Oak Openings Region Biodiversity Model Final Report (Phase I)

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Objective: Phase I of this research project will primarily build an updated land cover map for the Oak Openings Region.

Introduction

The Oak Openings Region is a biodiversity hotspot located in northwest Ohio and southwest Michigan. A critical first step to evaluating conservation and management strategies for the Oak Openings Region, we (Schetter and Root 2011) developed a foundational land cover map. This map was essential in identifying remnant natural communities and helping the Green Ribbon Initiative identify priority areas for acquisition, restoration, and management. However, 10 years later, there have been significant changes in the region as a result of anthropogenic activities (e.g., development, restoration), natural catastrophes (e.g., tornado) and invasive species (e.g., emerald ash borer). The Green Ribbon initiative has served as the catalyst for land acquisition, management and restoration efforts to create a corridor among the protected remnant natural habitats to facilitate connectivity for the native species (Grigore 2009). With all of these changes (both positive and negative) on the landscape, there is a need for an updated land cover classification.

We proposed the development of an updated land cover map that would not only include the region with the Brewer-Vankat boundary (Brewer and Vankat 2004, 2006), but extend to the entire region as delineated by the Green Ribbon Initiative. The land cover resulting map will identify the important land cover classes, illustrating their distribution and extent. This project utilized an approach similar to Schetter and Root (2011), but incorporated updated Landsat imagery and focused

on the GRLI activity core that includes the historic Oak Openings region, the Michigan extension of the region, and the historic Ohio prairies. Of particular interest were the extent and distribution of five critical ecosystems: upland savanna/prairie, wet prairie, upland deciduous forest, floodplain forest, and flatwoods/swamp forest. Our objective was to build an updated land cover map for the Oak Openings Region, expanding the entire historic area of both Ohio and Michigan.

Methods

Landsat Image selection and acquisition

We acquired three multi-season images from the early (1 March 2016 to 30 April 2016), mid (June-July 2016), and late growing season (October-November 2016) using the USGS Earth Explorer (USGS 2017). These three images were from Landsat 8 (Tier 1) on 16 April 2016, 19 June 2016, and 9 October 2016 for Path 20, Row 31 containing our entire study area. We utilized multi-season images since this approach improves classification accuracy for forests (Townsend and Walsh 2001) and grasslands (Peterson et al. 2002). To maximize the quality of the map classification, our image selection required the images to : (1) occur within a narrow 6 month timeframe, (2) feature 0% cloud cover within our study area, and (3) contain Level-1 Precision Terrain (L1T) image processing by USGS. All images were downloaded in GeoTif image format projected to Universal Transverse Mercator coordinates (UTM Datum WGS84). These Landsat 8 images were multispectral and contained 11 bands for use in classification, Table 1.

Training Site Selection

Training sites were identified across the entire Oak Openings Region to provide enough training pixels for a supervised classification. We used 33 bands (11 per image) and this required a minimum of 34 pixels per land cover class (n + 1 pixels required per class, where n is the number of used spectral bands). In April 2017, previous training sites (Schetter and Root 2011) were revalidated for accuracy and additional training sites were selected within Ohio and Michigan. Field surveys were done to validate previous training sites and evaluate new additional training sites. For the final classification, we used 89 training sites for 14 classes (average of six training sites per class).

Supervised Image Classification

Using the three multispectral Landsat 8 images, we performed a supervised classification in ArcGIS 10.2 (ESRI, Redlands, CA). We used a maximum likelihood classification model with equal prior probability, where each 30 m image pixel was assigned to a single land cover class. Although each selected image had <10% cloud cover, we did not need to perform an atmospheric correction because the images within our study area were cloud free. We used spectral bands 1-11 from each of the three selected images for a grand total of 33 bands, each with 30 m pixel resolution. A comparison of the bands available for Landsat 5 and 8 are shown in Table 1. This required a minimum of n+ 1 (where n = number of spectral bands) or 34 total pixels of each training class (ArcGIS 10.2). Training sites were delineated using ArcGIS 10.2. We performed the supervised land cover classification for the 14 land cover classes (i.e., the original land cover classifications from Schetter and Root 2011, Table 2, minus the agriculture) using the training data.

We then used a cropland "mask" created from the Ohio and Michigan cropland data layer downloaded from the USDA Geospatial Data Gateway through the Farm Service Agency (USGS 2016). We selected by state, then county, and checked the Cropland Data Layer by State box to retrieve the selected data. We used ArcGIS 10.2 to first erase the cropland layer from the classified land cover and then we merged the newly erased classified land cover map with the cropland layer to create a final 15-class image. Our final image was clipped to the extended Oak Openings Region (Grigore 2016). The result was a complete map of the region classified into 15 land cover classes.

Accuracy assessment

We used a combination of field surveys and orthophoto surveys to assess the accuracy of the land cover classification. To perform a structured accuracy assessment, we surveyed within the Brewer-Vankat boundaries (Brewer and Vankat 2004, 2006) to effectively compare our accuracy assessment with Schetter & Root (2011). We visually inspected five points per major community of concern (e.g., upland savanna, upland prairie, wet prairie, upland deciduous forest, floodplain forest, and swamp forest) on the ground to identify the land cover class and compare to the designation from the supervised classification. Ground points were delineated through ArcGIS 10.2 and were at least 150 m apart from one another to ensure a reasonable sample distribution. Points were excluded within training sites. To minimize travel time, at each point, we evaluated four adjacent neighboring

points (increasing the total number of ground truth points from 30 to 150). Visual inspections occurred during June 2017 to evaluate structural vegetative characteristics.

Land cover verification was also done using high resolution (0.3 m) color orthophotos acquired in 2017 (USGS 2017). Orthophotos were used for land cover classes that are distinguishable and could be confidently identified (e.g., croplands, dense urban, residential/mixed, perennial ponds, and upland coniferous forest). We analyzed five points per land cover class and four additional adjacent neighboring points (increasing the total number of ground truth points from 25 to 125) to identify the land cover class and compare the designation from the supervised classification. We then compiled the results into an error matrix (Table 5) to evaluate the accuracy of the supervised land cover classification.

Results

Map Characteristics

The final extended land cover map of the Oak Openings Region contains 15 land cover classes: turf/pasture, wet prairie, residential/mixed, perennial ponds, upland savanna, wet shrubland, swamp forest, upland coniferous forest, upland deciduous forest, floodplain forest, sand barrens, Eurasian meadow, upland prairie, dense urban, and cropland (Table 2, Figure 1). Extending the map to include the area within Michigan increased the total mapped area by 146,207 ha. We found that natural/seminatural land cover classes covered 23.4% of the region, while cultural land cover classes covered 76.6% of the total area.

To compare changes in land cover classes over time, we have displayed the original land cover area (ha) and percent area with the updated version clipped to the same extent, and the extended area of the Oak Openings Region (Table 1, Figure 2). We found that natural/seminatural classes decreased by 0.6%, whereas cultural classes increased by 0.7%. Overall, most land cover classes changed only modestly; for example, upland deciduous forest changed from 6.4% to 6.6% and floodplain forest changed from 8.9% to 8.5%. However, the most substantial changes between Schetter & Root (2011) and the new land cover map are within two cultural classes where turf/pasture

and cropland classes decreased by 6.6% and 1.6%, respectively, and upland prairie which increased by 2.3%.

Comparing Schetter & Root (2011) to the updated land cover map, we found that natural/seminatural land covers decreased over time in the Ohio counties, while cultural land covers increased (Table 3). Lucas County showed the greatest decrease of natural land covers, losing 20.4%, while Fulton and Henry County lost 2.2% and 1.5%, respectively. For Michigan's counties, Monroe County had the largest natural/seminatural land cover of 33.5%, while Oakland County had the smallest natural/seminatural land cover of 20.1% (Table 4).

Map Accuracy Assessment

A comparison of the previous land cover map and updated land cover map of the Oak Openings Region is shown in Figure 2. We evaluated 275 points using ground truthing (150 points) and orthophotos (125 points). We compiled our results into an error matrix (Table 5) and we found that the overall accuracy of the final 15-class map was 73.8%. Several land cover classes were all correctly predicted by our supervised land cover classification (e.g., perennial ponds, swamp forest, upland coniferous forest, and dense urban).

Discussion

We have successfully developed a land cover map using a supervised classification of multiple Landsat 8 images and extending the coverage from northwestern Ohio into Michigan. Based on our accuracy assessment and comparison with the previous land cover map (Schetter and Root 2011), we are confident in the map, although it can continue to be improved with additional training data. The Oak Openings Region is a biodiversity hotspot characterized by its highly heterogeneous landscape, making it an excellent model to assess mapping accuracy. Overall, our map accuracy was 73.8%, which was an improvement over the 60% accuracy of the original land cover map. The improved accuracy is likely a result of the additional spectral data available in Landsat 8 images versus Landsat 5 (see Table 1 for comparison). However, we verified only a selection of the land cover classes as a result of time constraints. The selected land covers may be easier to detect, such as perennial ponds and upland coniferous forest, and may not represent the accuracy for all land cover classes. Some caution is warranted, therefore, in the absence of further verification. In order to increase confidence in our

accuracy assessment, further field work should be conducted to verify the remaining land cover classes (e.g., turf/pasture, wet shrublands, sand barrens, and Eurasian meadows).

To further improve the accuracy assessment, additional points per land cover class would also increase confidence (five points to 10 points per land cover) in the classification. We simplified the ground truthing procedures, as compared to Schetter & Root (2011) because we could identify deficiencies within the map by comparing it to the original land cover map. The error matrix (Table 5) supports our differential success in the supervised land cover to accurately predict land cover classes. For some classes, such as upland conifers, we were highly successful in accurately matching the satellite image to the real world. Whereas our map poorly predicts wet prairie based on the ground truth points, which were primarily upland prairie. The original training data provided a decent classification, but some classes were too broad and overlapped with other land cover classes. With additional training points, the classification can be improved providing a more accurate map. Our recommendation would be to identify additional training points within land cover classes of concern and land cover classes that did poorly (e.g., floodplain forests) in the accuracy assessment.

In the original land cover map of the Oak Openings Region (Schetter and Root 2011), much of the land had been converted to human-modified land cover classes (73%), while less than 3% of was covered by upland early successional habitats, such as prairies and savannas (Schetter et al. 2013). However, our new land cover classification has shown that even though human-modified land cover classes have increased to 76.6%, early successional habitats have also increased to 7%. This increase in early successional habitats is likely a result of the work being undertaken by the Green Ribbon Initiative to increase the amount of protected lands and promote ecological conservation through restoration and enhancement of critical natural areas. With a large collaborative community (e.g., The Nature Conservancy, Metroparks, Toledo Zoo, Ohio Division of Wildlife, Michigan Nature Conservancy, etc.), it seems highly likely that the Green Ribbon Initiative has facilitated the positive changes within the prairie land cover classes (e.g., increasing wet prairie (0.1% to 0.3%) and upland prairie (1.3% to 3.6%)).

Lessons Learned

- Significant changes can occur that are critical to understand for prioritizing land management and conservation in the region. Updating the land cover map provides a useful approach to look at larger scale trends across the region and should be done periodically (e.g., every ten years).
- These classifications are limited by the scale of the input data. Here are our resolution is determined by the 30-m pixel size of the Landsat imagery. While this provides an excellent overview of the entire region, it is only a starting point for management and conservation that might operate on much smaller scales.
- We recommend that the map be further refined by collecting additional training data land cover classes of concern and land cover classes that did poorly (e.g., floodplain forests) in the accuracy assessment.

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Figures and Tables

Table 1. Spectral band comparison between Landsat 8, used for the updated land cover map, and Landsat 5 TM, used in original land cover map, from USGS (2016).

Landsat 8		**Landsat 5 TM**	
Band	**Wavelength (micrometers)**	**Band**	**Wavelength (micrometers)**
1-Coastal Aerosol	0.43-0.45	1-Blue	0.45-0.52
2-Blue	0.45-0.51	2-Green	0.52-0.60
3-Green	0.53-0.59	3-Red	0.63-0.69
4-Red	0.64-0.67	4-Near Infrared	0.77-0.90
5-Near Infrared	0.85-0.88	5-Short-wave Infrared 1	1.55-1.75
6-Short-wave Infrared 1	1.57-1.65	6-Thermal Infrared	10.40-12.50
7-Short-wave Infrared 2	2.11-2.29	7-Short-wave Infrared 2	2.09-2.35
8-Panchromatic	0.50-0.68		
9-Cirrus	1.36-1.38		
10-TIRS 1	10.60-11.19		
11-TIRS 2	11.5-12.51		

Table 2. Summary of land cover map results for the original land cover map (Schetter & Root), updated land cover map (Martin & Root) and updated extended region land cover map (Extended Boundary).

	Schetter & Root		Martin & Root		Extended Boundary	
Class	**Area (ha)**	**% area**	**Area (ha)**	**% area**	**Area (ha)**	**% area**
Natural/Seminatural	12989	27.2	12686	26.6	45380	23.4
Forest and Woodlands	9735	20.4	9387	19.7	26613	13.7
Swamp Forests	1496	3.1	1707	3.6	3506	1.8
Floodplain Forests	4259	8.9	4043	8.5	12012	6.2
Upland Deciduous Forests	3073	6.4	3162	6.6	10575	5.5
Upland Coniferous Forests	907	1.9	477	1.0	521	0.3
Savannas (Upland Savannas)	370	0.8	142	0.3	153	0.1
Shrublands (Wet Shrublands)	193	0.4	4	0.0	4	0.0
Prairies & Meadows	2438	5.1	2892	6.1	17313	8.9
Wet Prairies	40	0.1	166	0.3	381	0.2
Upland Prairies	610	1.3	1710	3.6	12446	6.4
Sand Barrens	359	0.8	10	0.0	12	0.0
Eurasian Meadows	1429	3.0	1006	2.1	4474	2.3
Water (Perennial Ponds)	253	0.5	260	0.5	1298	0.7
Cultural	34791	72.8	35077	73.5	148606	76.6
Built-up	18749	39.2	22903	48.0	90611	46.7
Dense Urban	1833	3.8	1967	4.1	11906	6.1
Residential/Mixed	16915	35.4	20936	43.8	78705	40.6
Vacant	16042	33.6	12175	25.5	57995	29.9
Turf/Pasture	3141	6.6	23	0.0	30	0.0
Croplands	12901	27.0	12151	25.4	57965	29.9
Total Mapped	47779	100	47763	100	193986	100

Table 3. Summary of land cover map by Ohio counties for the original land cover map (Schetter & Root) and updated land cover map (Martin & Root).

	Lucas County				Fulton County				Henry County			
	Schetter & Root		Martin & Root		Schetter & Root		Martin & Root		Schetter & Root		Martin & Root	
Class	**Area (ha)**	**% area**	**Area (ha)**	**% area**	**Area (ha)**	**% area**	**Area (ha)**	**% area**	**Area (ha)**	**% area**	**Area (ha)**	**% area**
Natural/Seminatural	9743	49.1	9726	28.7	2264	25.3	2066	23.1	936	19.4	862	17.9
Forest and Woodlands	7258	36.6	7111	21.0	1707	19.0	1554	17.4	742	15.4	694	14.4
Swamp Forests	1140	5.7	1322	3.9	227	2.5	224	2.5	124	2.6	156	3.2
Floodplain Forests	3175	16.0	3165	9.3	716	8.0	580	6.5	355	7.4	285	5.9
Upland Deciduous Forests	2342	11.8	2308	6.8	532	5.9	632	7.1	191	4.0	212	4.4
Upland Coniferous Forests	601	3.0	317	0.9	232	2.6	116	1.3	72	1.5	41	0.9
Savannas (Upland Savannas)	320	1.6	134	0.4	38	0.4	7	0.1	8	0.2	1	0.0
Shrublands (Wet Shrublands)	162	0.8	4	0.0	13	0.1	0	0.0	18	0.4	0	0.0
Prairies & Meadows	1795	9.0	2267	6.7	471	5.3	456	5.1	167	3.5	166	3.4
Wet Prairies	37	0.2	138	0.4	1	0.0	3	0.0	1	0.0	25	0.5
Upland Prairies	456	2.3	1383	4.1	113	1.3	254	2.8	40	0.8	71	1.5
Sand Barrens	219	1.1	9	0.0	98	1.1	1	0.0	41	0.9	0	0.0
Eurasian Meadows	1083	5.5	737	2.2	259	2.9	198	2.2	84	1.7	69	1.4
Water (Perennial Ponds)	209	1.1	211	0.6	37	0.4	49	0.6	1	0.0	0	0.0
Cultural	10095	50.9	24188	71.3	6698	74.7	6888	76.9	3891	80.6	3963	82.1
Built-up	3019	15.2	19117	56.4	1601	17.9	2738	30.6	624	12.9	1001	20.7
Dense Urban	1683	8.5	1813	5.3	83	0.9	95	1.1	19	0.4	57	1.2
Residential/Mixed	1336	6.7	17304	51.0	1518	16.9	2644	29.5	606	12.5	944	19.6
Vacant	7075	35.7	5071	15.0	5097	56.9	4150	46.3	3267	67.7	2963	61.4
Turf/Pasture	1560	7.9	23	0.1	704	7.9	0	0.0	263	5.4	0	0.0
Croplands	5515	27.8	5048	14.9	4393	49.0	4150	46.3	3004	62.2	2963	61.4
Total Mapped	19838	100	33915	100	8962	100	8953	100	4827	100	4826	100

Table 4. Summary of land cover map by Michigan counties for the updated land cover map updated extended region land cover map (Extended Boundary).

Class	Monroe County		Wayne County		Oakland County		Washtenaw County	
	Area (ha)	% area	Area (ha)	% area	Area (ha)	% area	Area (ha)	% area
Natural/Seminatural	12701	33.5	12026	24.6	192	20.1	2707	20.5
Forest and Woodlands	7842	20.7	6020	12.3	101	10.5	1385	10.5
Swamp Forests	964	2.5	349	0.7	12	1.2	224	1.7
Floodplain Forests	3896	10.3	3292	6.7	46	4.8	738	5.6
Upland Deciduous Forests	2962	7.8	2365	4.8	43	4.5	416	3.2
Upland Coniferous Forests	20	0.1	13	0	0	0	7	0
Savannas (Upland Savannas)	6	0	4	0	0	0	0	0
Shrublands (Wet Shrublands)	0	0	0	0	0	0	0	0
Prairies & Meadows	4595	12.1	5505	11.3	88	9.2	1043	7.9
Wet Prairies	95	0.3	79	0.2	2	0.2	13	0.1
Upland Prairies	2466	6.5	4373	9	81	8.5	1030	7.8
Sand Barrens	1	0	1	0	0	0	0	0
Eurasian Meadows	2033	5.4	1052	2.2	5	0.5	379	2.9
Water (Perennial Ponds)	258	0.7	498	1	3	0.4	279	2.1
Cultural	25171	66.5	36787	75.4	764	79.9	10123	76.6
Built-up	24005	63.4	36172	74.1	699	73.1	6775	51.3
Dense Urban	1753	4.6	6651	13.6	89	9.3	1348	10.2
Residential/Mixed	22252	58.8	29521	60.5	610	63.8	5427	41.1
Vacant	1166	3.1	614	1.3	65	6.8	3347	25.3
Turf/Pasture	7	0	0	0	0	0	0	0
Croplands	1159	3.1	614	1.3	65	6.8	3347	25.3
Total Mapped	37872	100	48812	100	956	100	12829	97

Table 5. Error matrix for the 15-class Oak Openings Region land cover map.

		Actual Land Cover (Reference Sites)															
	Class	TP	WP	RM	PP	US	WS	SF	UC	UD	FF	SB	EM	UP	DU	CR	Row total
Classified Land Cover (From map)	TP	**0**	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	WP	0	**0**	0	0	0	0	0	0	0	0	0	0	5	0	0	5
	RM	1	0	**15**	0	0	0	0	2	2	0	0	0	4	4	0	28
	PP	0	0	0	**23**	0	0	0	0	0	0	0	0	0	0	0	23
	US	0	0	0	0	**6**	0	0	0	2	0	0	0	0	0	0	8
	WS	0	0	0	0	0	**0**	0	0	0	0	0	0	0	0	0	0
	SF	0	0	0	0	0	0	**25**	0	0	0	0	0	0	0	0	25
	UC	0	0	0	0	0	0	0	**18**	1	0	0	0	0	0	0	19
	UD	0	0	0	0	5	0	4	0	**33**	0	0	0	0	0	0	42
	FF	0	0	0	0	1	0	0	1	17	**8**	0	0	1	0	0	28
	SB	0	0	0	0	0	0	0	0	0	0	**0**	0	0	0	0	0
	EM	0	0	5	0	0	0	0	0	0	0	0	**0**	1	0	0	6
	UP	0	5	0	2	5	0	0	0	1	0	1	0	**27**	0	0	41
	DU	0	0	0	0	0	0	0	0	0	0	0	0	0	**25**	0	25
	CR	2	0	0	0	0	0	0	0	0	0	0	0	0	0	**23**	25
Column Total		3	5	20	25	17	0	29	21	56	8	1	0	38	29	23	**275**

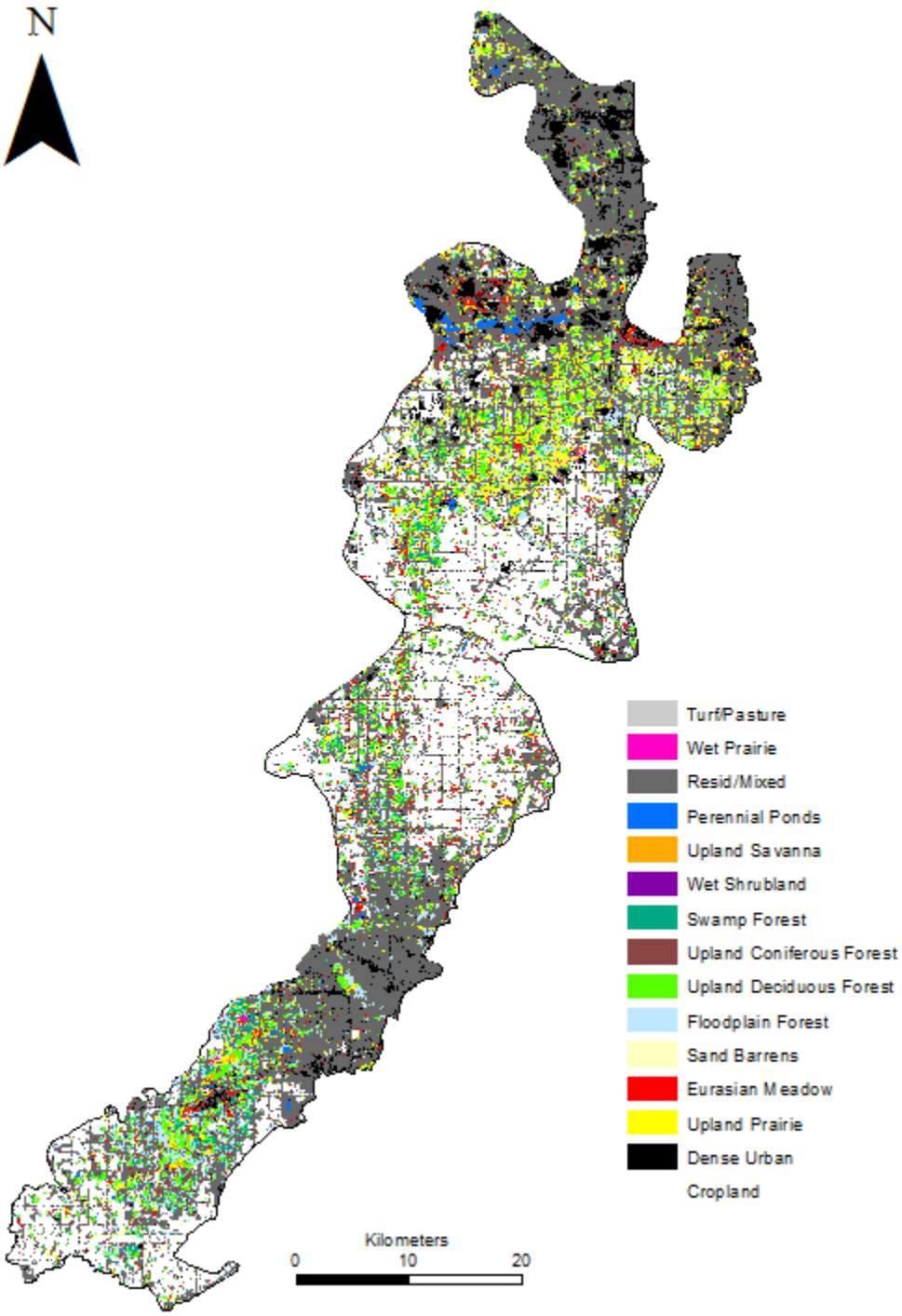
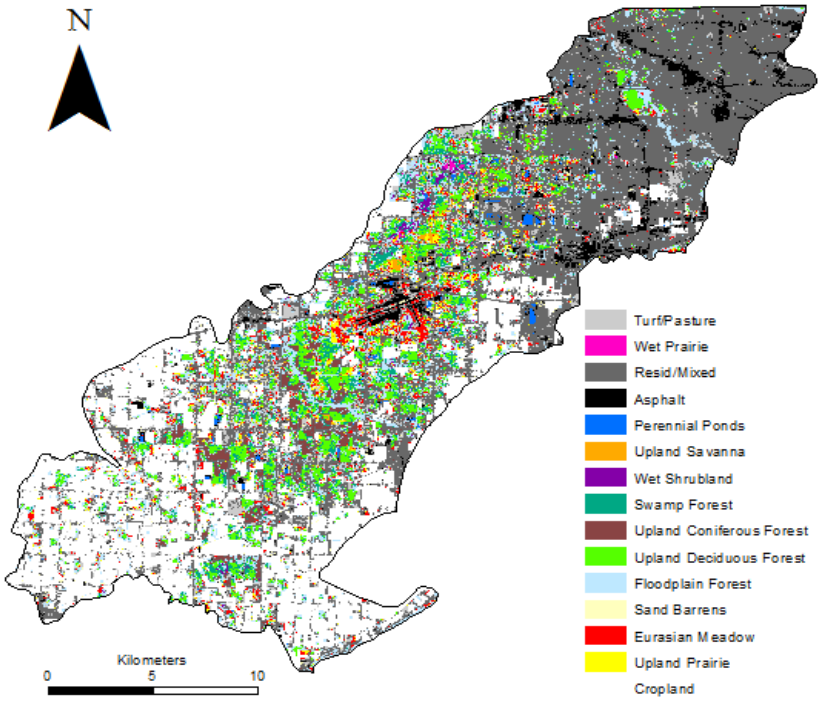
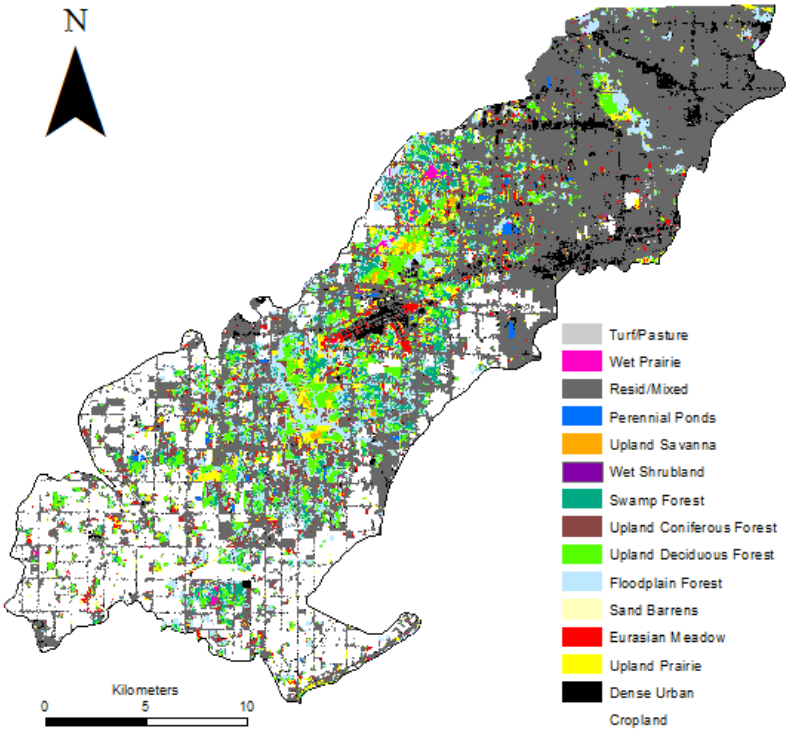


Figure 1. Extended land cover map of the Oak Openings Region of northwestern Ohio, based on supervised classification from Landsat 8 images (Martin & Root 2017).



(a) Schetter & Root 2011



(b) Martin & Root 2017

Figure 2. (a) Original land cover map (Schetter & Root 2011) and (b) updated land cover map (Martin & Root 2017) of the Oak Openings Region of northwestern Ohio.

References

Brewer L. G., and Vankat J. L. 2004. Description of vegetation of the Oak Openings of northwestern Ohio at the time of Euro-American settlement. *Ohio Journal of Science* 104:76–85.

Brewer L. G., Vankat J. L. 2006. Richness and diversity of oak savanna in northwestern Ohio: proximity to possible sources of propagules. *American Midland Naturalist* 155:1–10.

Grigore, M. 2009. *Living in the Oak Openings: A Homeowner's Guide to One of the World's Last Great Places*. Second Edition. The Nature Conservancy- Ohio Chapter, Homewood Press.

Grigore, M. 2016. *Living in the Oak Openings: A Homeowner's Guide to One of the World's Last Great Places*. Third Edition. The Nature Conservancy- Ohio Chapter, Homewood Press.

Peterson, D.L., K.P. Price, and E.A. Martinko. 2002. Discriminating between cool season and warm season grassland cover types in northeastern Kansas. *International Journal of Remote Sensing* 23:5015-5030.

Schetter, T. A., and K. V. Root. 2011. Assessing an imperiled oak savanna landscape in northwestern Ohio using Landsat data. *Natural Areas Journal* 31(2):118-130.

Schetter, T. A., Walters, T. L. and K. V. Root. 2013. A Multi-scale analysis of native and exotic plant species richness within a mixed-disturbance oak savanna landscape. *Environmental Managemen*t 52(3):581-594.

Townsend, P.A., and S.J.Walsh. 2001. Remote sensing of forested wetlands: application of multitemporal and multispectral satellite imagery to determine plant community composition and structure in southeastern USA. *Plant Ecology* 157:129-149.

[USGS] United States Department of Agriculture Farm Service Agency. 2016. Common land units. Available Online <https://datagateway.nrcs.usda.gov/>. Accessed 3 April 2017.

[USGS] U.S. Geological Survey. 2017. USGS Earth Explorer. Available online <https://earthexplorer.usgs.gov>. Accessed 20 March 2017.