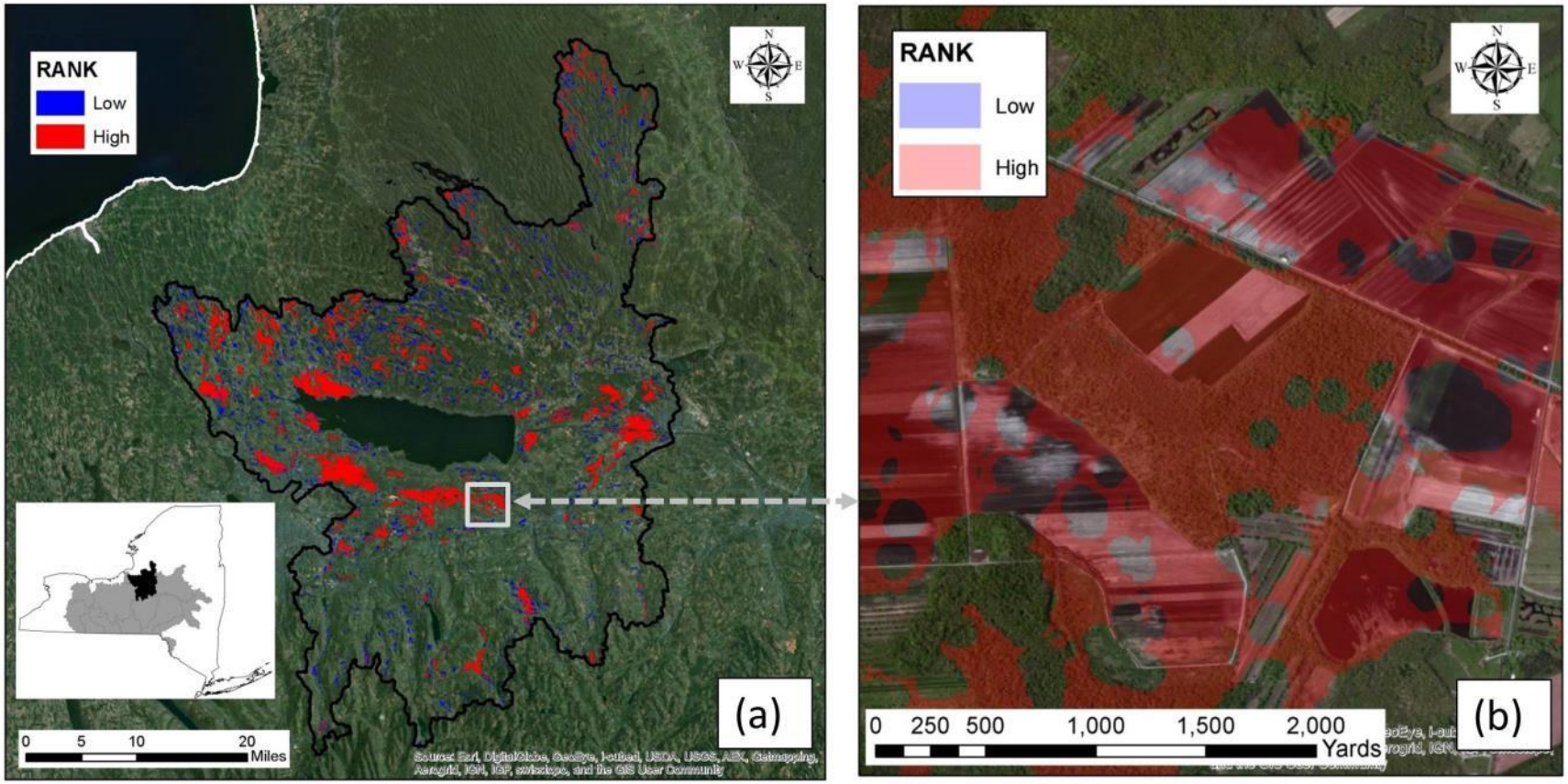
Cayuta/Catatonk/Owego Service Area: (a) NY - portion of 8-digit HUA in ILF Service Area **(b)** shows a highly ranking area with wetland reestablishment potential.



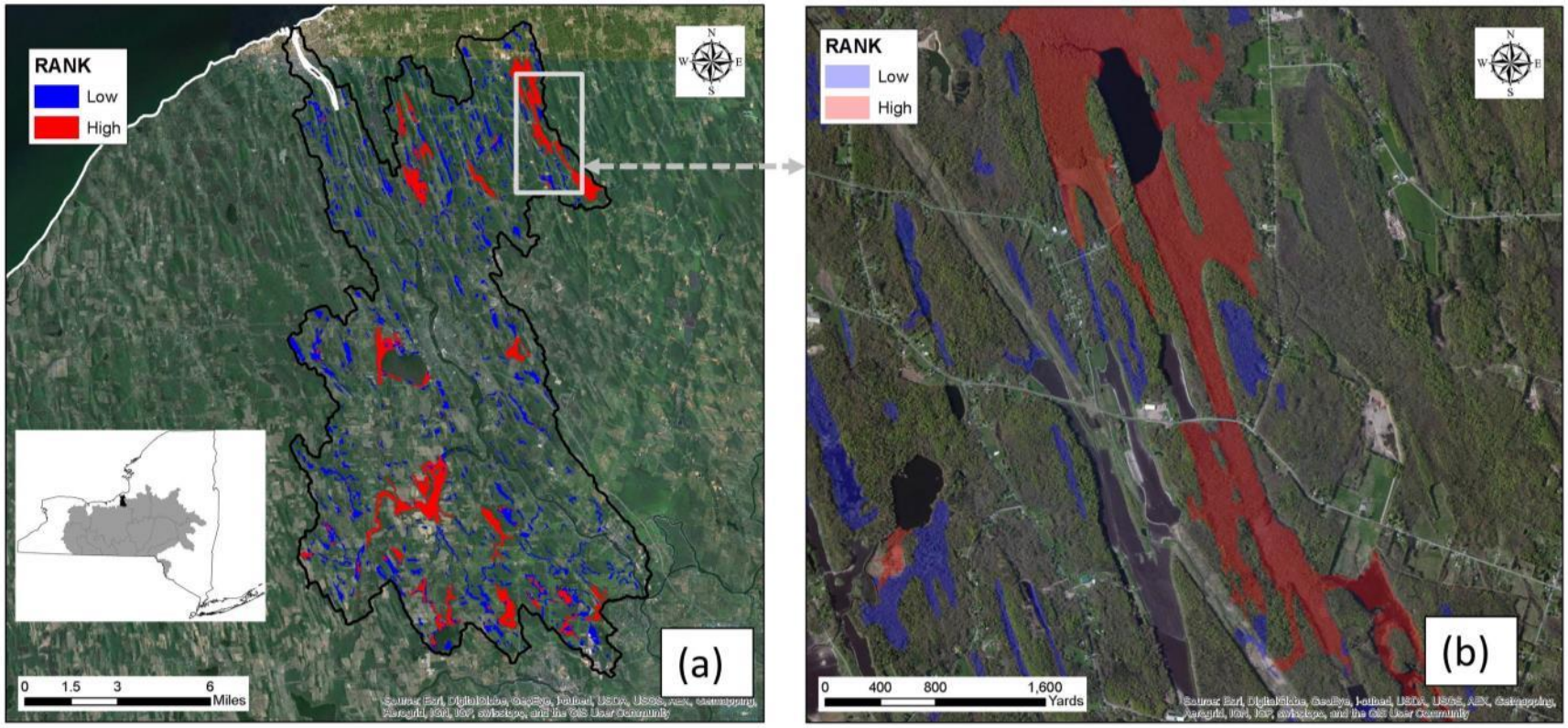
Tioughnioga/Chenango River Service Area: (a) Entire 8-digit HUA **(b)** shows a highly ranking area with excellent wetland protection and reestablishment opportunities **(c)** shows areas suitable for wetland reestablishment. Spreading globeflower (*Trollius laxus*) was historically known from the site. TWT ownership includes northern white cedar swamps, floodplain forest, open rich graminoid fens as well as forested upland buffers. Bald eagles have been observed at this site on several occasions.



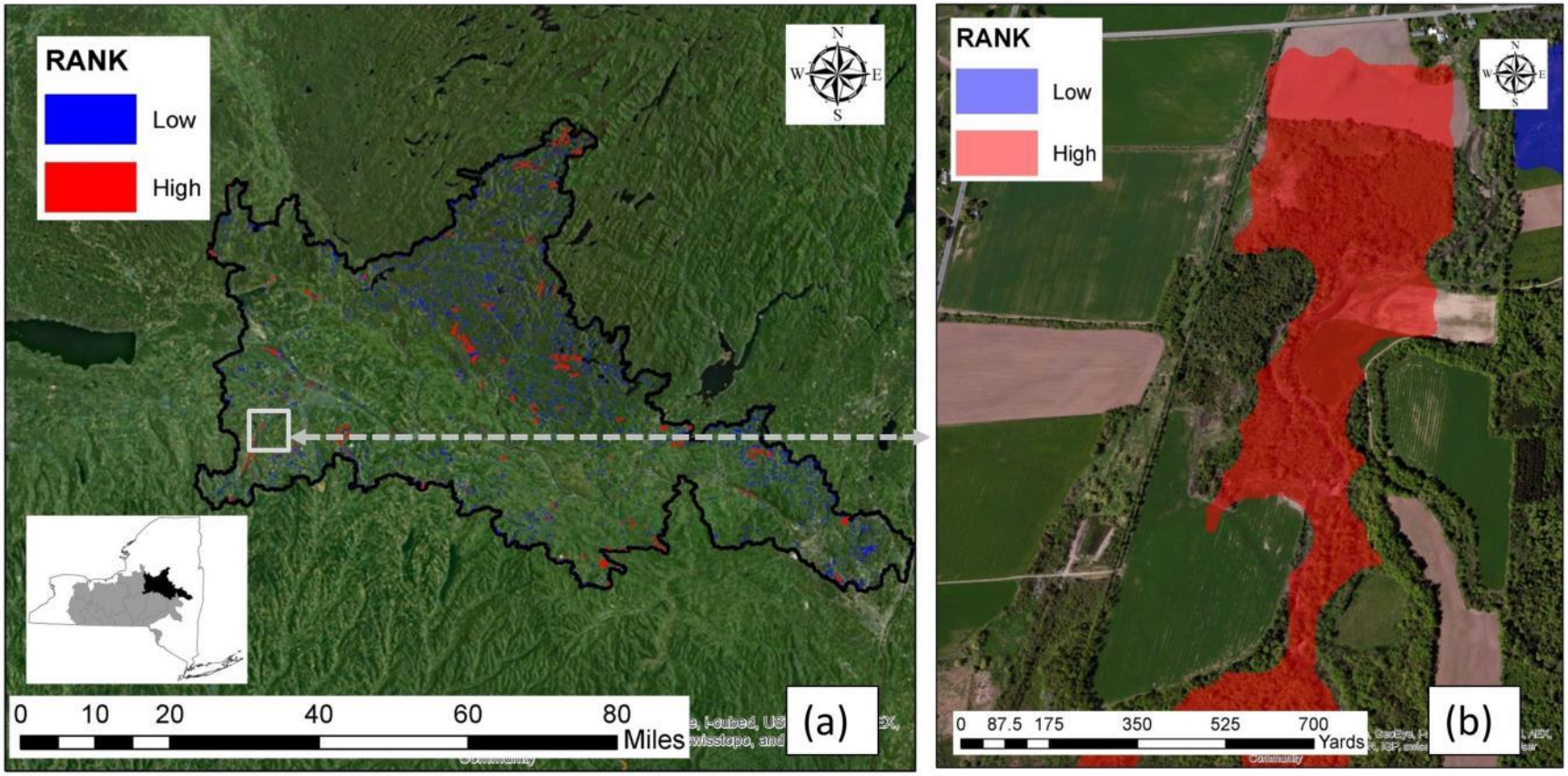
Unadilla/Susquehanna Service Area: **(a)** NY - portion of 8-digit HUA in ILF Service Area **(b)** shows a priority preservation, enhancement, and reestablishment area along the Unadilla River (Unadilla-Susquehanna 8-digit HUA) where TWT has established ownership of multiple parcels. Additional parcels are located downstream where a larger reestablishment project is underway. Notable species observed at the TWT sites include Bald Eagles, pink lady's slipper orchids, meadow spikemoss (*Selaginella apoda*), *Trillium* spp., and northern pale green orchid (*Platanthera flava*). Pearly mussels have also been documented in the Unadilla River.



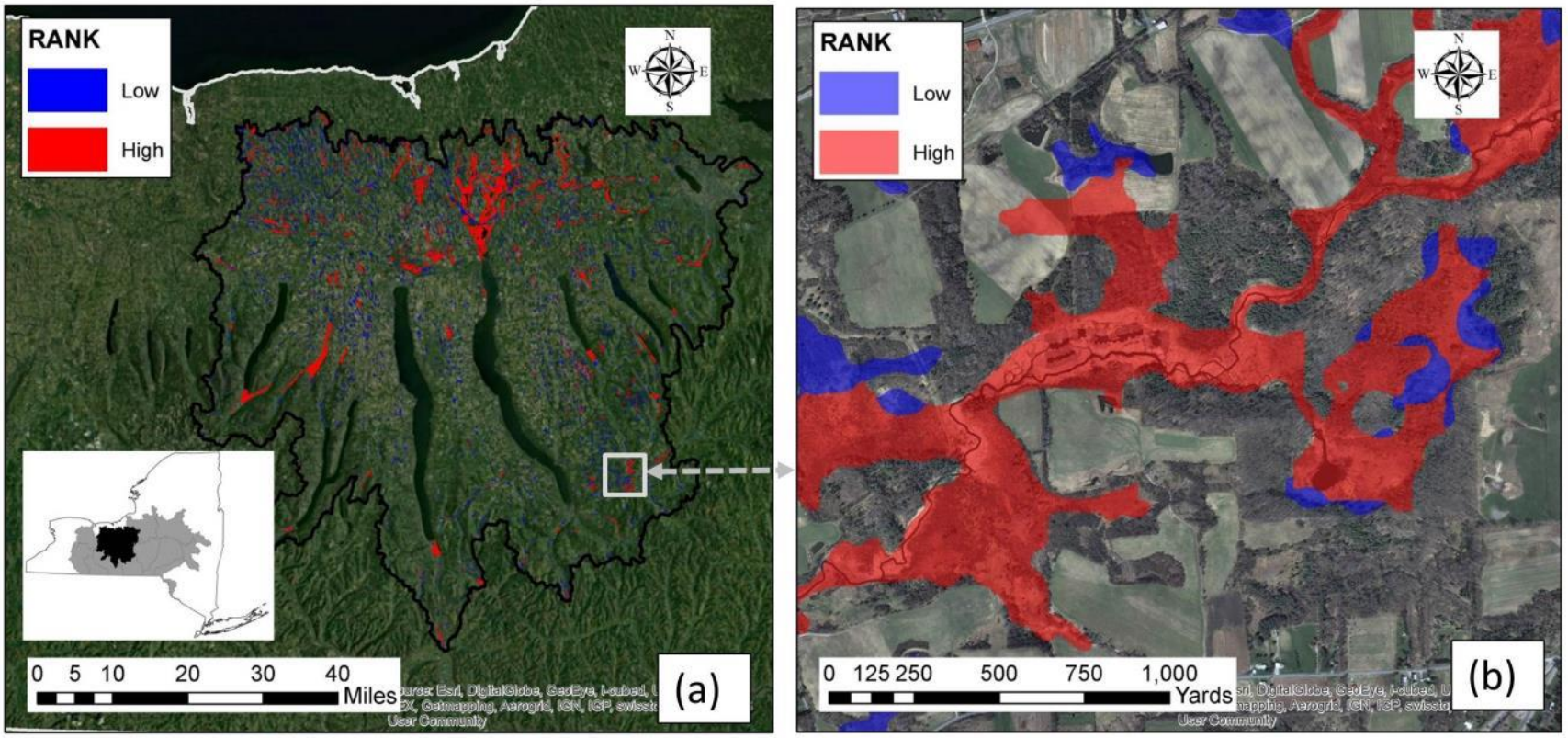
Oneida Service Area: (a) Entire 8-digit HUA **(b)** shows a highly ranking area with excellent wetland reestablishment potential; several opportunities exist within this service area for muckland restoration. Several species of greatest conservation need are historically associated with the drained medium fens found throughout much of the service area. TWT and Upper Susquehanna Coalition have taken steps to identify propagule sources as well as nurseries that could provide a means to reestablish rare plant species in such settings. Relative to other 8-digit HUA's this watershed boasts some of the regionally more important remaining wetlands including sites supporting species listed on the endangered species list.



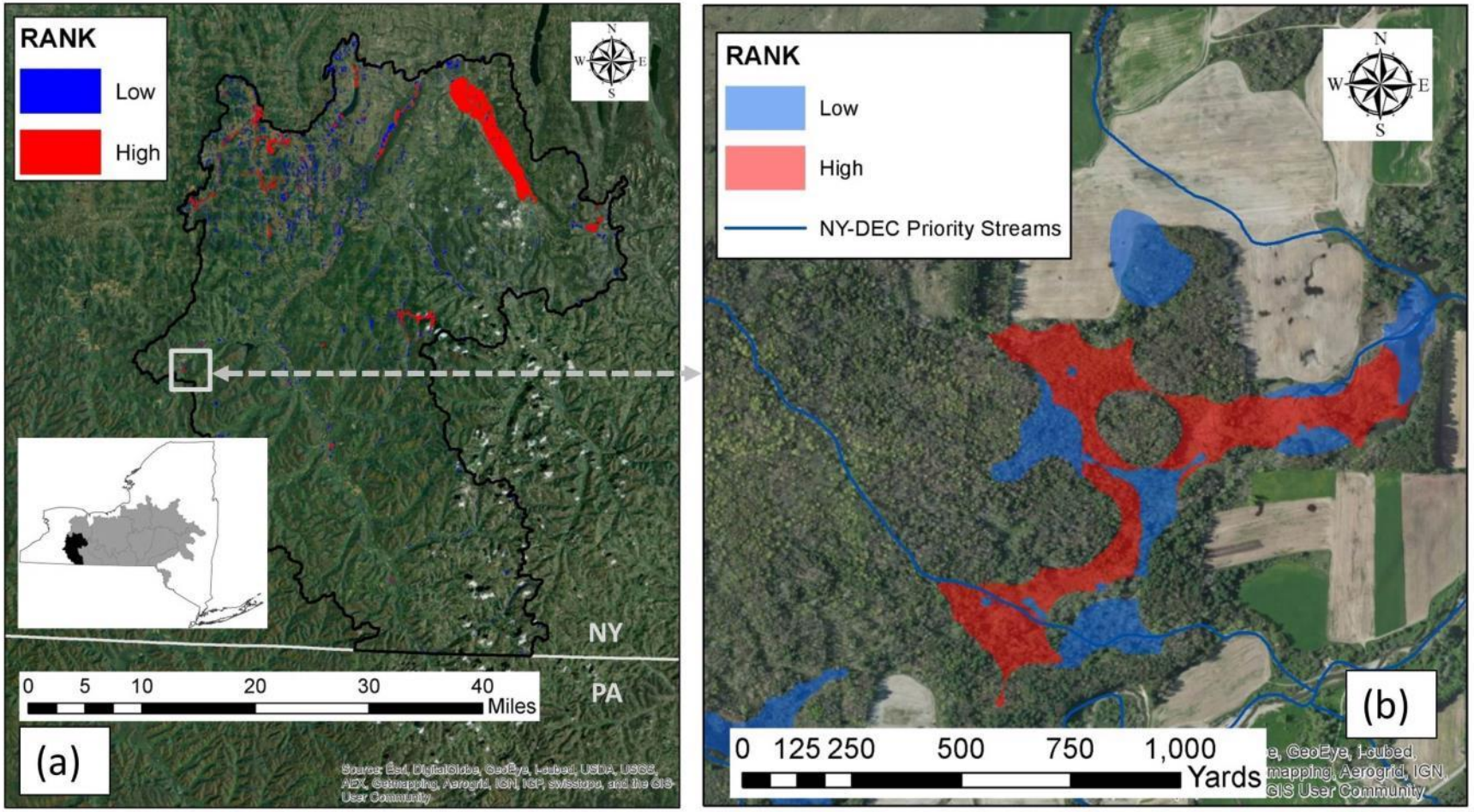
Oswego Service Area: (a) Entire 8-digit HUA **(b)** shows a highly ranking wetland complex with medium fen and forested wetland communities. Surrounding dark areas are previously drained mucklands that may offer additional wetland reestablishment opportunities. Several species of greatest conservation need are historically associated with the drained medium fens found throughout much of the service area.



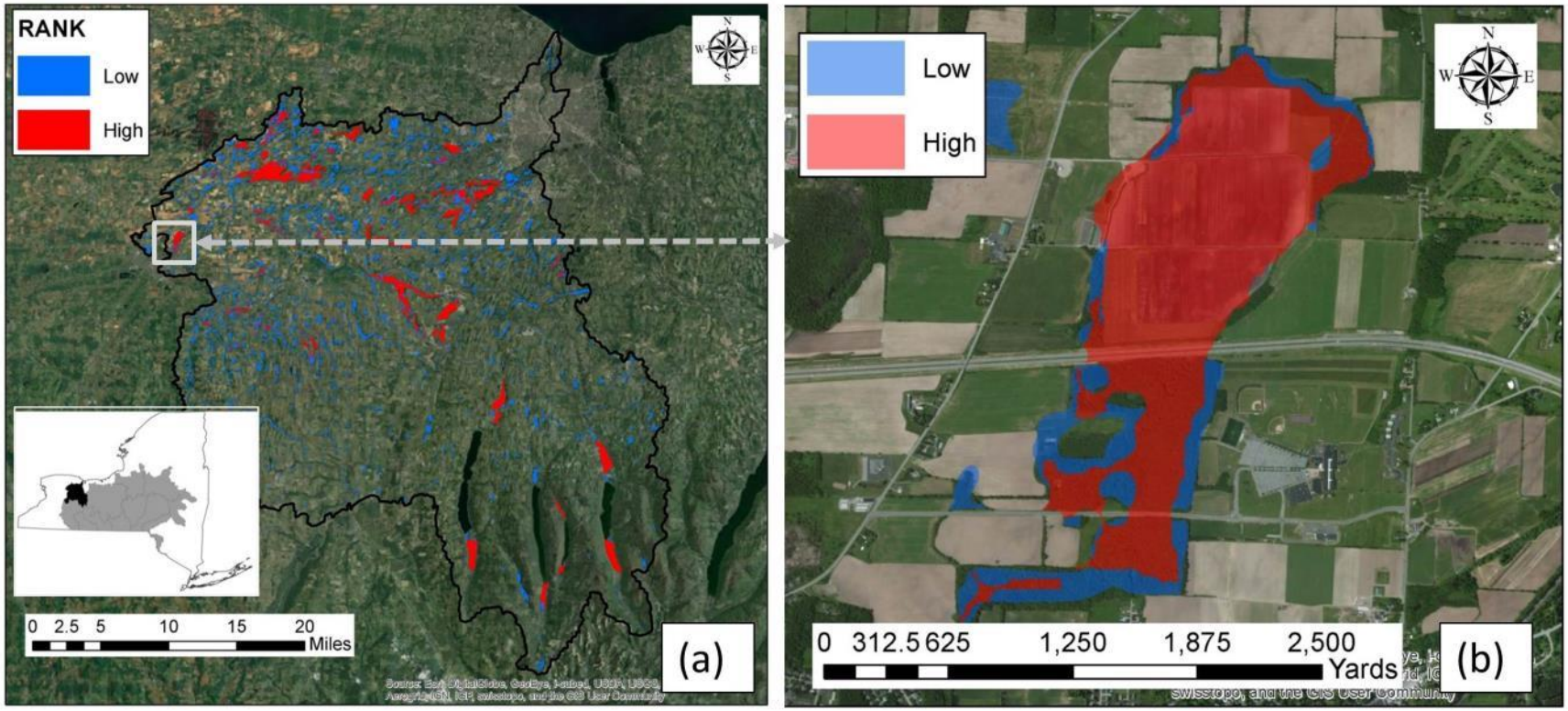
Mohawk Service Area: (a) Entire 8-digit HUA **(b)** shows a highly ranking area with excellent wetland reestablishment potential along Oriskany Creek. Oriskany Creek is known as an excellent trout fishing stream. Potential mitigation areas extend into the Adirondack Park Region where projects may contribute to furthering protection of a very large wilderness area.



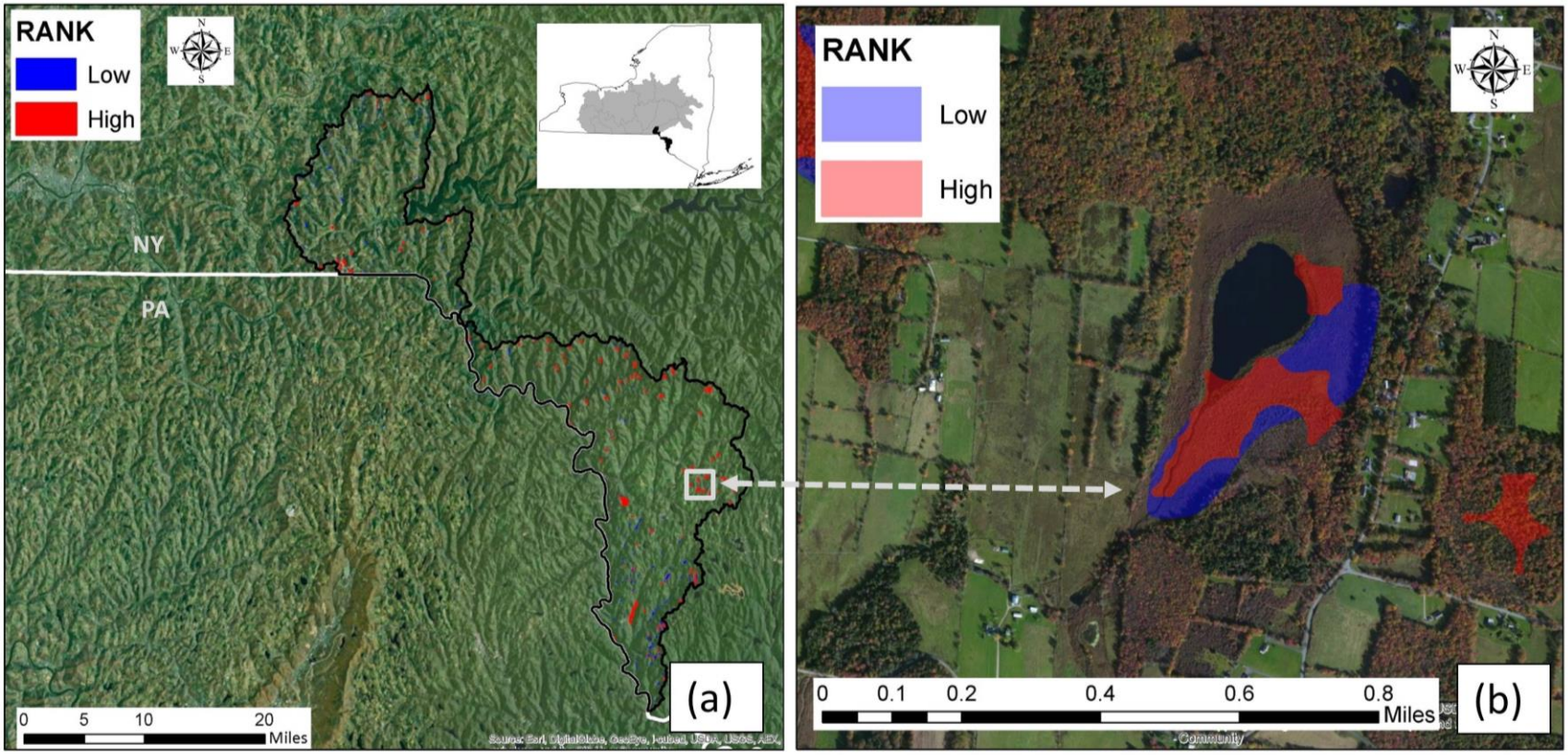
Finger Lakes Service Area: (a) Entire 8-digit HUA **(b)** shows a highly ranking area with excellent wetland reestablishment potential and a high density of known fens of high biological quality along Fall Creek. Several sites visited by USC staff support rare species such as Schweinitz's sedge (*Carex schweinitzii*), spreading globeflower (*Trollius laxus*), and a large diversity of orchid species.



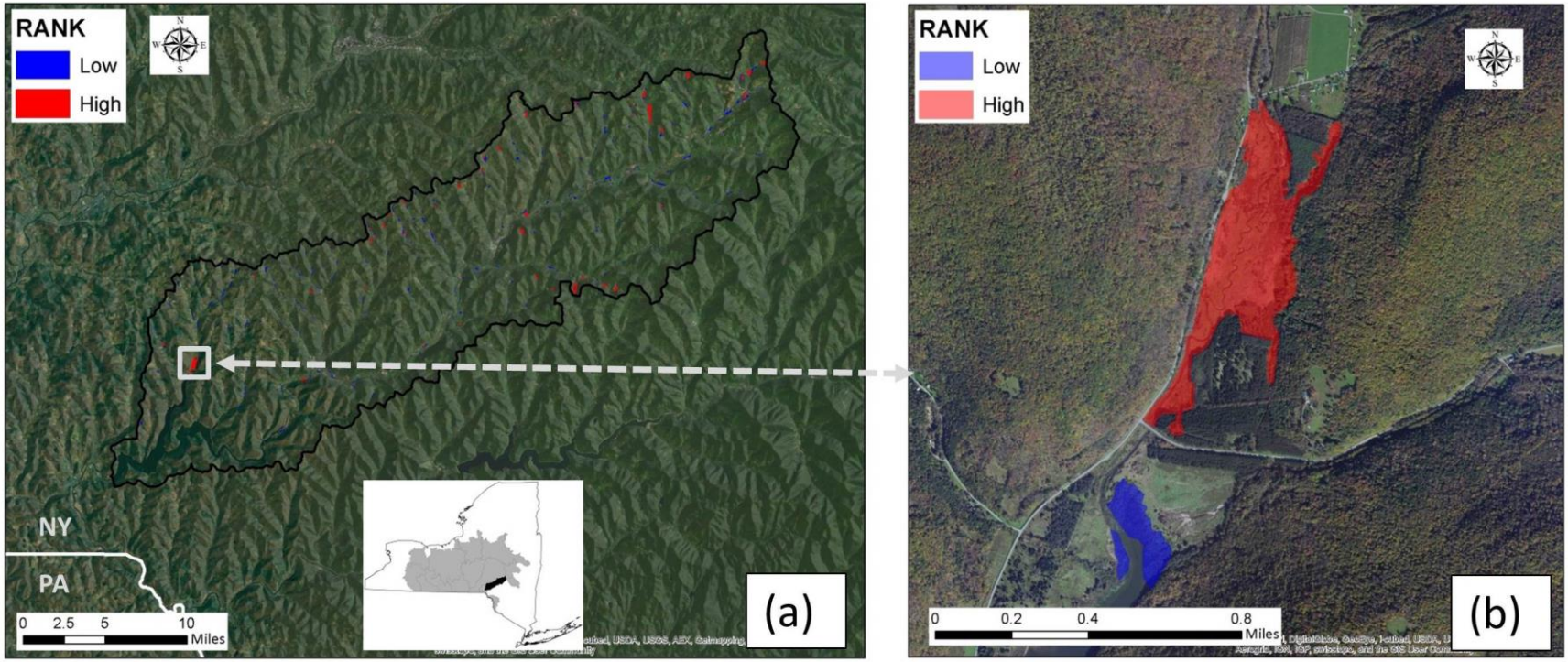
Upper Genesee Service Area: (a) Entire 8-digit HUA **(b)** shows a highly ranking area with excellent wetland reestablishment potential adjacent to DEC priority streams (Caneadea Creek and tribs). Adjacent agricultural fields also appear to offer wetland reestablishment opportunities as well.



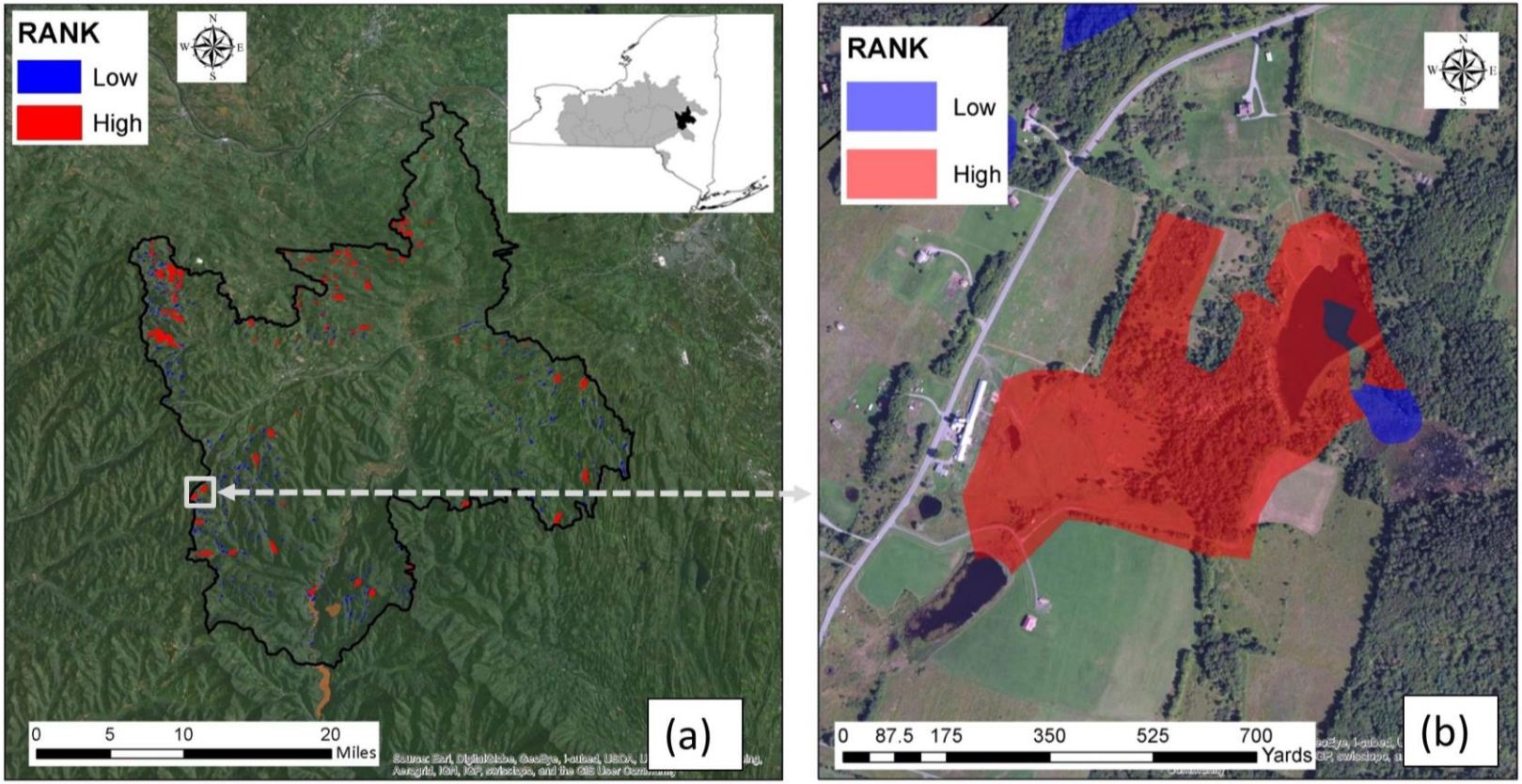
Lower Genesee Service Area: (a) Entire 8-digit HUA **(b)** shows a highly ranking area with excellent wetland preservation potential in a wetland with drained muckland to the north, and remnant wetland to the south. Other targets in the watershed include rich fens and northern white cedar swamps supporting large numbers of rare species.



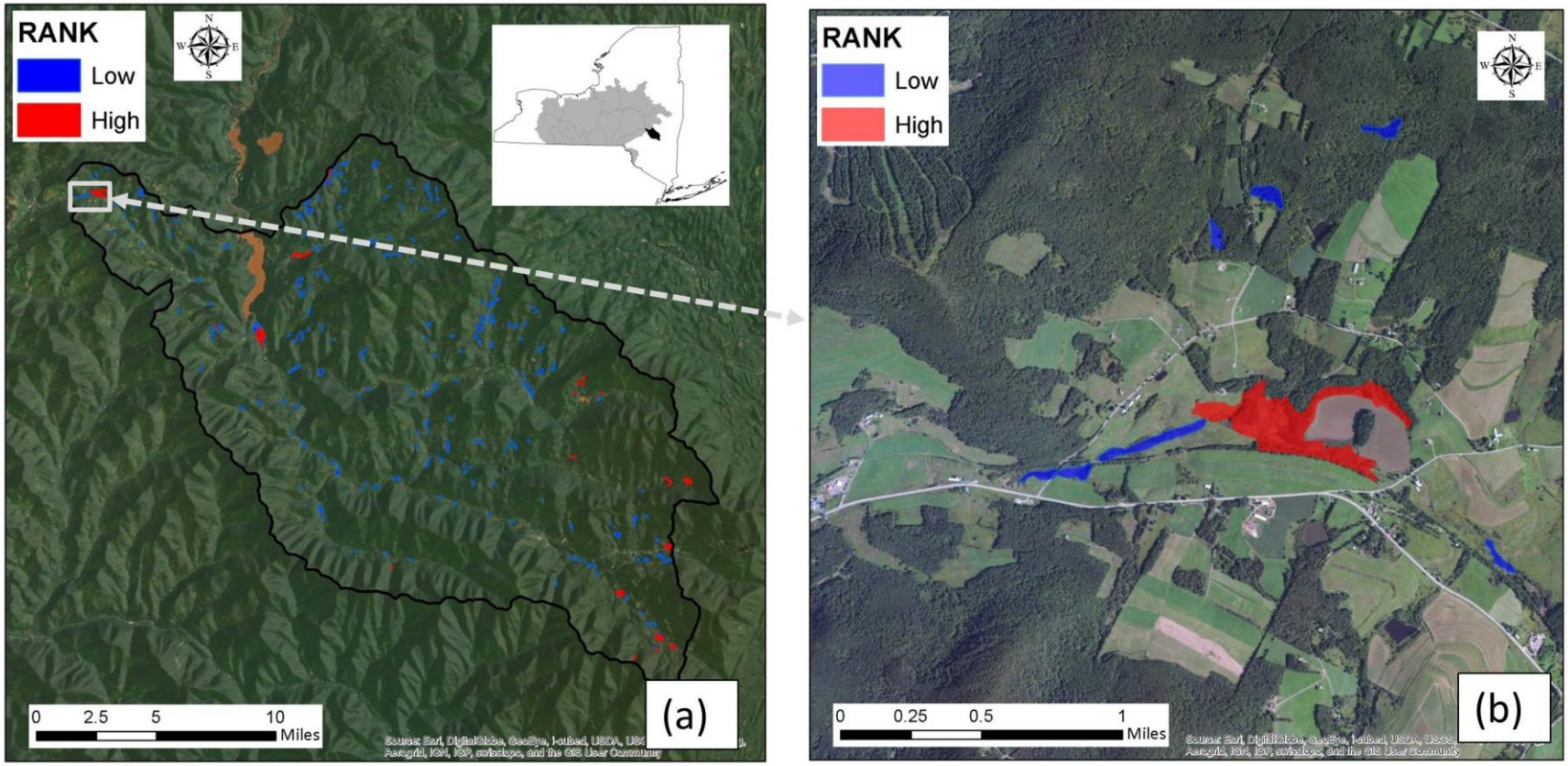
Upper Delaware Service Area: (a) Upper Delaware 8-digit HUA excluding NYC portion **(b)** shows a highly ranking area.



Upper Delaware NYC Service Area: (a) NYC portion of Upper Delaware 8-digit HUA **(b)** shows a highly ranking area along Trout Creek's, lower and minor tributaries. Trout Creek is a DEC priority stream. Additional restoration opportunities appear along much of Trout Creek.



Schoharie Service Area: (a) Schoharie 8-digit HUA excluding NYC portion **(b)** shows a highly ranking area with wetland reestablishment potential.



Schoharie NYC Service Area: (a) NYC portions of the Schoharie 8-digit HUA **(b)** shows a highly ranking area lying along minor tributaries to the Schoharie Reservoir.

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