Influence of land use and land cover on aquatic habitat in tributaries of the Grand River, Ohio.

by

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Influence of land use and land cover on aquatic habitat in tributaries of the Grand River, Ohio.

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ABSTRACT

Land use and cover patterns, such as forest vs. farmed lands (which in Northeast Ohio include both technological modern farms and traditional Amish properties), can greatly influence ecological functioning at multiple scales. Too often, alterations in land use have been made with little or no consideration of potential impacts on adjacent systems, including streams. The objective of this thesis was to evaluate influences of land cover on habitat for fish and other aquatic vertebrates within tributaries of the Grand River in Ashtabula, Trumbull, and Geauga Counties. I used Geographic Information System tools to delineate watersheds of 8 tributaries, and to determine percentages of forested, wetland, and farmland in each. I used a combination of land parcel search by common Amish surnames, in addition to ground trothing to differentiate Amish vs non-Amish properties. I conducted Qualitative Habitat Evaluation Indices (QHEI) at publicly assessable points on each stream, and also calculated stream gradient above assessment sites. I used Pearson Correlation and Principle Components Analysis (PCA) to investigate associations among land cover, stream gradient, and habitat quality variables. Watersheds closest to the Grand River were predominantly forest and wetlands. There was a distinct spatial separation between Amish and non-Amish farms, with Amish farms concentrated in uplands to the west of the Grand River Valley near the village of Middlefield. QHEI scores ranged from 47 (poor/fair) to 80 (excellent). In-stream factors such as sediment heterogeneity and riffle-pool development contributed the most to high QHEI scores. High Gradient streams also scored the highest in habitat quality. PCA also revealed these patterns in land cover, interestingly suggested that land cover was not strongly

influencing stream habitat quality. Habitat assessment sites located substantial distances from farms, so perhaps the natural land cover in between may be sufficiently buffering impacts of human land uses.

ACKNOWLEDGEMENTS

First and foremost I would like to thank my thesis advisor, Dr. Thomas Diggins, for helping, guiding, and mentoring me through my project. He has spent a lot of time working with me on my wording and taking car trips listening to me rant about politics. I have gained a tremendous amount of knowledge environmentally using QHEI scores and working on wetland habitats. Also, I would like to thank my committee members Dr. Peter Kimosop, Dr. Bradley Shellito, and Dr. Ian Renne. The GIS was a huge influence on this project and I can't thank them enough for the countless hours of questions needed answered. A special thank you to both Biology and Geography departments for the necessary equipment and programs needed for this project. I also would like to thank Dunkin Donuts for the countless hours of making me large coffees throughout this project. A huge thank you to my family (especially mom and dad) and my fiancé (Victoria) for putting up with me at my stressed times as well as pushing and driving me to finish this thesis. I also want to thank the Lord for blessing me with this opportunity to learn, grow, and be a great person.

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Introduction

Land use and cover patterns, such as forest vs. farmed lands (which in Northeast Ohio include both technological modern farms and traditional Amish properties), can greatly influence ecological functioning at multiple scales. Detrimental human land uses have often been the key element in the downward trend of the health stream environments (Karr et al. 1985). Lotic communities are very sensitive to degradation of the surrounding watershed due to their extremely close interdependence with the adjacent terrestrial system (Karr 1981). Too often, alterations in land use have been made with little or no consideration of potential impacts on adjacent systems, including streams. If alterations such as positive or negative farming techniques adjacent to the streams were to occur within these stream ecosystems one would expect an immediate impact of fish communities within the streams (Angermeier 1984). An 8-year study done by Toth (1982) on *Ericymba* minnows in streams in Northeastern Indiana showed the soil erosions from improper farming techniques caused perturbations in stream communities which was the main cause for the collapse of the *Ericymba* population within their study site (Toth 1982). Woody debris in forested ecosystems can impact in a positive way the quality of food and habitat resources that are available to stream fish.

Deforestation for lumber or clearing land for farming are examples of how humans can alter forested ecosystems for their own personal use. A study done on forest management practices such as harvesting or deforestation on Mid-Atlantic streams did show on a local scale a decrease in quality of local streams (Thornton 2014). According to Karr (1981), these changes affect not only fish, but other groups of stream organisms such as turtles, frogs, and benthic invertebrates. Consequently, aquatic biota can often reflect the quality of the environment by the number and type of species located in a study site (Karr 1981).

Benthic invertebrates are an important and highly overlooked food source for stream fish (Angermeier 1983). With this being true, we know practices such as poor farming techniques and negative human impacts can alter not only fish but benthic invertebrates. This in turn will reduce the number of benthic invertebrates causing a negative influence on this ecosystems food web. This ultimately will affect the fish population negatively by lowering the food these fish have access to within these streams (Schlosser 1991). Despite there being other methods such as chemical testing which can depict the quality of streams, this thesis applies the most practical and universally accepted methods. Our study will be focused around fish species and the quality of the streams they inhabit using IBI. Human impacts of land use surrounding these streams will have a negative impact such as a poor quality of stream and the population of fish during each of the seasons in Ohio such as affecting the migration in the spring and winter of particular species such as steelhead. These seasonal migrations, along with other outside factors such as pollution or chemical overloads, can have a huge impact on the life stages of fish such as spawning, feeding, and reproduction. These factors which can affect the growth and survival of stream fish include spatial environmental heterogeneity which has a mix of concentrations of (e.g. rainfall, temperature, wind) filling its area, trophic interactions (a food chain or a food web), and temporal environmental variability which is the evolution and joint interaction in raising offspring. (Schlosser 1991).

The objective of this thesis is to evaluate influences of land use and land cover on habitat for fish and other aquatic vertebrates within tributaries of the Grand River, located in Northeast Ohio (Figures 1 – 3). Ohio is one of a few states that have quantitative aquatic use requirements for lotic systems, which incorporate biological monitoring into water quality standards (D'Ambrosio et al. 2008). Although analysis of water chemistry is useful for examining the quality of streams, it is costly and equipment-intensive, and results are often indicative of only short-term trends. A study done on Black Creek watershed in Allen County Indiana on impacts of pesticides and PCBs on streams and fish showed an increase in PCBs on fish tissue as well as evidence that herbicide runoff is inevitable in adjacent streams (Dudley and Karr 1980). However, broad-scale non-chemical factors such as flow alteration, habitat degradation, and discharge of heated effluents are typically not directly assessed by chemical analyses (Karr 1981).

With evidence that human impacts on streams can have negative influences on the streams and fish within them, factors such as farming techniques and differences in semi-natural/non-farmed, 21st century technological, and traditional Amish farmed land cover will be analyzed and taken into account in this study. Figure 4 shows a 21st century farm with technological impacts while Figure 5 shows an Amish farmstead with an emphasis on zero electricity. With different farming techniques of different farmers another question arises is comparing the effects of fall vs spring plowing. Jiang et al. (2014) conducted a study in Prince Edward Island, Canada, about the effects of fall vs. spring plowing and during this study they found a negative impact on adjacent streams during fall plowing compared to the spring from the runoff of unnatural pesticides into nearby adjacent streams (Jiang et al. 2014).

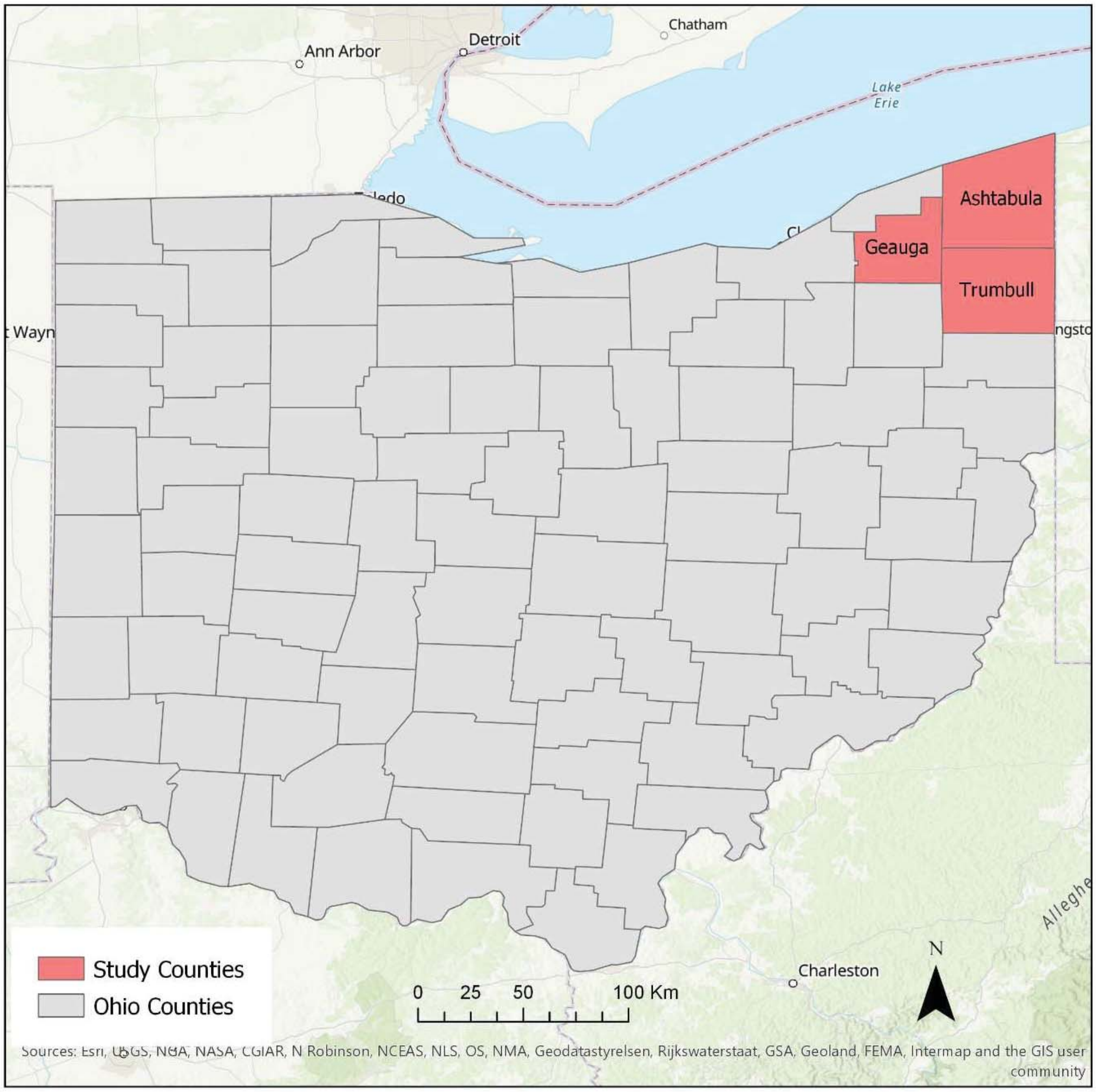


Figure 1. State of Ohio, with the three counties of our study area (Ashtabula, Trumbull, Geauga) highlighted in red.

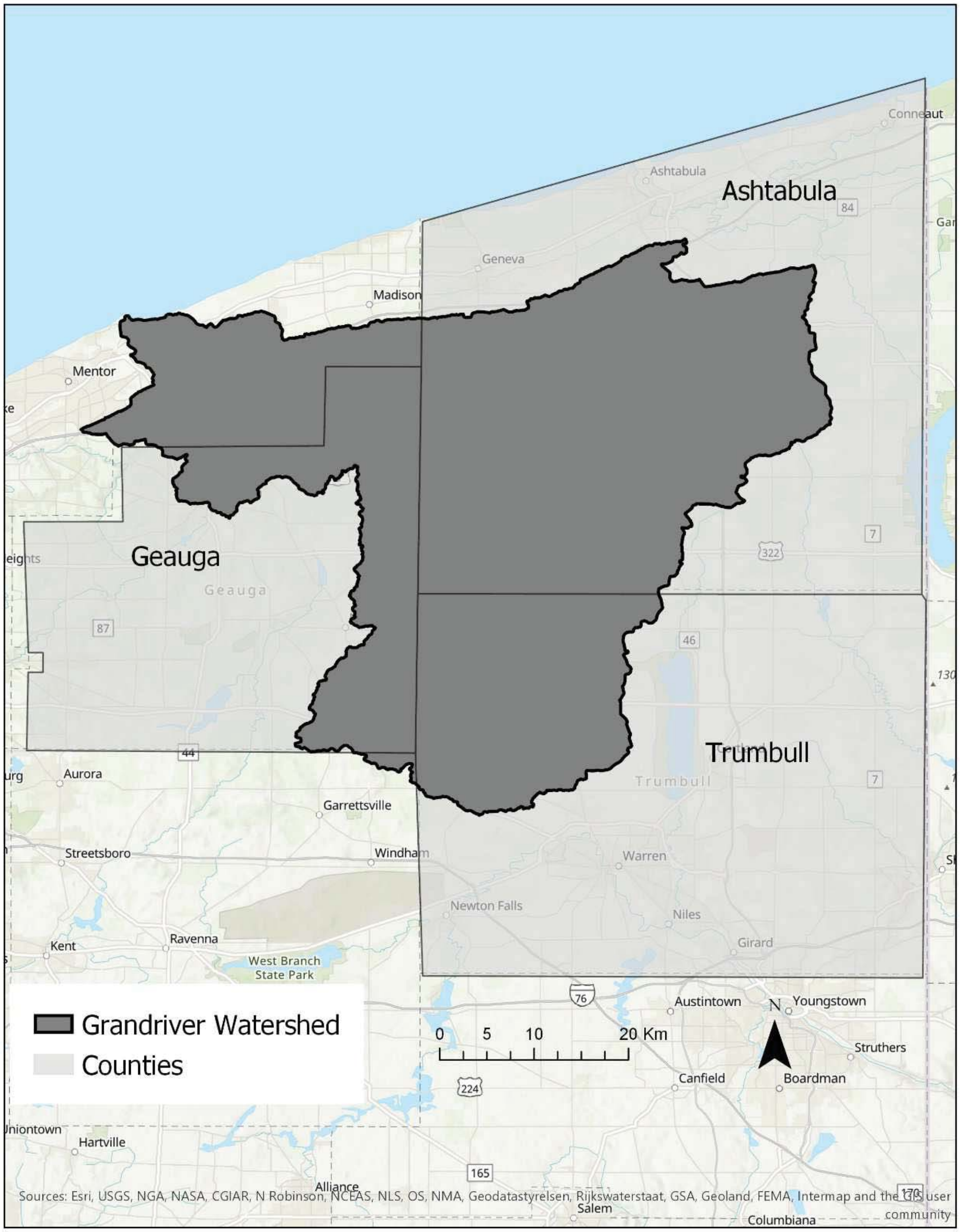


Figure 2. Grand River Watershed.

Figure 3. Pictures of the Grand River, ranging from upstream, within the Swine Creek Reservation Park (top picture), to a mid-reach location just downstream from study sites for this thesis (center), to further downstream where the river follows an escarpment (bottom).

Figure 4. Non-Amish farmstead, employing 21st century agricultural technology.

Figure 5. Amish farmstead employing traditional (19th century) agricultural techniques without power equipment or manufactured chemical agents.

Study Site

I conducted this thesis in the Ohio counties of Trumbull, Ashtabula, and Geauga (Figure 1), with emphasis on tributaries to the Grand River (Figures 2 and 3). Trumbull County has a total area of 1,619 square kilometers and has a population of approximately 225,000 people. Ashtabula County is farther downstream along the Grand River, and is 1,821 square kilometers in size. Geauga County is 1,046 square kilometers in area, and lies directly west of both Trumbull and Ashtabula Counties. Throughout these farmlands and forested game lands is a river known as the Grand River, which arises in Trumbull County and flows north through Ashtabula County to Lake Erie. Flowing into the Grand River are numerous tributaries which will be the focus of this study. Although the Grand River does not flow through Geauga County, some of its watershed and tributaries are found there.

Amish communities reside in the Northwestern part of Trumbull County, as well as the southwestern and eastern parts of Ashtabula and Geauga Counties, respectively. In our counties, the Amish are considered part of the Middlefield Community, which is considered the second largest Amish community in Ohio, and the fourth largest Amish community in the country (Amish Population Profile 2018). Amish populations have been growing since 1992, and the primary reason is local growth rather than Amish immigrating to these areas. These families will have five or more children on average and the primary reason they have grown is within their community rather than by emigration. Also according to Amish Population Profile (2018) Ohio especially has had a larger overall increase in the number of settlements, districts, and populations since 1992. Districts are defined as separate fellowships also known as congregations while settlements are newly relocated areas not previously inhabited by Amish. The other term "population", is defined as the total number of Amish within the specific boundary. Ohio from 1992 to 2016 experienced an increase in settlements from 33 to 58 with an increase of 25 settlements. Districts of Amish have also increased from 258 to 537 over this time, an increase of 279 districts. Total Amish population has increased from 34,830 to 72,495 in Ohio (Amish Population Profile 2018). Another reason these Amish have had good success in Northeastern Ohio is that Amish establish new settlements in states that have already had Amish communities as well as fertile farmland.

A second reason these Amish have had such a success is to also consider that not all Amish necessarily farm. Finding areas of non-farm work in specialized occupations in what they concentrate in is important. In our study site there are an abundant of employment opportunities such as woodwork, horse tack, and other building specialties that these Amish are experts at and can work.

The third reason according to Amish Population Profile (2018) is that Northeastern Ohio is geographically isolated in rural areas where the Amish are able to live their traditional, family-based lifestyles. Finally, our study area in Northeastern Ohio provides a good quality of life to Amish. This includes weather for farming season and elevated vs flat farming terrain for farming locations as well as proximity to other families and churches. This encourages Amish to seek living areas with less traveling distances which is ideal for areas of our study site.

Our study site not only has a benefit for Amish but also 21st century farmers as well. These benefits are similar to 21st century farmers with the flat farming terrain and the optimal weather for growing crops. Our study site has little to no development which encourages farmers to grow crops because of less pollution from urbanization output. Other benefits for agriculture are soils (excellent glacial soils), topography, climate (reliable rainfall and a decent growing season), and proximity to markets.

GIS Methods

Geographic Information Systems (GIS) refers to the hardware and software used for a computer-based analysis, interpretation, and visualization of map data (Shellito 2017). It was critical to this thesis because it can create maps of watersheds and streams in much more detail than on topographic maps or any other widely assessable sources. The data obtained for this thesis are publicly accessible and were obtained through sites such as The National Map, Earth Explorer, and the auditors of the study counties. The major goals of the GIS methods pursued here was to delineate watersheds of tributaries to the Grand River, and to quantify the proportion of various land uses within each.

First, I identified stream sampling (habitat assessment) locations and delineated watersheds within which I would calculate percentages of land cover, including forest, aquatic (open water and wetlands), and Amish and non-Amish farm properties. The first step in ArcGIS was to download a Digital Elevation Model (DEM), which shows the elevation of the study area down to one meter. DEMs can be found and accessed at on-line sites such as Ohio Geographically Referenced Information Program (OGRIP) and the National Map.

Next, was formulating a series of steps in ArcGIS which led to delineating watershed boundaries. These steps generated important information such as surface water flow direction (i.e., in each 1-m cell), flow accumulation (i.e., indicating differences in surface water between cells), and eventually stream order (i.e., classifying streams according to their number of tributaries). Finally, ArcGIS is able to generate a watershed of each study stream by delineating “pour points” (i.e., digitized points indicating the downstream start of the watershed).

Next, land cover data was downloaded from the National Map of the three counties (Geauga, Trumbull and Mahoning County) and overlaid onto the watersheds previously generated. Figure 6 shows a representation of this and also shows what each color indicates. Once overlaid, I used an ArcGIS tool called “Extract by Mask”, which takes the land cover data and clips it into a watershed boundary. This is important for determining the percentages of land cover within each stream watershed. Land cover data are next stored in each watershed’s “Attribute Table”, which is an ArcGIS table that contains quantitative information for map shapefiles.

Next, I contacted auditors from Ashtabula, Geauga, and Trumbull Counties and received land parcel data, indicating size and ownership. This is Important to this thesis by allowing me to split land within study watersheds into Amish vs non-Amish owned. I found the top 10 most common Amish last names in NE Ohio (Amish America 2013), which are presented in Table 1. Figure 7 shows the Amish parcels identified by this preliminary surname search. However, parcel ownership by a last name that is likely to be Amish does not guarantee the property is an Amish farm. For example, although Miller is a common name in Amish communities, it is a common name in general, and need not necessarily indicate an Amish farm. Also, there are likely many Amish landowners and farmers within the study area who do not have one of the “common” Amish surnames that I used for my parcel search. Consequently, I drove around the study watersheds and noted features such as buggies, traditional white/blue/black clothes on the clotheslines, and lack of electrical wires that indicated an Amish property. Then I adjusted parcel ownership to reflect these features.

Finally, percentages of forest, aquatic, Amish farmland, and non-Amish farmland were calculated for entire watersheds of small Grand River tributaries (Hoffman-Norton Road North and South Creeks, and a small creek within Swine Creek Reservation Park), and within a selected sub-watershed of larger tributaries (Mill, Center, and Baughman Creeks, and an upstream and a downstream reach of Swine Creek). To better reflect more local influences land cover on stream habitat, I concentrated only on watershed areas within 3 – 4 km of the habitat assessment site. I used nearby roads to as boundaries for these sub-watersheds.

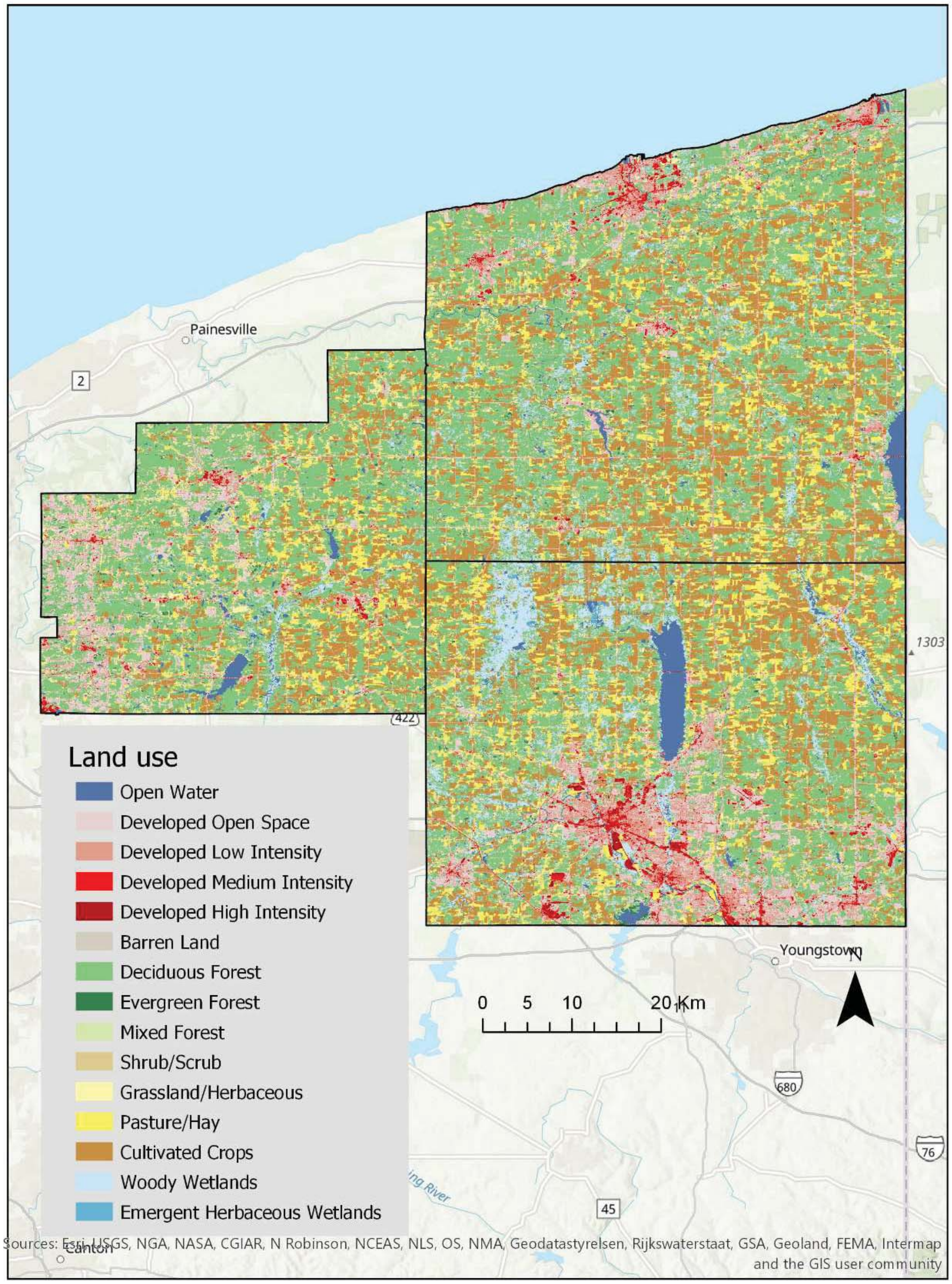


Figure 6. Land cover for three study counties, as indicated by legend.

Table 1. Potential Amish surnames used for initial county auditor search of land parcel ownership.

Miller
Stolzfus
Yoder
Beiler
Schwartz
Troyer
Bontrager
King
Graber
Fisher

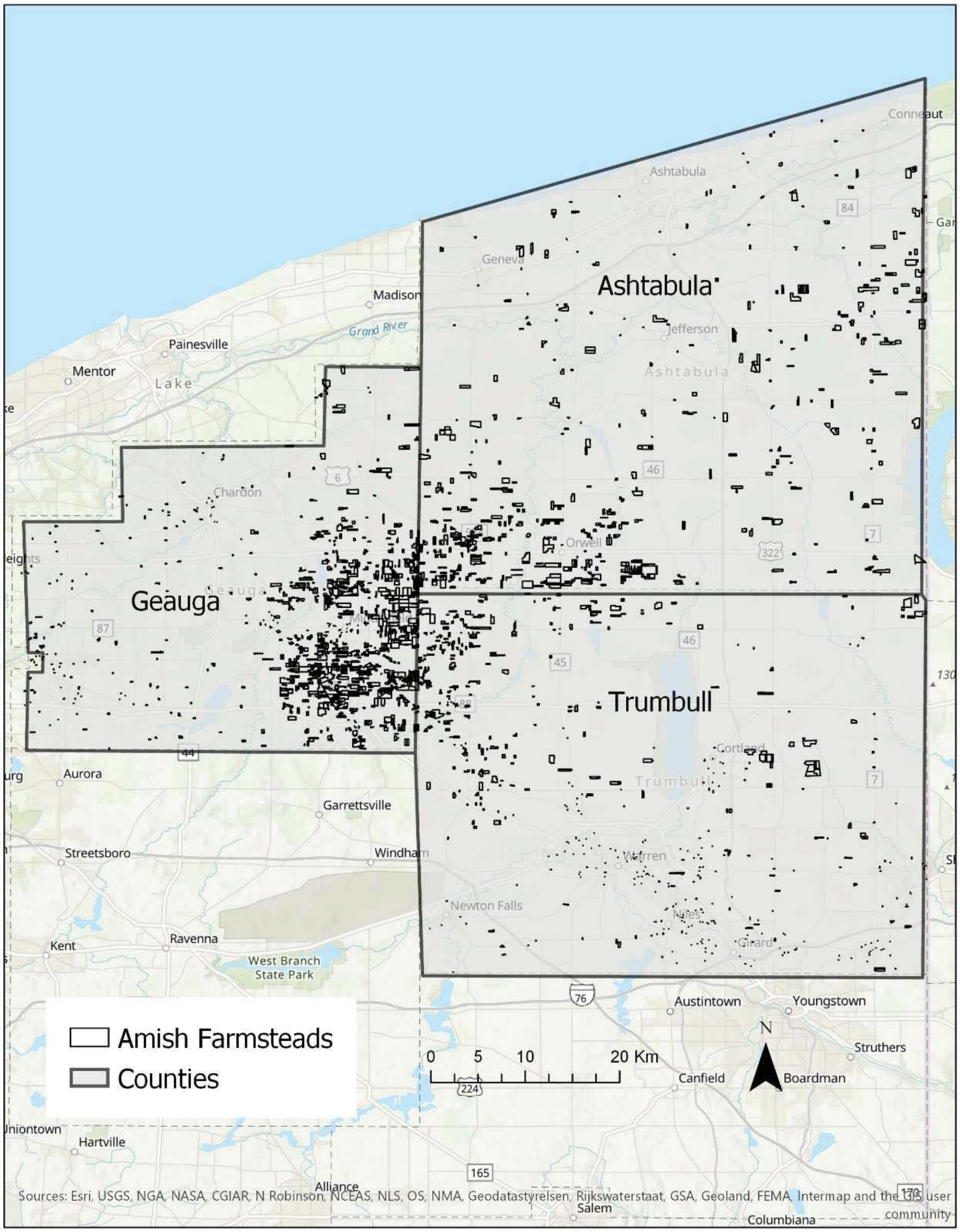
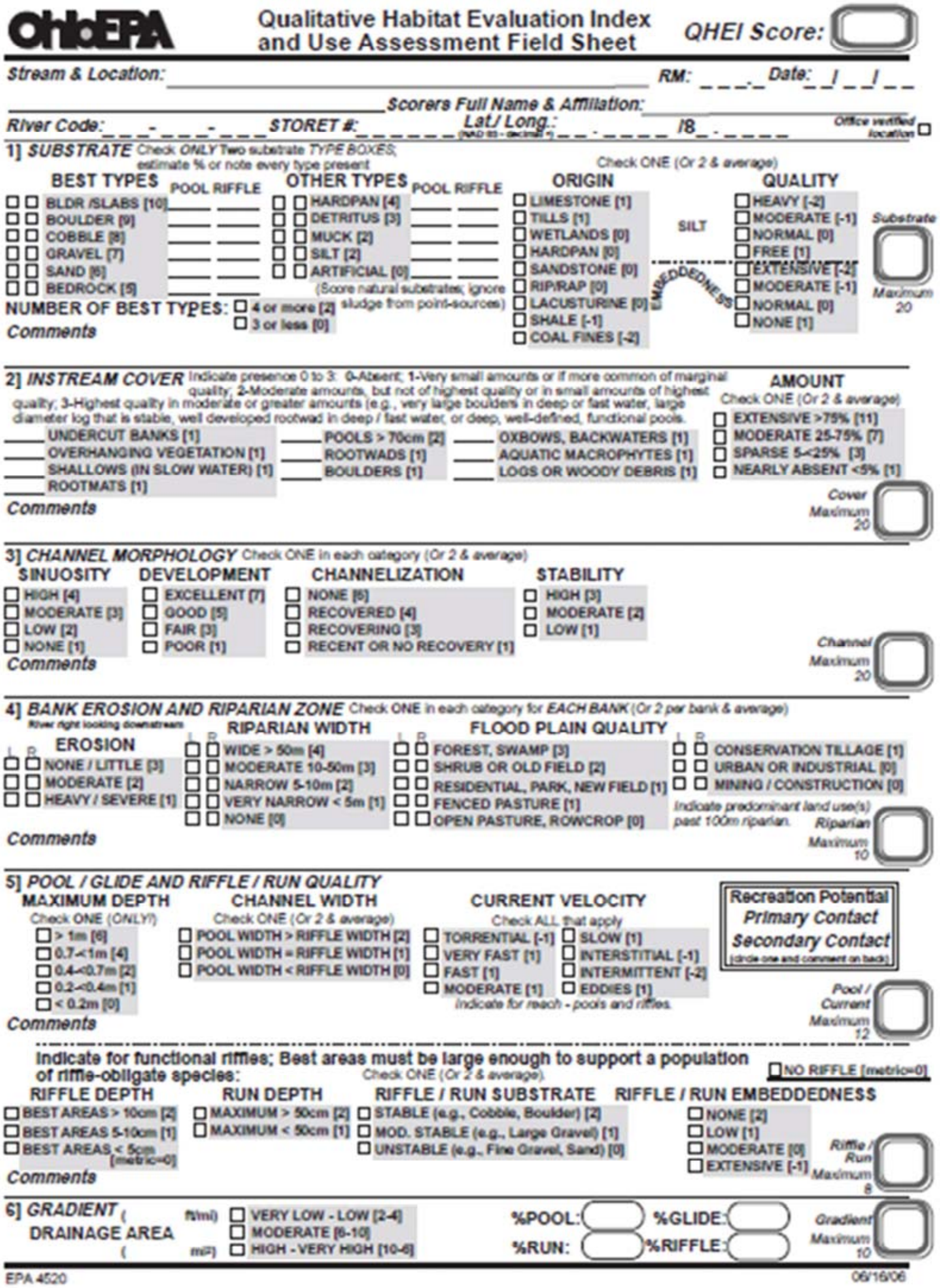


Figure 7. Land parcels within study counties owned by families with "common" Amish surnames listed in Table 1. Indicated parcels need not necessarily all be Amish holdings, nor do they necessarily include all Amish lands. The large concentration of highlighted parcels represents the Middlefield OH Amish community.

Field Methods

To begin, I wanted to make sure all sites were accessible and publically owned. To do this I hiked as well as drove around the study area and determined which streams I wanted to assess. Next, the Qualitative Habitat Evaluation Index (QHEI, Ohio EPA [2006]) was calculated for each study stream at a previously established accessible study reach. This index records semi-qualitative habitat features such as presence, extent, and quality of in-stream cover, woody debris, channel morphology, and sedimentary characteristics of the streams (Figure 8 shows a QHEI score sheet used in the field). The QHEI is reported on a 0-100-point score (Figure 9) for stream habitat quality, which ranges from ≥70 for excellent habitat quality to < 30 for very poor habitat (Ohio EPA 2006).

I also determined the stream gradient immediately above each study site for a distance between 1km and 5km (depending upon stream), taking the elevations on Google Earth at each QHEI assessment point and at points near identifiable road bridges upstream. Interestingly, stream gradients measured this way were quite close to those visually estimated at QHEI points as part of the field assessment.



OhioEPA

Qualitative Habitat Evaluation Index and Use Assessment Field Sheet

QHEI Score:

Stream & Location: RM: ___ Date: _/_/_

Scorers Full Name & Affiliation:

River Code: __-___-___ STORET #: ______ Lat/ Long.: (NAD 83 - decimal °) __.____ /8_.____ Office verified location

1] SUBSTRATE Check ONLY Two substrate TYPE BOXES; estimate % or note every type present

BEST TYPES POOL RIFFLE: BLDR /SLABS [10]; BOULDER [9]; COBBLE [8]; GRAVEL [7]; SAND [6]; BEDROCK [5]

OTHER TYPES POOL RIFFLE: HARDPAN [4]; DETRITUS [3]; MUCK [2]; SILT [2]; ARTIFICIAL [0] (Score natural substrates; ignore sludge from point-sources)

NUMBER OF BEST TYPES: 4 or more [2]; 3 or less [0]

Check ONE (Or 2 & average)

ORIGIN: LIMESTONE [1]; TILLS [1]; WETLANDS [0]; HARDPAN [0]; SANDSTONE [0]; RIP/RAP [0]; LACUSTURINE [0]; SHALE [-1]; COAL FINES [-2]

QUALITY: SILT: HEAVY [-2]; MODERATE [-1]; NORMAL [0]; FREE [1]. EMBEDDEDNESS: EXTENSIVE [-2]; MODERATE [-1]; NORMAL [0]; NONE [1]

Substrate Maximum 20

Comments

2] INSTREAM COVER Indicate presence 0 to 3: 0-Absent; 1-Very small amounts or if more common of marginal quality; 2-Moderate amounts, but not of highest quality or in small amounts of highest quality; 3-Highest quality in moderate or greater amounts (e.g., very large boulders in deep or fast water, large diameter log that is stable, well developed rootwad in deep / fast water, or deep, well-defined, functional pools.

___ UNDERCUT BANKS [1]; ___ OVERHANGING VEGETATION [1]; ___ SHALLOWS (IN SLOW WATER) [1]; ___ ROOTMATS [1]; ___ POOLS > 70cm [2]; ___ ROOTWADS [1]; ___ BOULDERS [1]; ___ OXBOWS, BACKWATERS [1]; ___ AQUATIC MACROPHYTES [1]; ___ LOGS OR WOODY DEBRIS [1]

AMOUNT Check ONE (Or 2 & average): EXTENSIVE >75% [11]; MODERATE 25-75% [7]; SPARSE 5-<25% [3]; NEARLY ABSENT <5% [1]

Comments

Cover Maximum 20

3] CHANNEL MORPHOLOGY Check ONE in each category (Or 2 & average)

SINUOSITY: HIGH [4]; MODERATE [3]; LOW [2]; NONE [1]

DEVELOPMENT: EXCELLENT [7]; GOOD [5]; FAIR [3]; POOR [1]

CHANNELIZATION: NONE [6]; RECOVERED [4]; RECOVERING [3]; RECENT OR NO RECOVERY [1]

STABILITY: HIGH [3]; MODERATE [2]; LOW [1]

Comments

Channel Maximum 20

4] BANK EROSION AND RIPARIAN ZONE Check ONE in each category for EACH BANK (Or 2 per bank & average)

River right looking downstream

EROSION (L R): NONE / LITTLE [3]; MODERATE [2]; HEAVY / SEVERE [1]

RIPARIAN WIDTH (L R): WIDE > 50m [4]; MODERATE 10-50m [3]; NARROW 5-10m [2]; VERY NARROW < 5m [1]; NONE [0]

FLOOD PLAIN QUALITY (L R): FOREST, SWAMP [3]; SHRUB OR OLD FIELD [2]; RESIDENTIAL, PARK, NEW FIELD [1]; FENCED PASTURE [1]; OPEN PASTURE, ROWCROP [0]; CONSERVATION TILLAGE [1]; URBAN OR INDUSTRIAL [0]; MINING / CONSTRUCTION [0]

Indicate predominant land use(s) past 100m riparian.

Comments

Riparian Maximum 10

5] POOL / GLIDE AND RIFFLE / RUN QUALITY

MAXIMUM DEPTH Check ONE (ONLY!): > 1m [6]; 0.7-<1m [4]; 0.4-<0.7m [2]; 0.2-<0.4m [1]; < 0.2m [0]

CHANNEL WIDTH Check ONE (Or 2 & average): POOL WIDTH > RIFFLE WIDTH [2]; POOL WIDTH = RIFFLE WIDTH [1]; POOL WIDTH < RIFFLE WIDTH [0]

CURRENT VELOCITY Check ALL that apply: TORRENTIAL [-1]; VERY FAST [1]; FAST [1]; MODERATE [1]; SLOW [1]; INTERSTITIAL [-1]; INTERMITTENT [-2]; EDDIES [1]. Indicate for reach - pools and riffles.

Recreation Potential: Primary Contact / Secondary Contact (circle one and comment on back)

Comments

Pool / Current Maximum 12

Indicate for functional riffles; Best areas must be large enough to support a population of riffle-obligate species: Check ONE (Or 2 & average). NO RIFFLE [metric=0]

RIFFLE DEPTH: BEST AREAS > 10cm [2]; BEST AREAS 5-10cm [1]; BEST AREAS < 5cm [metric=0]

RUN DEPTH: MAXIMUM > 50cm [2]; MAXIMUM < 50cm [1]

RIFFLE / RUN SUBSTRATE: STABLE (e.g., Cobble, Boulder) [2]; MOD. STABLE (e.g., Large Gravel) [1]; UNSTABLE (e.g., Fine Gravel, Sand) [0]

RIFFLE / RUN EMBEDDEDNESS: NONE [2]; LOW [1]; MODERATE [0]; EXTENSIVE [-1]

Comments

Riffle / Run Maximum 8

6] GRADIENT (ft/mi) DRAINAGE AREA (mi²): VERY LOW - LOW [2-4]; MODERATE [6-10]; HIGH - VERY HIGH [10-6]

%POOL: %GLIDE: %RUN: %RIFFLE:

Gradient Maximum 10

EPA 4520 06/16/06

Figure 8. Qualitative Habitat Evaluation Index score sheet as used by evaluators in the field.

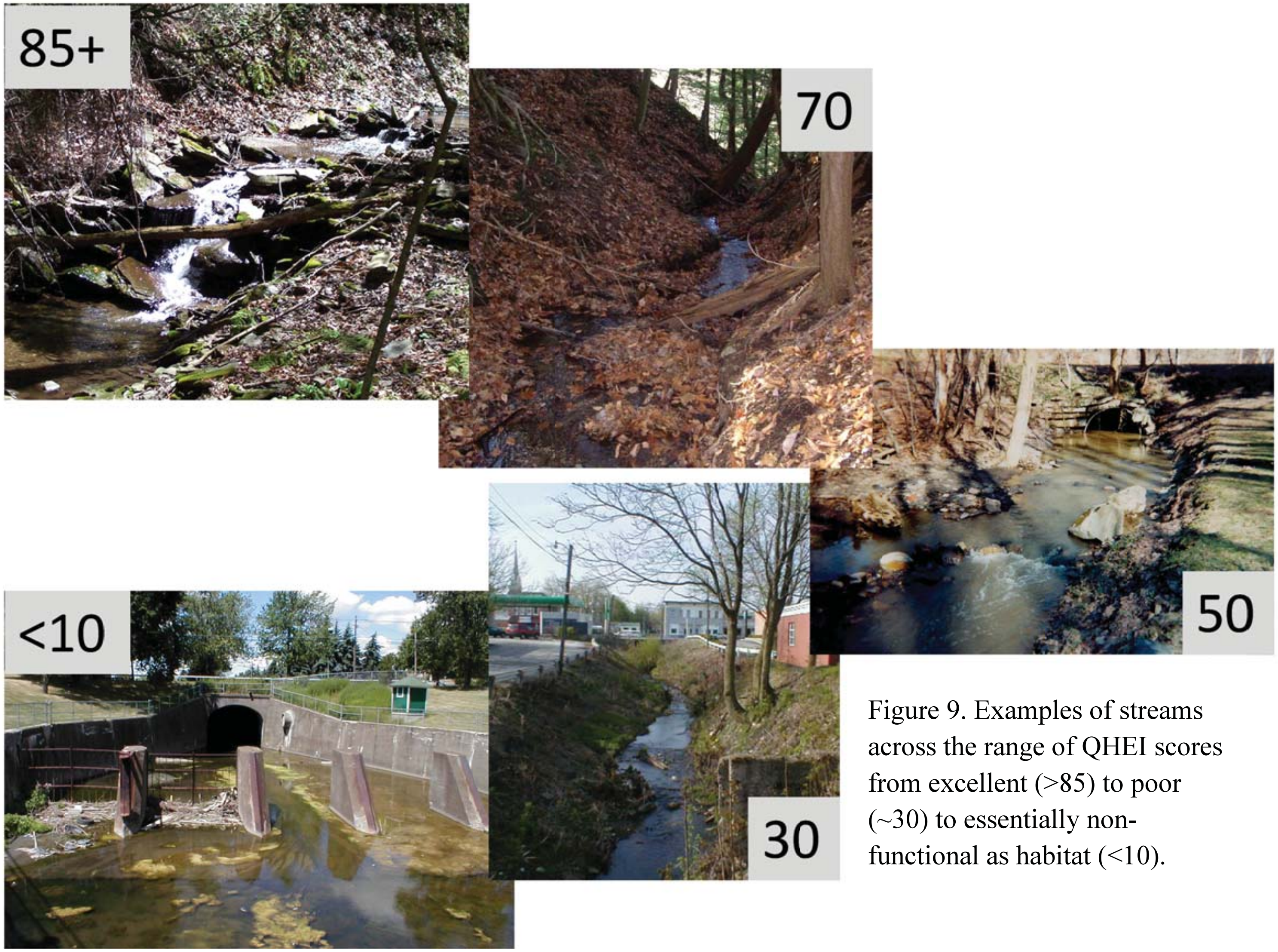


Figure 9. Examples of streams across the range of QHEI scores from excellent (>85) to poor (~30) to essentially non-functional as habitat (<10).

Results

This thesis revealed a lot of variability in watershed land cover among streams. Figures 10-17 present land cover distributions and parcels, including preliminary Amish vs. non-Amish ownership. Also, in addition to the figures, Table 2 reports the total watershed areas along with the percentages of land cover types. Swine Creek (downstream reach) and Center Creek represent watersheds with higher percentages of aquatic (open water and wetlands) land cover, while some watersheds such as the Swine Creek Reservation stream and Swine Creek (upstream reach) had very little such cover. Watersheds that are more dominated by forest include both Hoffman Norton Road streams and Swine Creek (upstream). In contrast, Baughman Creek and Swine Creek (downstream) were on the lower end of forest cover. In terms of farmland, Mill Creek, Swine Creek (downstream), Swine Creek (upstream), and the Swine Creek Reservation stream all had abundant Amish farming. Center Creek, Baughman Creek, and both Hoffman Norton Road streams had entirely non-Amish farming. Not unexpectedly, watersheds west of the Grand River and near Amish communities in Mesopotamia and Middlefield were mostly Amish farming, while those to the east were dominated by non-Amish farming.

Table 3 presents stream gradients in the 1 – 5-km reaches above habitat evaluation sites. Streams centrally located in relation to the Grand River itself and the wetland dominated State of Ohio game lands (Center, Mill, Baughman, Swine Creek downstream) had very low gradients. Swine Creek (upstream) and the Swine Creek Reservation stream had the highest gradients, and are located in the hillier land to the west.

There was a very strong negative correlation between watershed percentage of Amish farmland and non-Amish farmland (Table 4). There was also a *positive* correlation between stream gradient and watershed Amish farmland. The latter simply indicates that Amish farmland is increasingly common in the higher elevations to the west of the Grand River, and nearer to the Village of Middlefield and its Amish community.

Table 5 reports QHEI scores, ranging from 47 (poor) to 80 (excellent), along with each major category score for each watershed. Taking this data, Table 6 shows correlations between total QHEI scores and each of the major categories of this habitat assessment. Total QHEI score was highly correlated with stream gradient (estimated at the QHEI site) and with substrate heterogeneity. In contrast, QHEI was negatively correlated with riparian zone width, which was strongly negatively correlated with substrate heterogeneity (Table 6). The low gradient wide-floodplain streams such as Center and Mill Creeks had homogeneous fine sediments in their channels, which depressed their total QHEI scores.

Table 7 and Figure 18 present results of Principle Components Analysis (PCA) of watershed areas, percentages of land cover, and calculated near-upstream gradients for study streams. The graph in Figure 18 presents a bubble plot of watersheds in PCA ordination, in which watershed percentage of Amish farmland and stream gradient are positively associated with the x-axis, and percentage non-Amish negatively associated with the x-axis. Aquatic land cover was positively associated with the *y-axis*, and forest cover negatively. Table 8 presents Pearson bivariate correlations of total QHEI scores and PCA axis scores based on land cover percentages in study stream watersheds. This analysis indicated no correlations between QHEI scores and PCA axis scores.

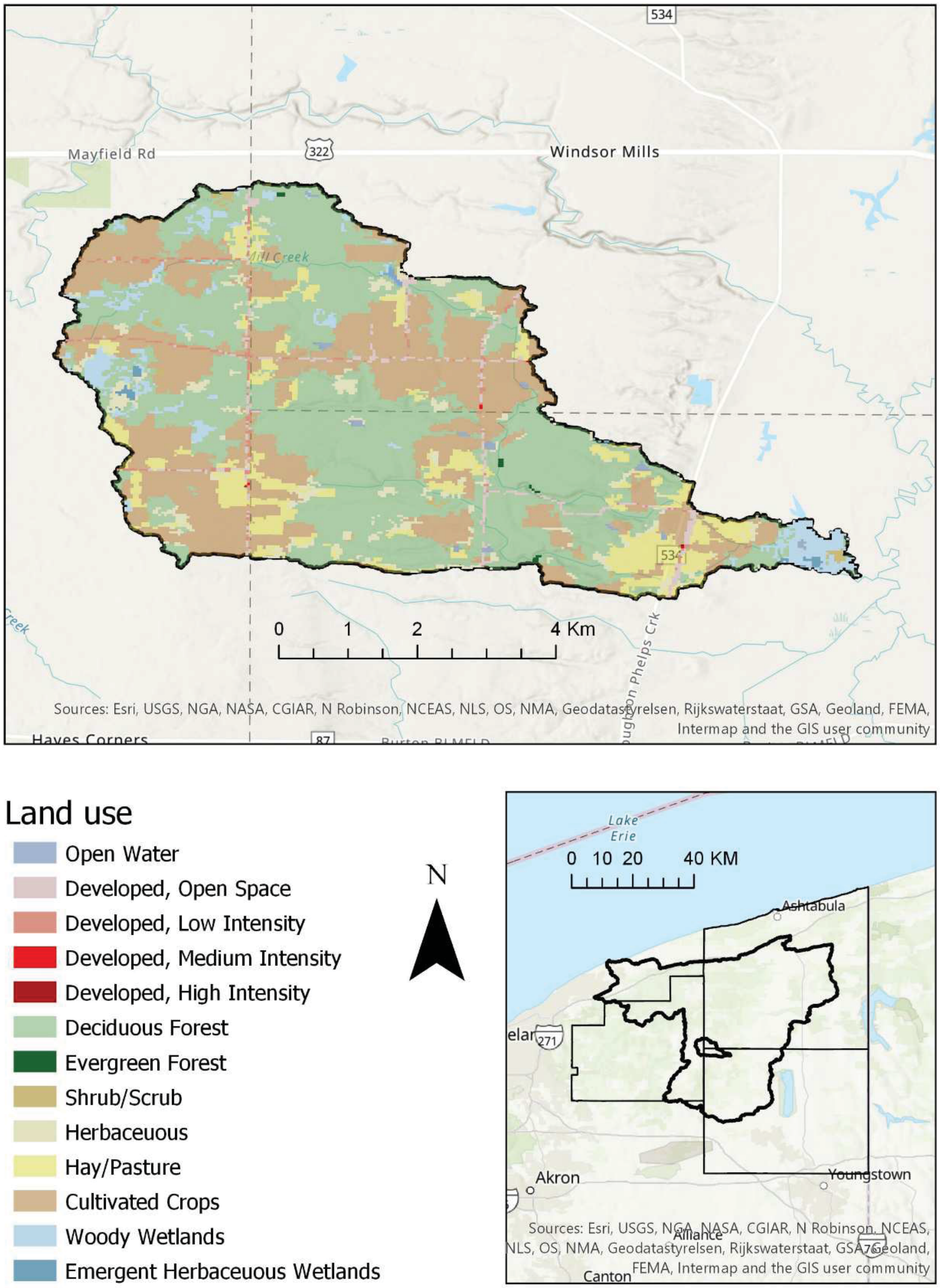


Figure 10a. Land cover map of the Mill Creek watershed and location within the Grand River Watershed. Land uses are as indicated in legend.

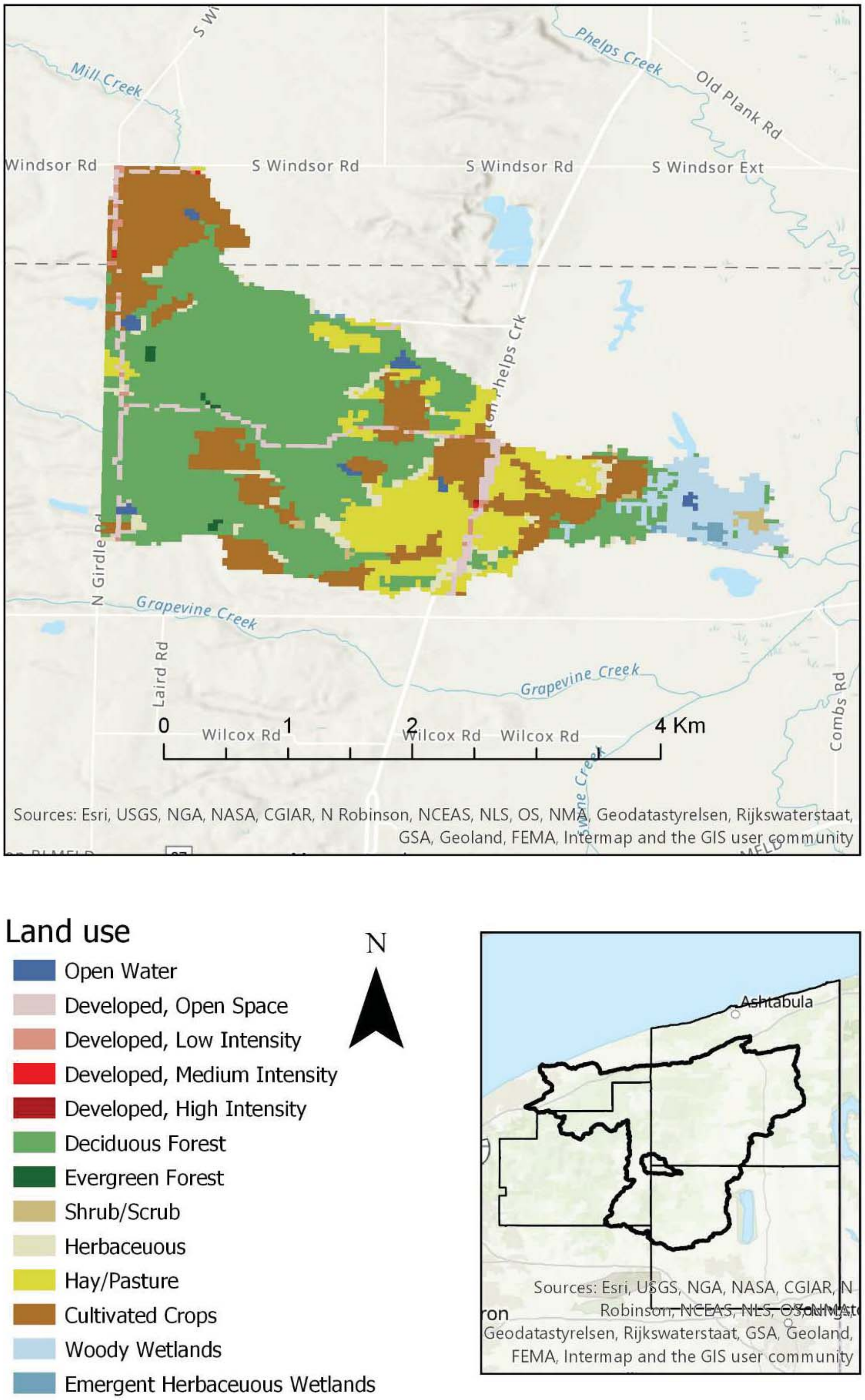


Figure 10b. Land cover within portion of Mill Creek watershed in which land cover was compared to habitat quality (QHEI scores).

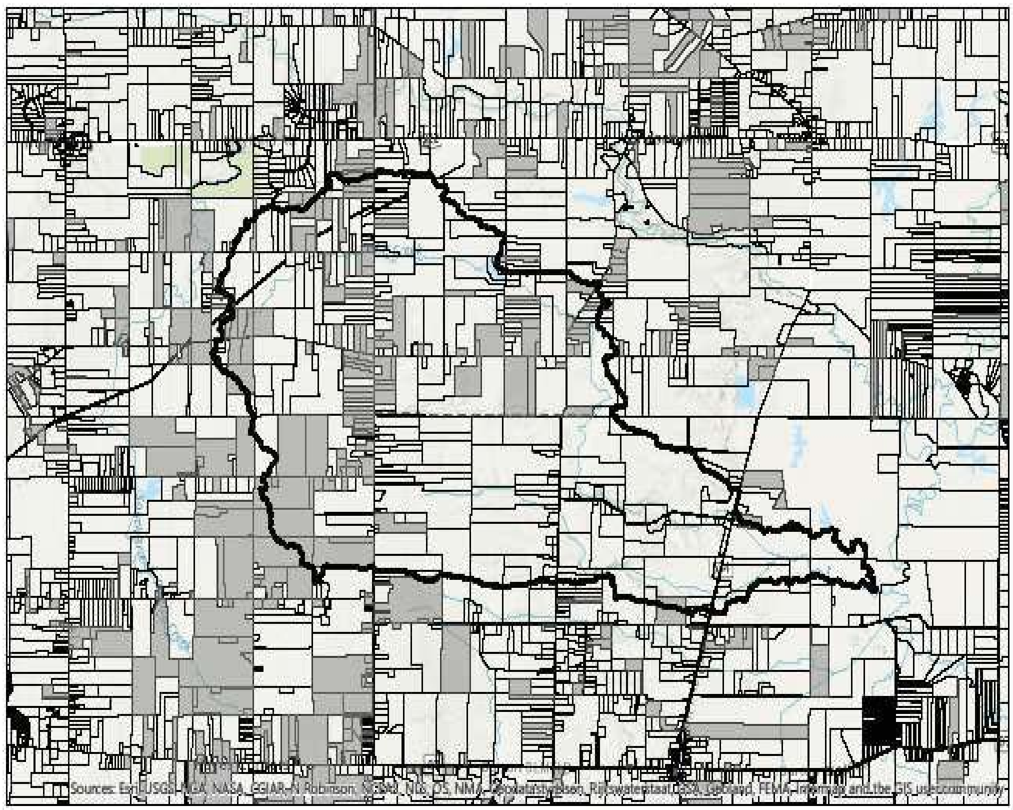


Figure 10c. Land parcels within the Mill Creek watershed. Parcels putatively identified as Amish by surname search are shown in grey.

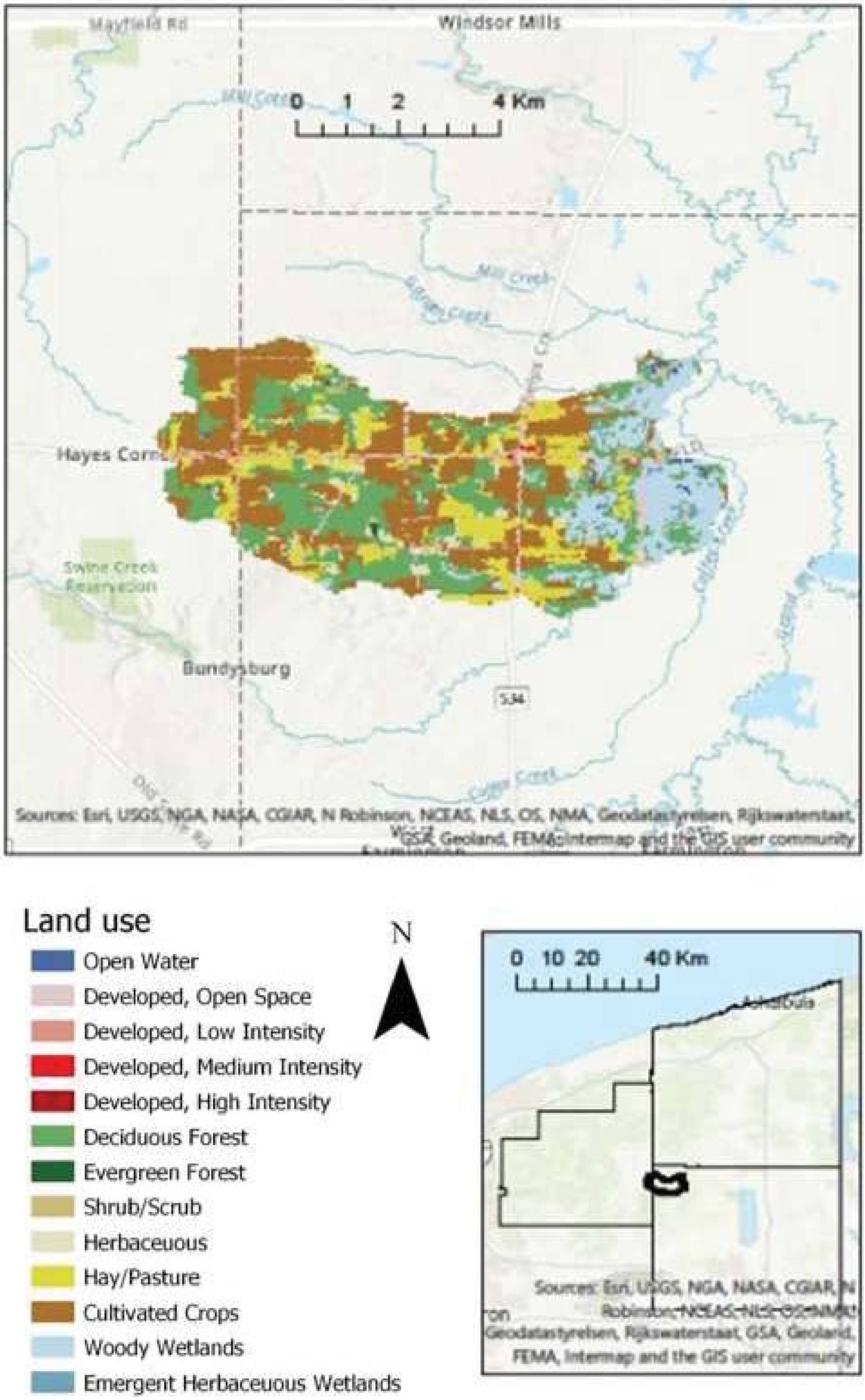


Figure 11a. Land cover map of the Swine Creek (downstream) watershed and location within the Grand River Watershed. Land uses are as indicated in legend.

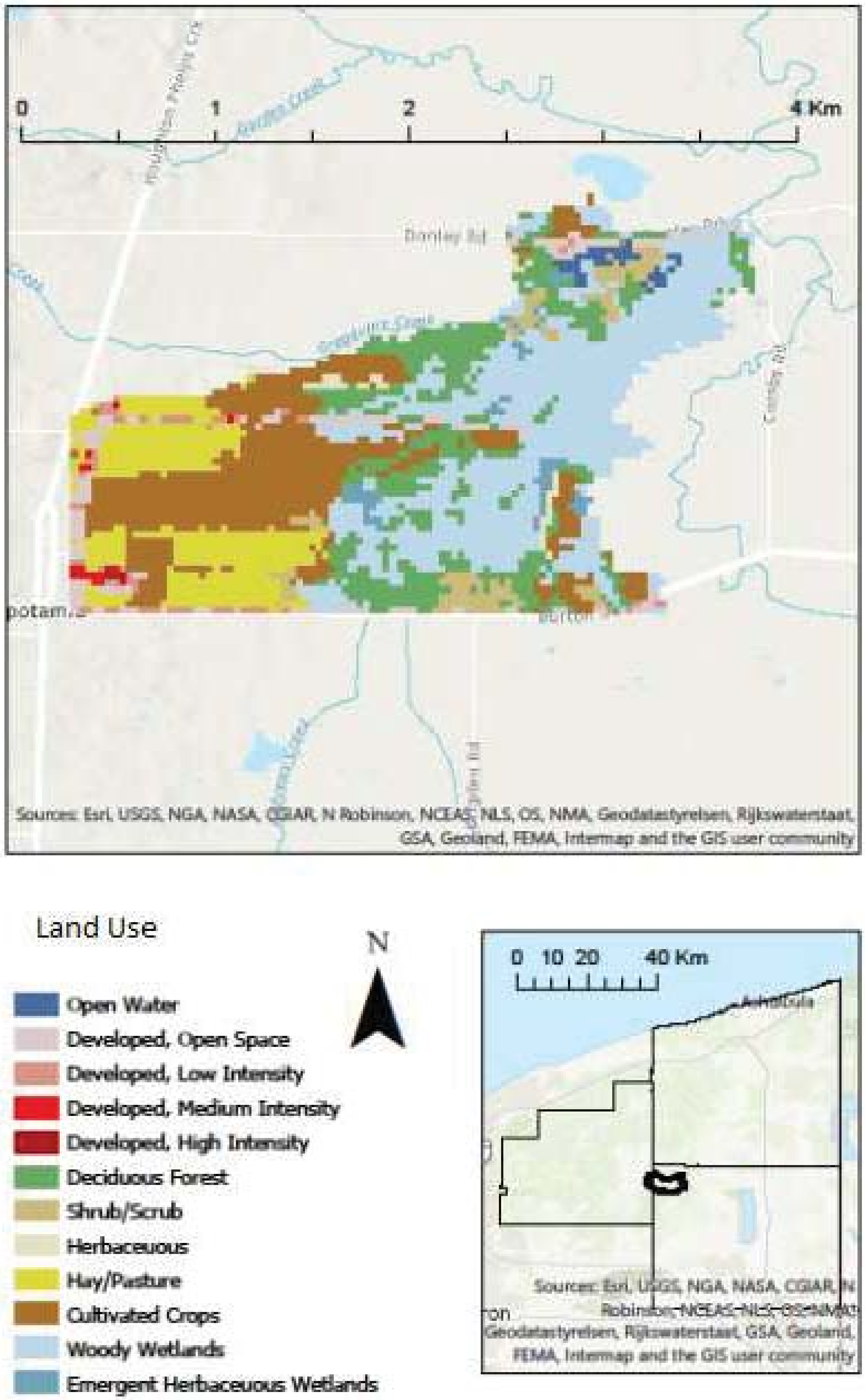


Figure 11b. Land cover within portion of Swine Creek (downstream) watershed in which land cover was compared to habitat quality (QHEI scores).

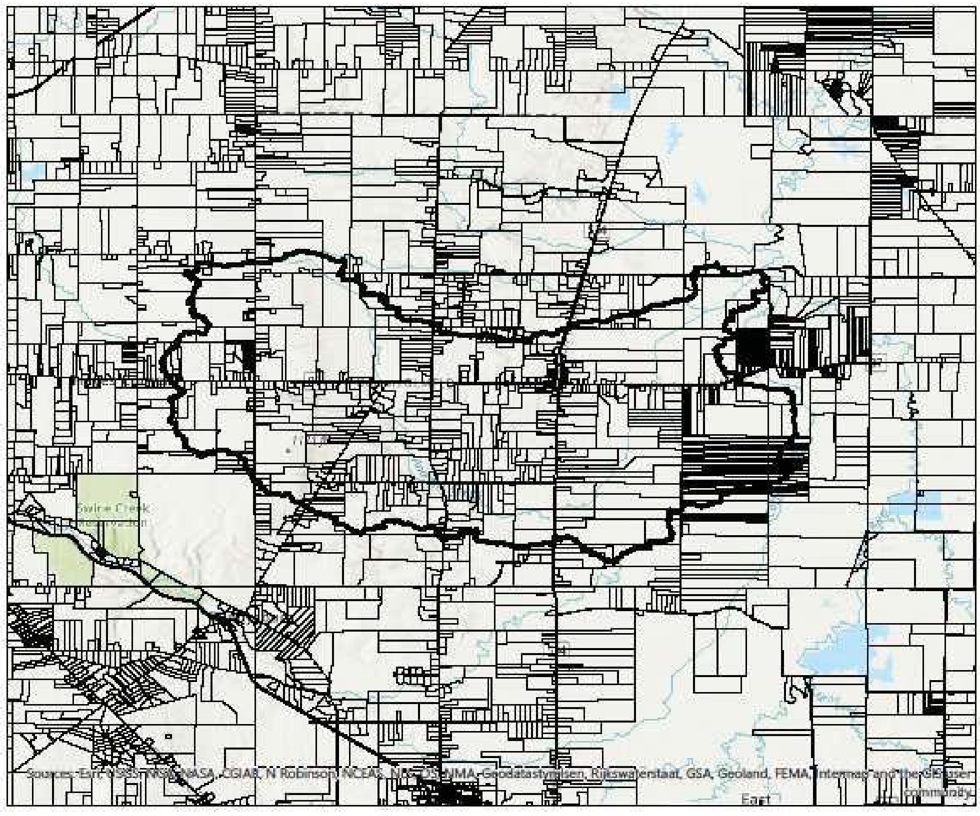


Figure 11c. Land parcels within the Swine Creek (downstream) watershed. Parcels putatively identified as Amish by surname search are shown in grey.

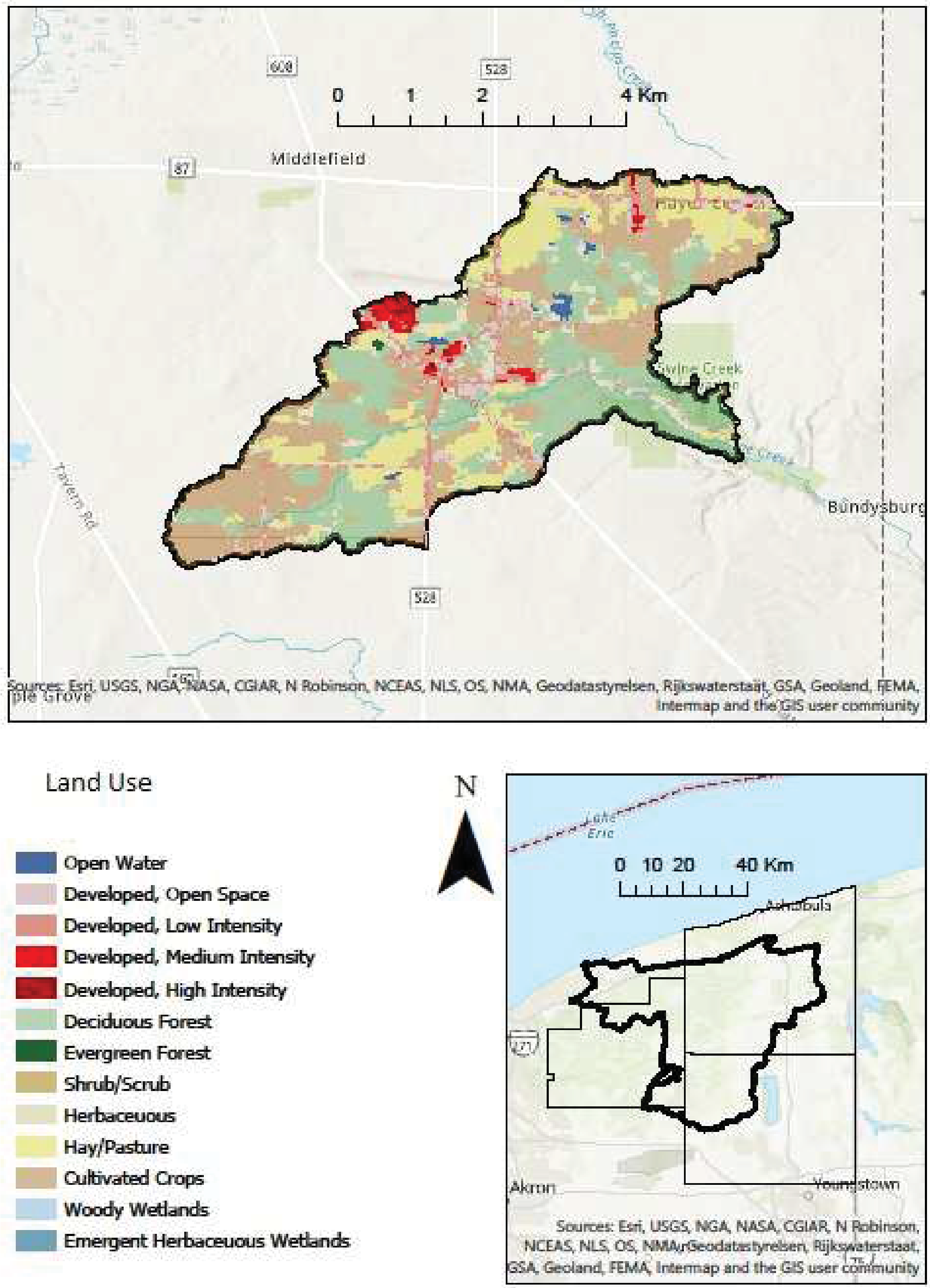


Figure 12a. Land cover map of the Swine Creek (upstream) watershed and location within the Grand River Watershed. Land uses are as indicated in legend.

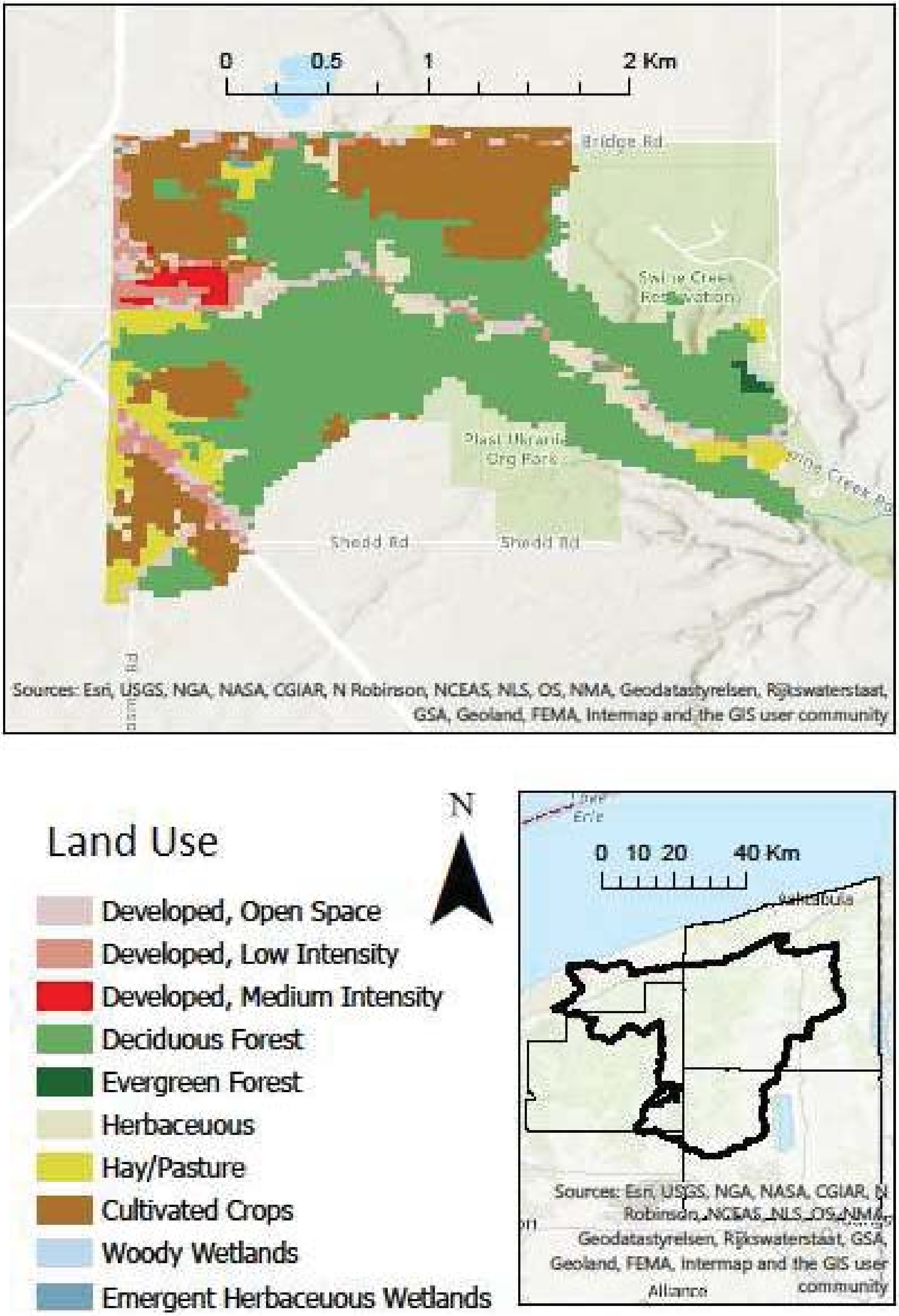


Figure 12b. Land cover within portion of Swine Creek (upstream) watershed in which land cover was compared to habitat quality (QHEI scores).

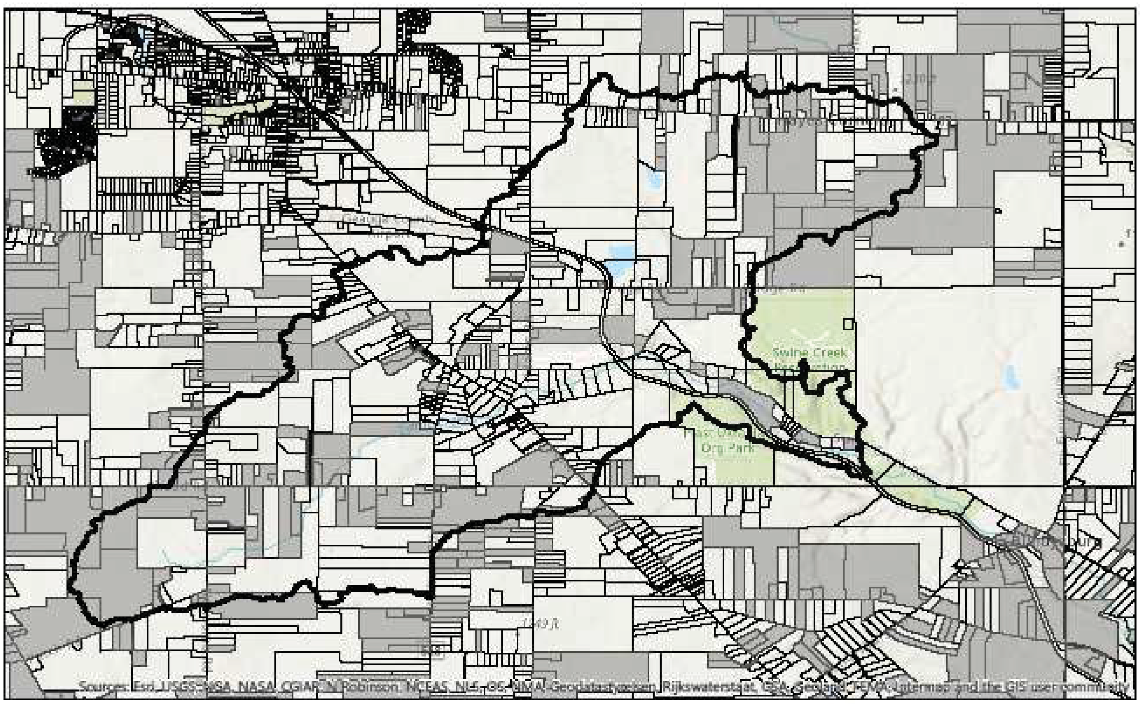


Figure 12c. Land parcels within the Swine Creek (upstream) watershed. Parcels putatively identified as Amish by surname search are shown in grey.

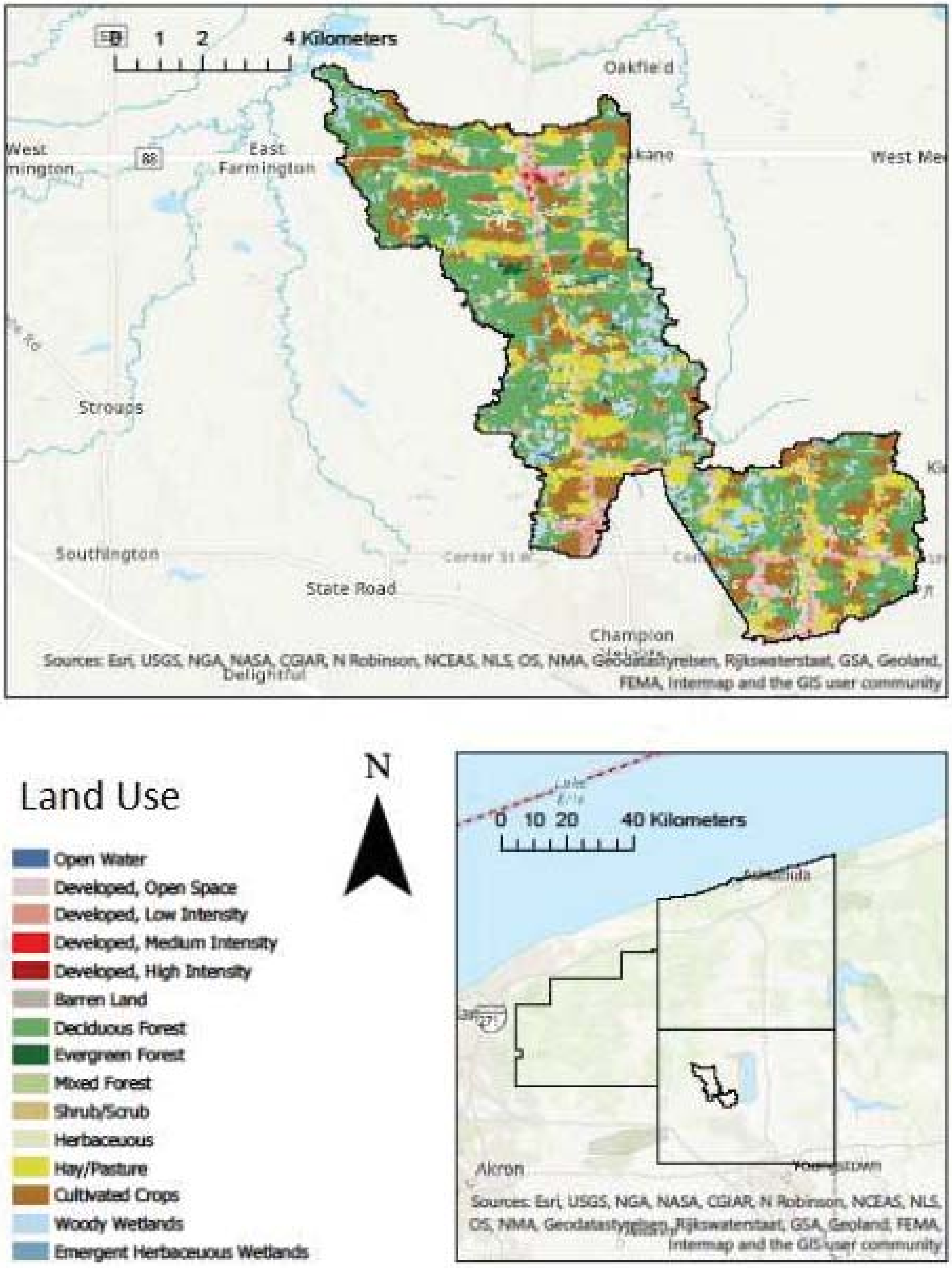


Figure 13a. Land cover map of the Center Creek watershed and location within the Grand River Watershed. Land uses are as indicated in legend.

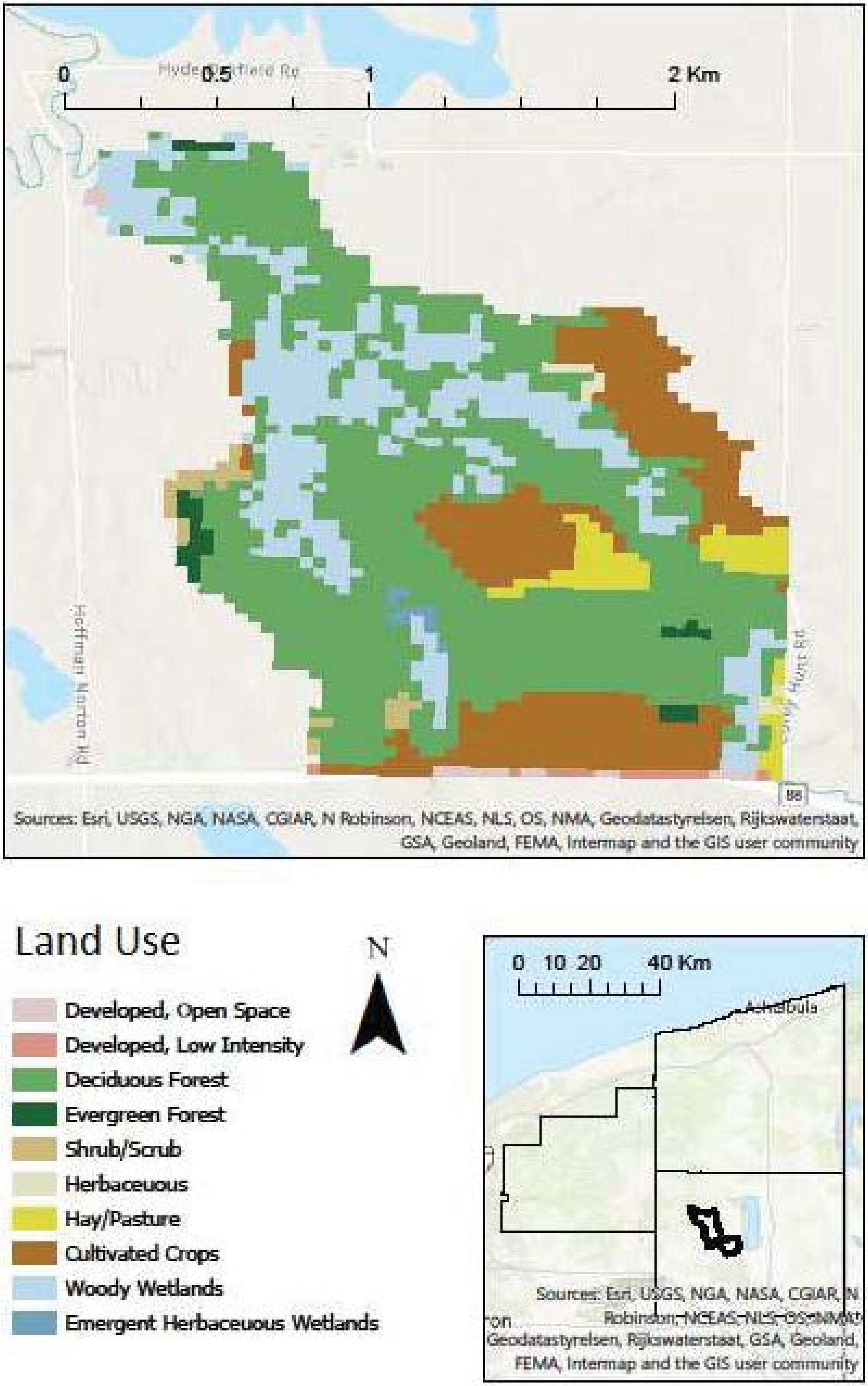


Figure 13b. Land cover within portion of Center Creek watershed in which land cover was compared to habitat quality (QHEI scores).

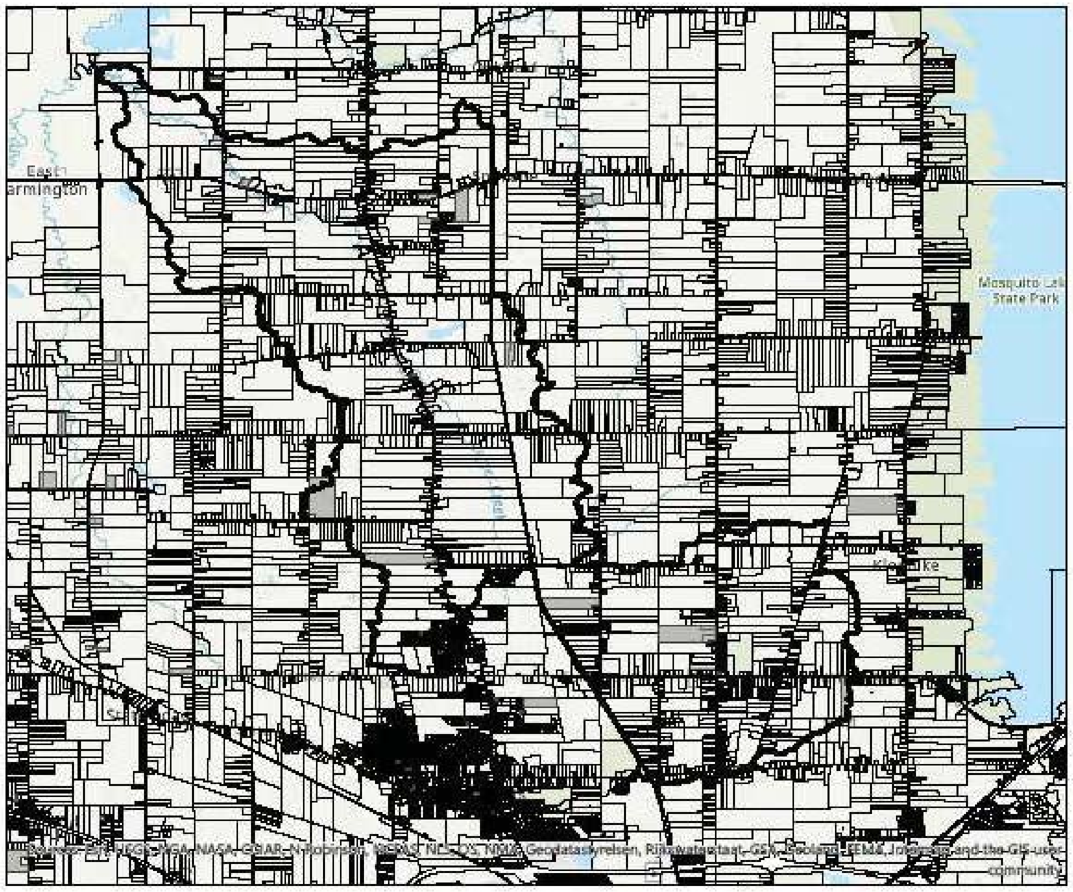


Figure 13c. Land parcels within the Center Creek watershed. Parcels putatively identified as Amish by surname search are shown in grey.

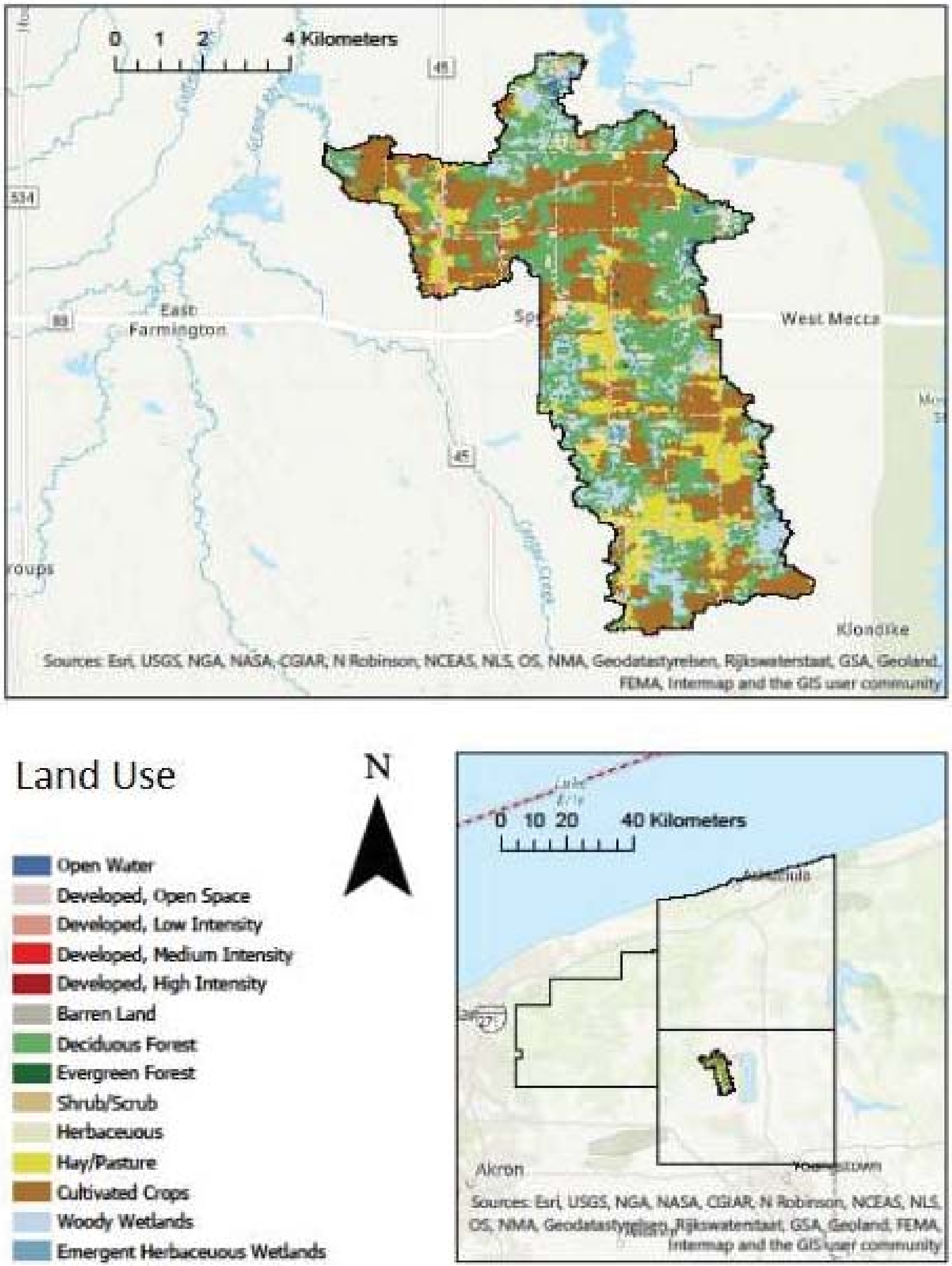


Figure 14a. Land cover map of the Baughman Creek watershed and location within the Grand River Watershed. Land uses are as indicated in legend.

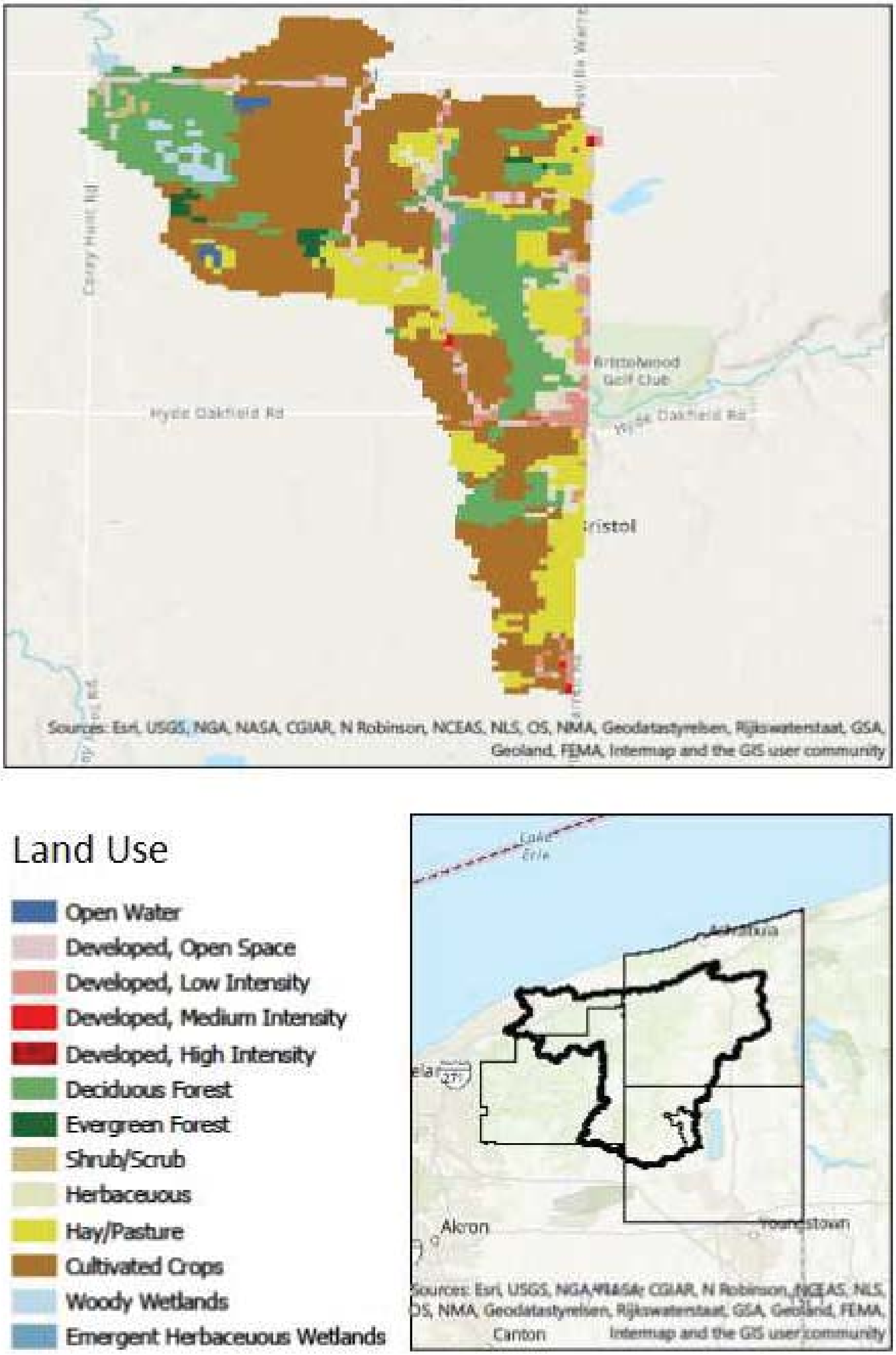


Figure 14b. Land cover within portion of Baughman Creek watershed in which land cover was compared to habitat quality (QHEI scores).

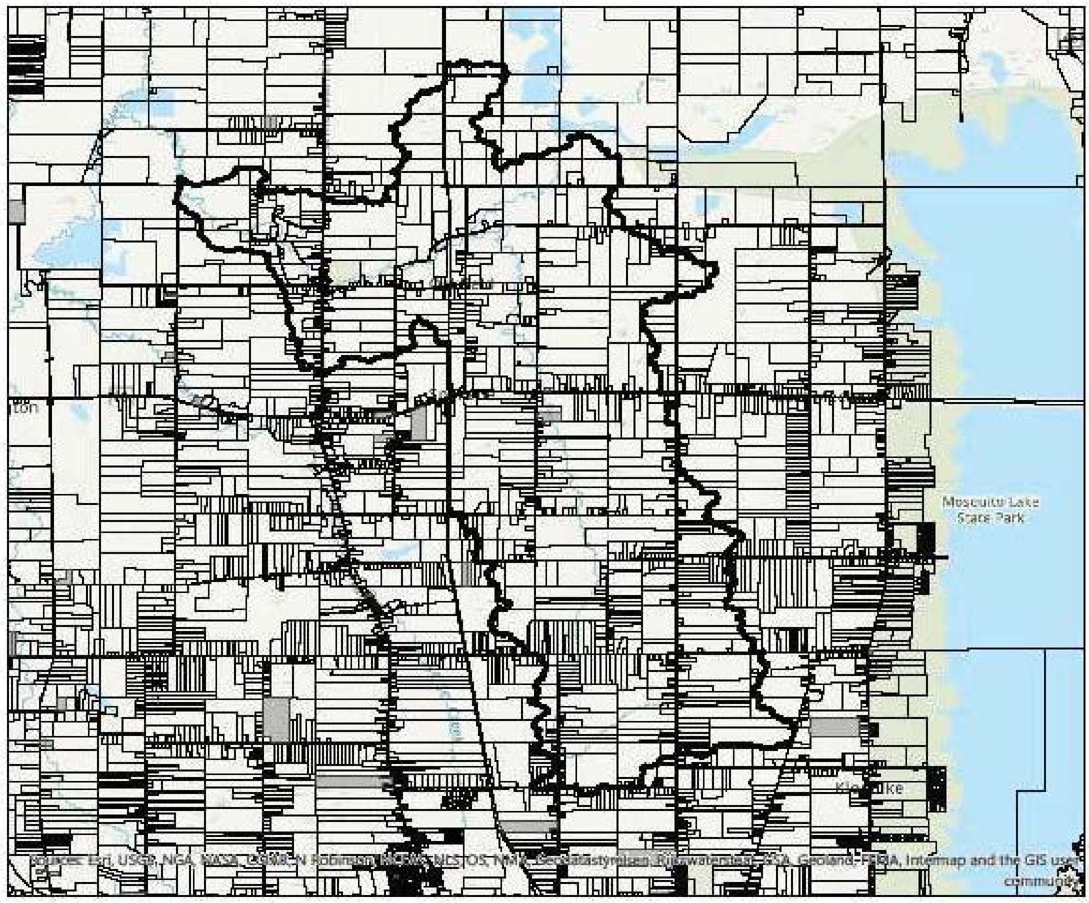


Figure 14c. Land parcels within the Baughman Creek watershed. Parcels putatively identified as Amish by surname search are shown in grey.

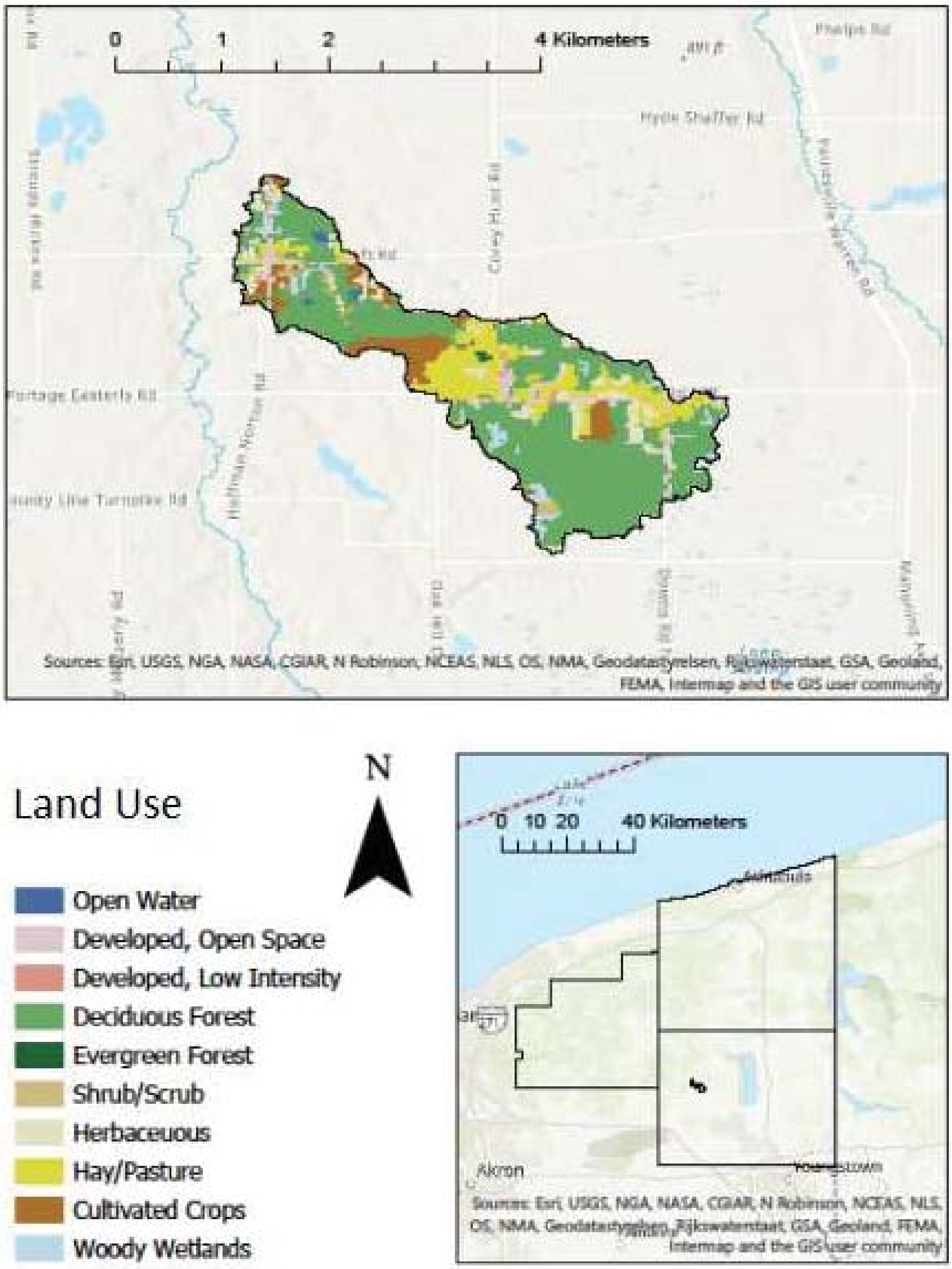


Figure 15a. Land cover map of the Hoffman-Norton Road (North) Creek watershed and location within the Grand River Watershed. Land uses are as indicated in legend.

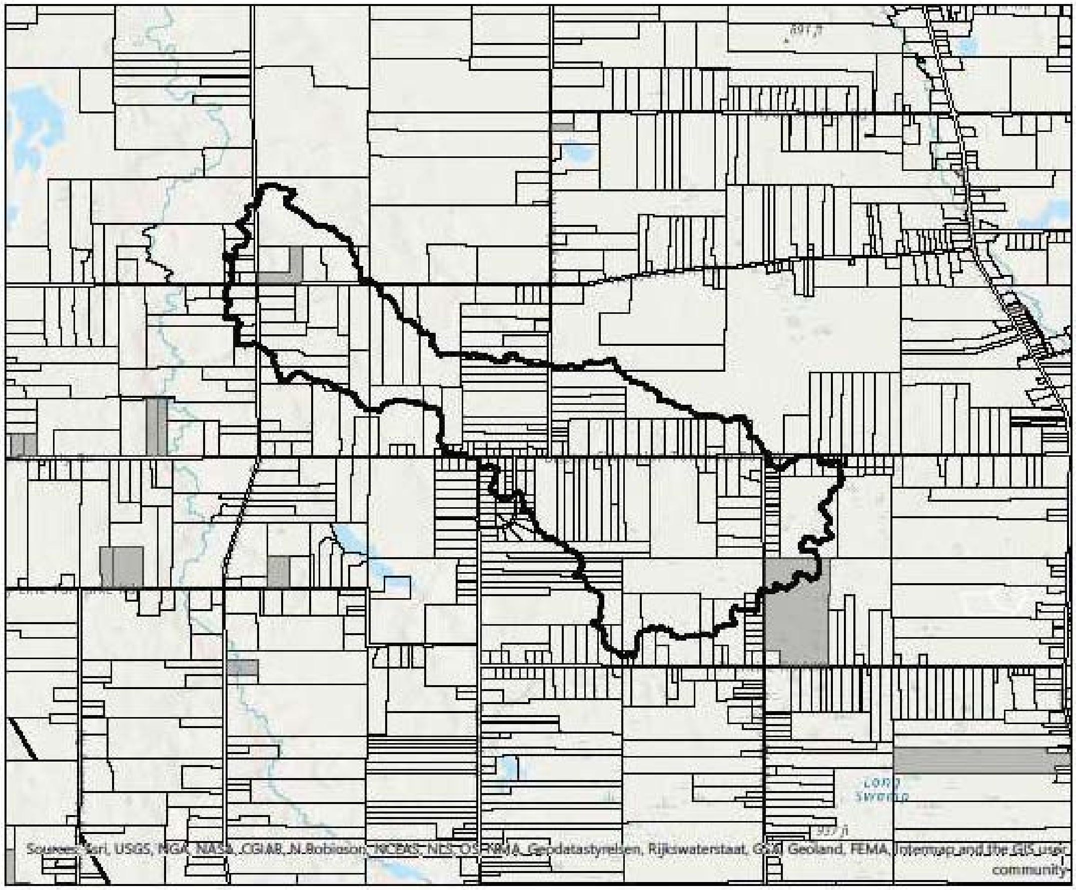


Figure 15b. Land parcels within the Hoffman-Norton Road (North) Creek watershed. Parcels putatively identified as Amish by surname search are shown in grey.

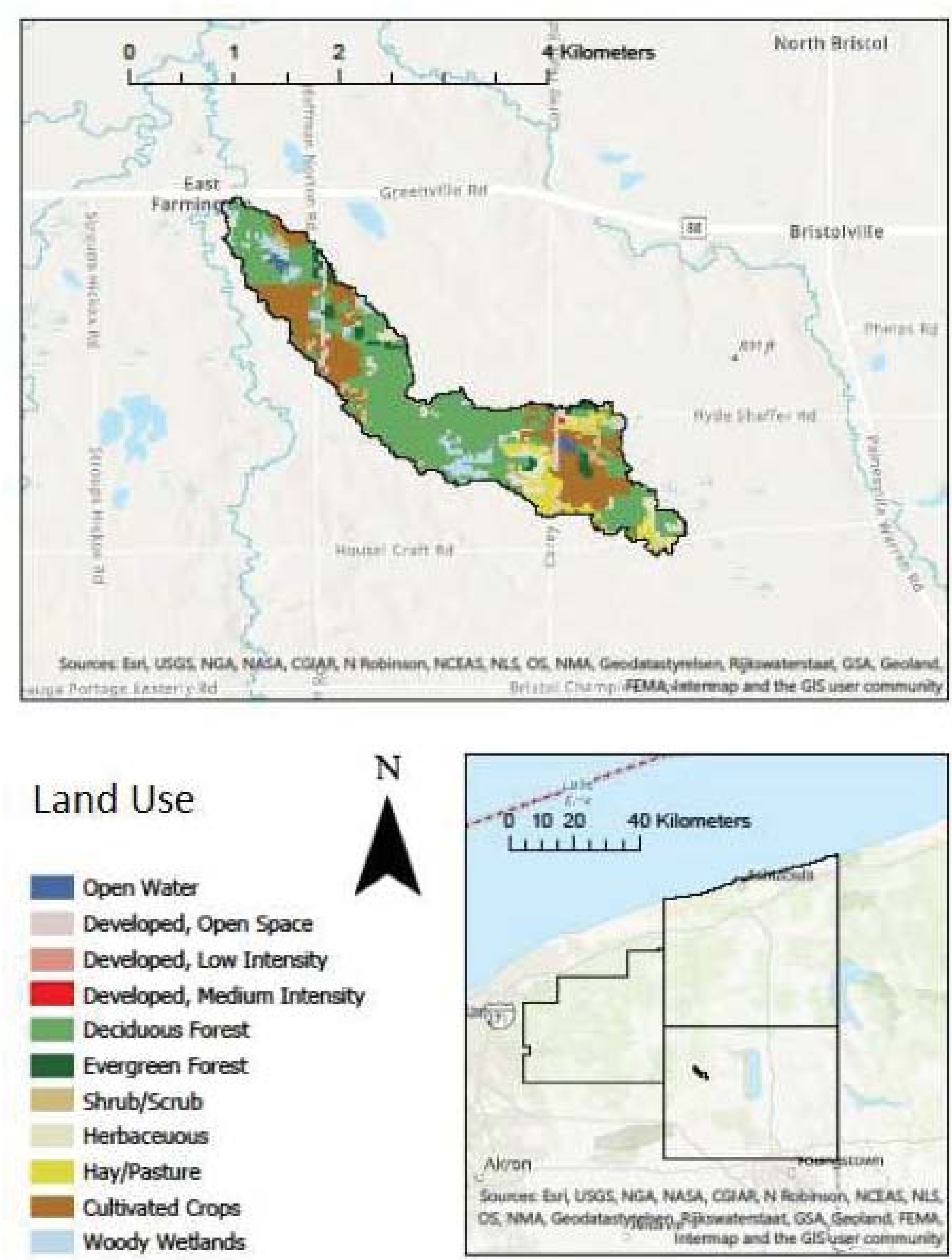


Figure 16a. Land cover map of the Hoffman-Norton Road (South) Creek watershed and location within the Grand River Watershed. Land uses are as indicated in legend.

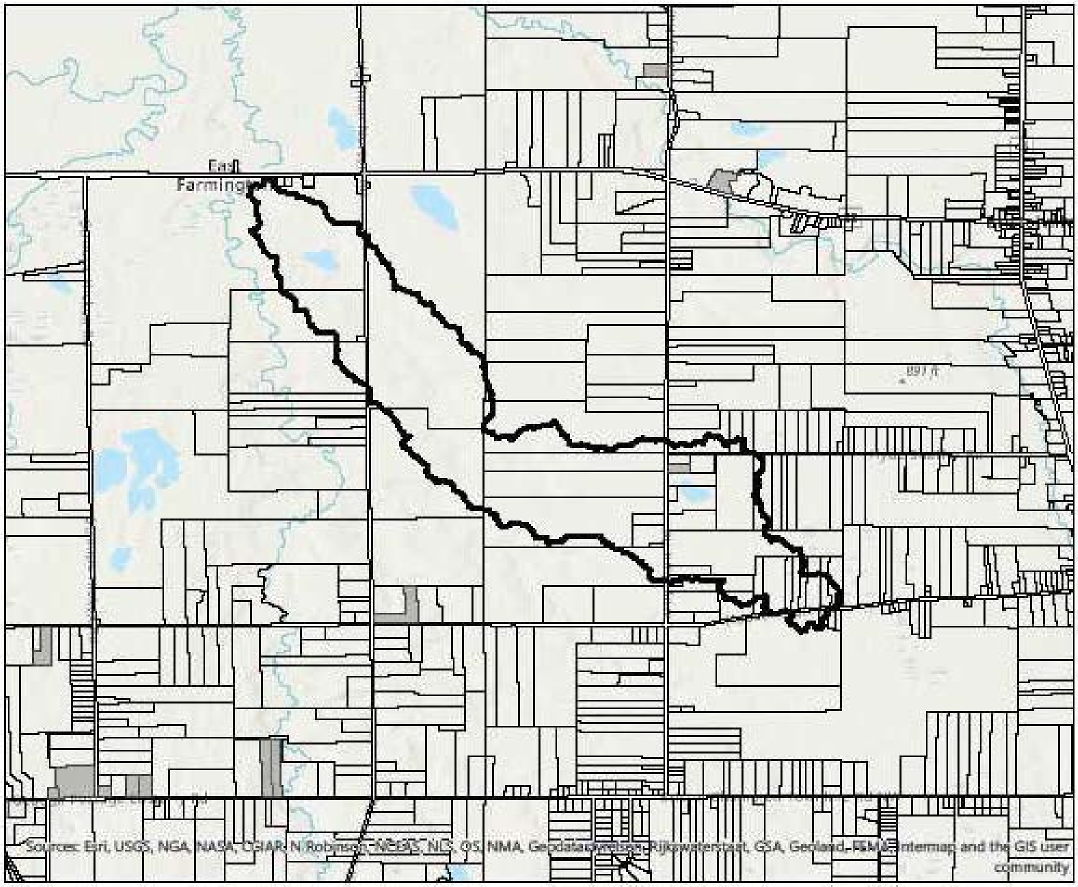


Figure 16b. Land parcels within the Hoffman-Norton Road (South) Creek watershed. Parcels putatively identified as Amish by surname search are shown in grey.

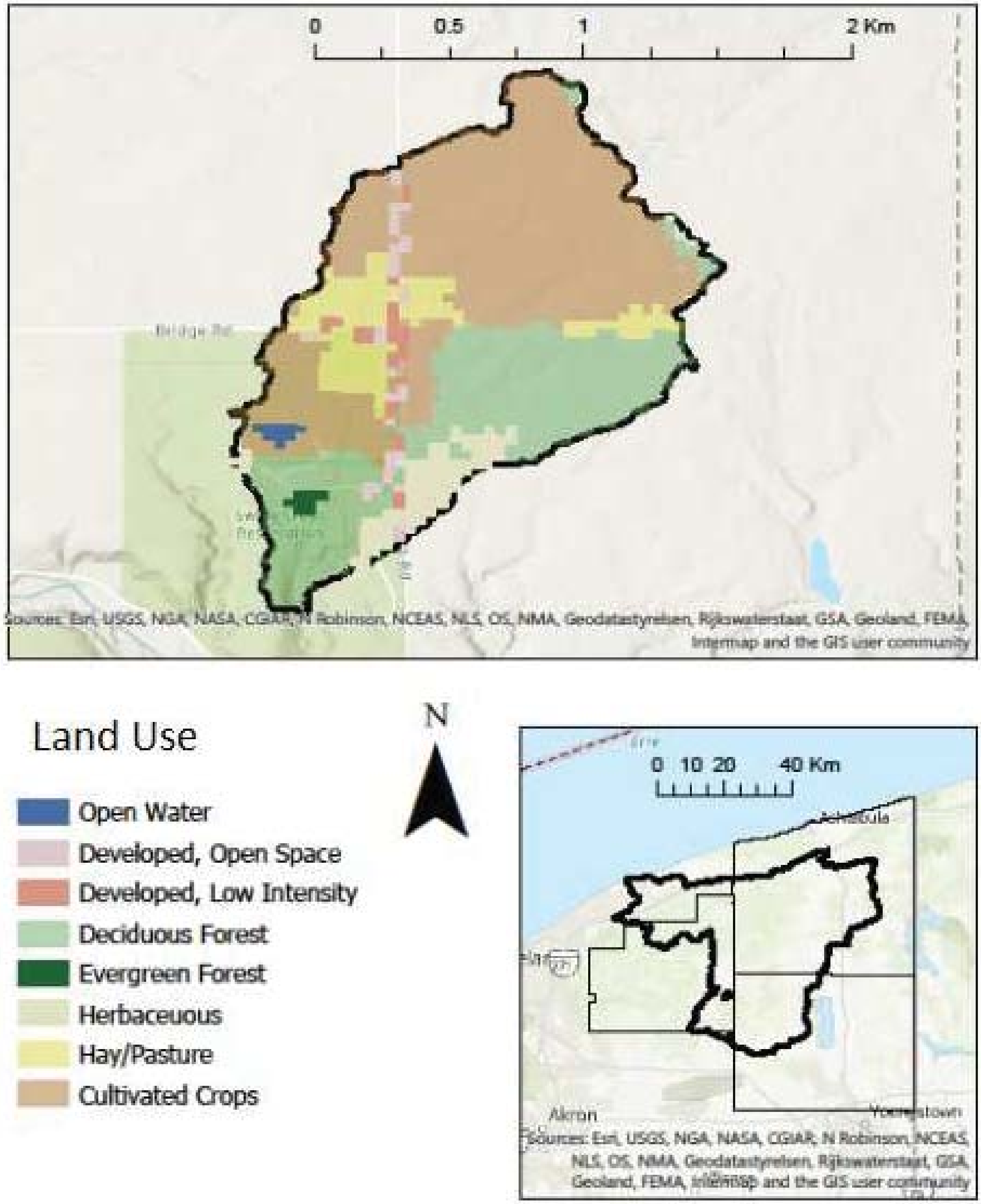


Figure 17a. Land cover map of the Swine Creek Reservation Creek watershed and location within the Grand River Watershed. Land uses are as indicated in legend.

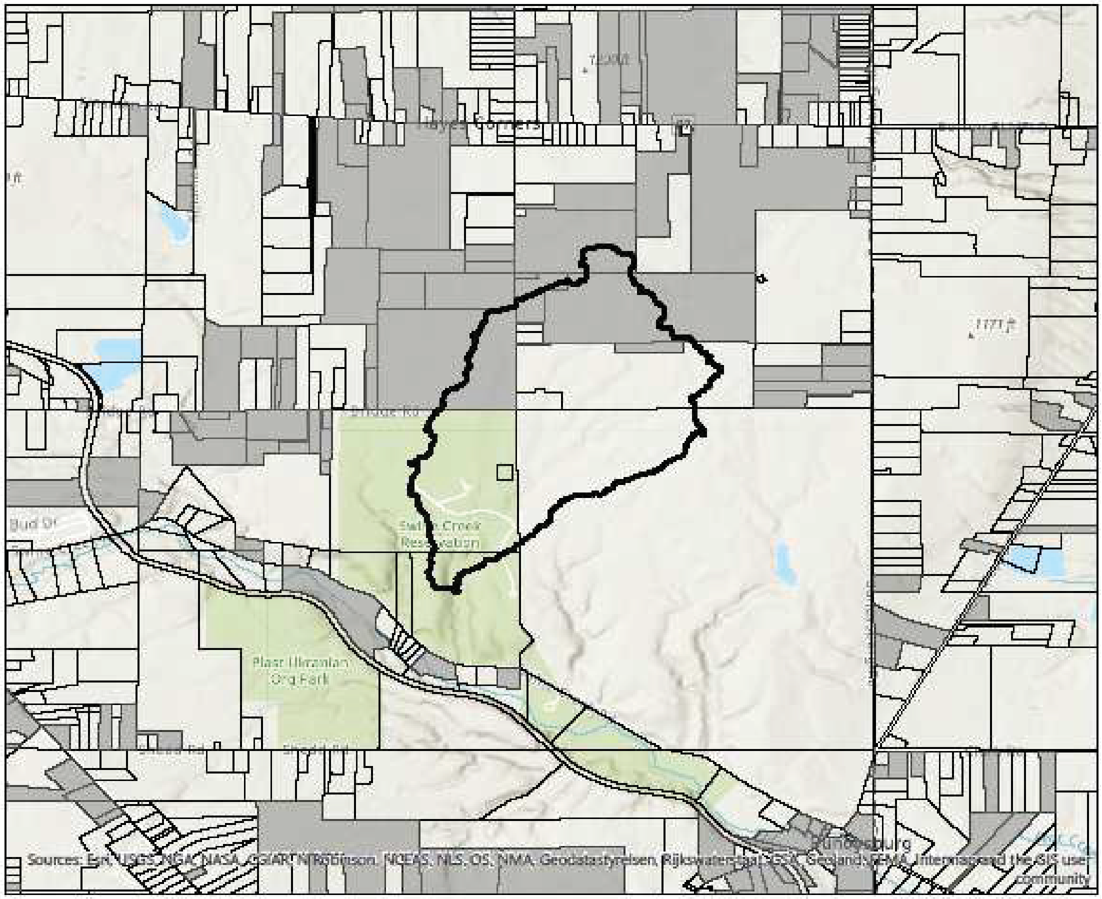


Figure 17b. Land parcels within the Swine Creek Reservation Creek watershed. Parcels putatively identified as Amish by surname search are shown in grey.

Table 2. Total watershed area and percentages of land cover types for study streams.

Stream Name	Total Area (sq km)	Amish farming (%)	Non-Amish farming (%)
Mill Creek	29.7	34.1	5.5
Swine (downstream)	30.2	41	0
Swine (upstream)	17.5	33.9	3.5
Center Creek	52.6	0	23.8
Baughman	47.9	0	75.2
Hoffman Norton S	4.8	0	27.1
Hoffman Norton N	4.5	0	34.1
Swine Creek Res	1.6	65.8	0

Stream Name	Forest (%)	Aquatic (%)
Mill Creek	53.6	6.8
Swine (downstream)	19.9	39.1
Swine (upstream)	62.5	0.1
Center Creek	55.8	20.4
Baughman	22.6	2.2
Hoffman Norton S	68.8	4.1
Hoffman Norton N	57.9	8
Swine Creek Res	33.6	0.6

Table 3. Stream gradient for ~1 – 5-km segments upstream from habitat assessment sites for each stream, giving segment length, upstream and downstream elevations, and upstream locations in relation to nearby roads.

		Elevations (ft)		
Stream Name	**Segment length (ft)**	**Upstream**	**Upstream Location**	**QHEI site**
Mill Creek	10455	818	OH 534	798
Swine (downstream)	8155	810	OH 87	799
Swine (upstream)	12009	1103	Old State Rd	956
Center Creek	15226	840	Cory-Hunt Rd	814
Baughman	8906	831	Fenton Rd	819
Hoffman Norton S	2906	850	Housel-Craft Rd	839
Hoffman Norton N	10920	888	Cory-Hunt Rd	837
Swine Creek Res	5600	1200	Open field	1069

	Above QHEI site	
Stream Name	**Gradient (ft/mi)**	**Gradient (m/km)**
Mill Creek	10.1	1.9
Swine (downstream)	7.1	1.3
Swine (upstream)	64.4	12.2
Center Creek	9.0	1.7
Baughman	7.1	1.3
Hoffman Norton S	19.9	3.8
Hoffman Norton N	24.6	4.7
Swine Creek Res	123.0	23.2

Table 4. Pearson bivariate correlations of land cover percentages and upstream gradients for study streams.

		Area	AmishFarm	OtherFarm	Forest	Aquatic	StreamGrad
Area	Pearson Correlation	1	-.334	.386	-.343	.378	-.598
	Sig. (2-tailed)		.419	.346	.405	.356	.118
	N	8	8	8	8	8	8
AmishFarm	Pearson Correlation	-.334	1	-.746*	-.364	.043	.703
	Sig. (2-tailed)	.419		.033	.375	.920	.052
	N	8	8	8	8	8	8
OtherFarm	Pearson Correlation	.386	-.746*	1	-.162	-.270	-.436
	Sig. (2-tailed)	.346	.033		.701	.518	.280
	N	8	8	8	8	8	8
Forest	Pearson Correlation	-.343	-.364	-.162	1	-.402	-.023
	Sig. (2-tailed)	.405	.375	.701		.324	.957
	N	8	8	8	8	8	8
Aquatic	Pearson Correlation	.378	.043	-.270	-.402	1	-.467
	Sig. (2-tailed)	.356	.920	.518	.324		.244
	N	8	8	8	8	8	8
StreamGrad	Pearson Correlation	-.598	.703	-.436	-.023	-.467	1
	Sig. (2-tailed)	.118	.052	.280	.957	.244	
	N	8	8	8	8	8	8

*. Correlation is significant at the 0.05 level (2-tailed).

Table 5. Qualitative Habitat Evaluation Index (QHEI) scores, as total for each stream and presented by major categories of habitat criteria.

	Max = 20	20	20	10	20
Stream Name	**Substrate**	**Cover**	**Channel**	**Riparian**	**Pool-glide-riffle**
Mill Creek	8	9	17	10	7
Swine (downstream)	9	10	15	10	9
Swine (upstream)	19	17	18	8	10
Center Creek	5	13	18	10	9
Baughman	14	10	15	9	9
Hoffman Norton S	5	13	15	8	3
Hoffman Norton N	5	16	11	9	3
Swine Creek Res	20	13	18	8	16

Stream Name	Max = 100 **TOTAL QHEI**	At QHEI site **Gradient (ft/mi)**
Mill Creek	53	15
Swine (downstream)	57	15
Swine (upstream)	78	50
Center Creek	57	10
Baughman	61	20
Hoffman Norton S	48	20
Hoffman Norton N	47	20
Swine Creek Res	80	100

Table 6. Pearson bivariate correlations of total QHEI scores, scores for major habitat criterion categories, and at-site gradient estimates for study streams.

		Substrate	Cover	Channel	Riparian	RifflePool	QHEI	Gradient
Substrate	Pearson Correlation	1	.174	.507	-.543	.804*	.950**	.812*
	Sig. (2-tailed)		.681	.200	.165	.016	.000	.014
	N	8	8	8	8	8	8	8
Cover	Pearson Correlation	.174	1	-.111	-.590	-.098	.266	.309
	Sig. (2-tailed)	.681		.794	.123	.817	.524	.456
	N	8	8	8	8	8	8	8
Channel	Pearson Correlation	.507	-.111	1	-.064	.699	.669	.412
	Sig. (2-tailed)	.200	.794		.881	.054	.070	.311
	N	8	8	8	8	8	8	8
Riparian	Pearson Correlation	-.543	-.590	-.064	1	-.148	-.479	-.661
	Sig. (2-tailed)	.165	.123	.881		.726	.230	.074
	N	8	8	8	8	8	8	8
RifflePool	Pearson Correlation	.804*	-.098	.699	-.148	1	.881**	.755*
	Sig. (2-tailed)	.016	.817	.054	.726		.004	.030
	N	8	8	8	8	8	8	8
QHEI	Pearson Correlation	.950**	.266	.669	-.479	.881**	1	.828*
	Sig. (2-tailed)	.000	.524	.070	.230	.004		.011
	N	8	8	8	8	8	8	8
Gradient	Pearson Correlation	.812*	.309	.412	-.661	.755*	.828*	1
	Sig. (2-tailed)	.014	.456	.311	.074	.030	.011	
	N	8	8	8	8	8	8	8

*. Correlation is significant at the 0.05 level (2-tailed).

**. Correlation is significant at the 0.01 level (2-tailed).

Table 7. Results of Principle Components Analysis (PCA) of watershed areas, percentages of land cover, and calculated near-upstream gradients for study streams. Component Matrix is synonymous with "loadings", which indicate the relative contribution of the original land cover variables to each PCA axis.

Total Variance Explained

Component	Initial Eigenvalues			Extraction Sums of Squared Loadings		
	Total	% of Variance	Cumulative %	Total	% of Variance	Cumulative %
1	2.623	43.716	43.716	2.623	43.716	43.716
2	1.758	29.297	73.013	1.758	29.297	73.013
3	1.100	18.334	91.347			
4	.412	6.867	98.214			
5	.107	1.786	100.000			
6	1.110E-016	1.850E-015	100.000			

Extraction Method: Principal Component Analysis.

Component Matrix[a]

	Component	
	1	2
Area	-.712	.448
AmishFarm	.864	.454
OtherFarm	-.728	-.308
Forest	.019	-.771
Aquatic	-.273	.810
Gradient	.874	-.071

Extraction Method: Principal Component Analysis.

a. 2 components extracted.

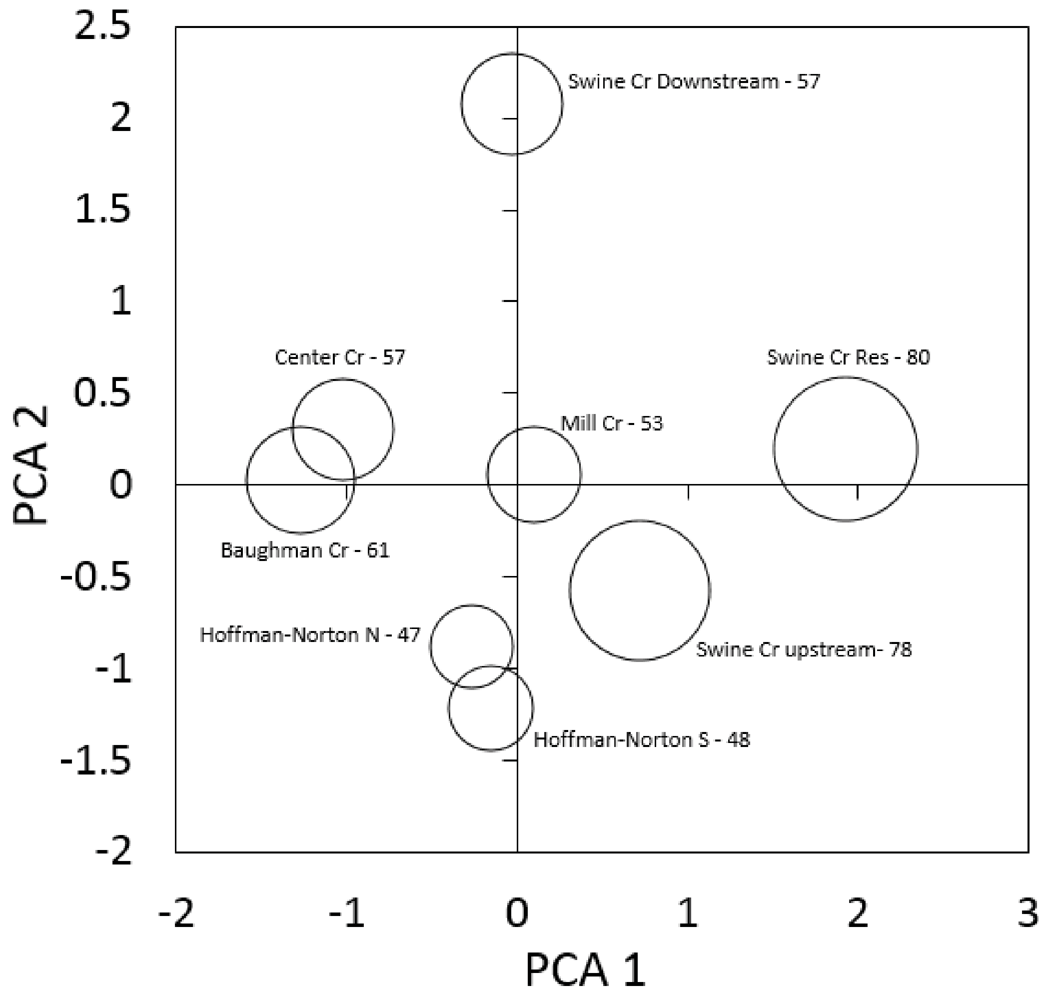


Figure 18. Bubble graph presenting results of Principle Components Analysis of land cover and stream segment gradient immediately upstream from habitat evaluation sites in each stream. Bubble size represents QHEI score. Output of PCA, including “loadings” of land cover variables, is presented in Table 7.

Table 8. Pearson bivariate correlations of total QHEI scores and PCA axis scores based on land cover percentages in study stream watersheds. No correlations were significant.

		QHEI	REGR factor score 1 for analysis 1	REGR factor score 2 for analysis 1
QHEI	Pearson Correlation	1	.660	.137
	Sig. (2-tailed)		.075	.746
	N	8	8	8
REGR factor score 1 for analysis 1	Pearson Correlation	.660	1	.000
	Sig. (2-tailed)	.075		1.000
	N	8	8	8
REGR factor score 2 for analysis 1	Pearson Correlation	.137	.000	1
	Sig. (2-tailed)	.746	1.000	
	N	8	8	8

Discussion

The major objective of this thesis was evaluating human and natural land cover influences (i.e. forests, wetlands, Amish and non-Amish farmland) on adjacent streams. The land cover throughout my study area was a mixture between wetlands (predominantly located within the State of Ohio Grand River Valley game lands), farmland (Amish vs non-Amish), and forest. During this thesis, I learned that the studied wetland areas within the Grand River watershed are incredibly complex, with deltas and oxbows throughout. The wetlands were located in lower elevation and flatter areas, where an abundance of side channels, oxbows, and marshes often made it difficult to recognize the actual stream channels.

The farmland was located to the east and west of the game lands at higher elevations and in hillier but still gentle terrain. Stream channels were much more easily recognized in these areas. There was an abundance of Amish farms west of the Grand River near Mesopotamia and Middlefield, while non-Amish farms dominated to the east. Amish communities are close knit and it was very unlikely to see an Amish farmstead away from these Amish communities. However, there *are* a few non-Amish farms within these communities.

The Qualitative Habitat Evaluation Index was assessed for all study watersheds. Habitat scores calculated for this thesis ranged from “poor” quality (40’s) to “excellent” (80). Higher scoring streams (i.e. earning an excellent rating) have courser substrate, higher channel sinuosity, narrower riparian width, and well developed riffle-pool sequences. In contrast, lower scoring streams have heavy embeddedness (i.e. coarser sediments, where present, are embedded in mud and silt), straighter channels, and little to no riffle-pool development. It should be noted that QHEI scores are intended as an evaluation of sport fishing habitat, and thus tend to favor riffle-pool development, in-stream cover, and heterogeneous substrate. While the streams flowing through the wetland-dominated game lands had lower QHEI scores, that doesn't mean they are unhealthy streams. Rather, these streams can support much aquatic life, just not necessarily highly sought game fish. Higher QHEI scores usually indicate habitat for fishes such as basses, pike, and even trout in colder waters. In contrast, lower scoring streams, with their sluggish fine sediment reaches are more likely to support catfish and carp. Although stream gradient doesn't affect QHEI scores directly, higher gradient stream channels are often characterized by the types of features (especially coarse and heterogeneous sediments) that generate a large QHEI score.

Interestingly, there was no correlation between land use in general (as represented by PCA axes) and QHEI scores. However, QHEI scores were barely non-significantly related ($p = 0.075$) to PCA axis 1, which strongly reflected stream gradient. Habitat evaluations during this thesis suggested human alterations of land cover have not necessarily had a huge impact on stream habitat. Perhaps the natural buffers at my stream sites between farming activities and streams were sufficient to protect habitat. All assessment sites were on forested public lands, and were several hundred meters away from actual farmland. Also, it may be that the farming practices within the study watersheds were only of modest impact. I did not note any severe land degradation or any mining, quarrying, or construction projects affecting the surrounding streams. Future studies that would be interesting would be to see if there are any associations between chemical constituents (i.e. nitrogen runoff, chemical vs natural fertilizer, and other pesticides used on crops) and QHEI scores. These inputs could likely differ between natural and human-dominated land cover, and between Amish and non-Amish farmland.

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