BMP Development for Swan Creek Watershed: Pilot

SG518-17

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Abstract

The University of Toledo implemented agricultural practices mapping from remote sensing for a watershed in Northwest Ohio - Swan Creek. This project addresses the first priority area in the LEPR 2013: Nonpoint Source Pollution. The goal of this project was to understand the spatial distribution of Best Management Practices (BMPs) and their use by farmers. Many BMPs act to retain dissolved reactive phosphorus (DRP) on agricultural fields (buffer strips and tillage practices) while others may enhance DRP runoff such as no-till or tile drain installation. Harmful algal blooms (HAB) on Lake Erie have been related to the increase in dissolved reactive phosphorus (DRP) runoff from agricultural fields (Baker et al 2014). BMPs have the potential to reduce DRP runoff. There is a need to map the use of BMPs in the watershed that feeds Western Lake Erie. This project used existing techniques and developed others to map BMPs and other agricultural practices in the Swan Creek watershed. A combination aerial photographs and Landsat satellite images were used to develop each BMP layer, including crop type, tile drainage systems and wetlands. Members of the University of Toledo team collected *in situ* field data in 2016 and 2017 of tillage practice and cover crops. Information from the National Agricultural Statistics Service's Cropland Data Layer (CDL) was also used. CDL information was used to acquire crop rotation patterns. A hotspot analysis of Swan Creek was performed using weights input from community leaders in agriculture and conservation and areas with high BMP implementation as well as areas with low BMP implementation were identified.

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Technical Report

Activities and Timeline:

Quarter 1 – January – March 2017

- Created preliminary maps for tillage practice and cover crop maps.
- Presented this project at the Lake Erie Millenium Project meeting at the University of Windsor, February 23, 2017. This presentation led to many connections with groups interested in mapping agricultural practices in the Lake Erie watershed.
- Had a meeting with members of the Lake Erie Commission March 4, 2017 – presented preliminary maps and gained inportant information about what the Lake Erie Commission is expecting from the project.

Quarter 2 – April – June 2017

- Driving transects were completed by University of Toledo student Kimberly Panozzo and post-doc Dr. Yitong Jiang with the help of Peter Carr from Fulton County Soil and Water Conservation Service.
- Wetlands mapping was completed. Ultimately, we decided not to use the wetlands layer in our hotspot map as there is very little in the watershed.

Quarter 3 – July – September 2017

- Imagery (aerial and satellite) was acquired for Swan Creek watershed.
- Buffer strip maps were created for grass and forested areas around drainage systems including ditches and streams.

Quarter 4 – October – December 2017

- Met with Sandra Kosek-Sills and a couple other community members including Kari Gerwin from the Toledo Metropolitan Area Council of Governments (TMACOG) in mid-December 2017 to get feedback on the data layers created.
- A significant portion of the work was completed during the fourth quarter of 2017. Each data layer was finalized and interpolated. These layers were weighted using weights gathered from stakeholders and information gathered from the literature. The final interpolation and hotspot analysis was performed with spatial statistics applied to look for clusters of areas with high BMP implementation as well as areas with low BMP implementation.

BMP layer Creation

The Swan Creek watershed drains parts of Fulton County, Lucas County and a small portion of Henry County (Figure 1). The watershed has significant agriculture in it but also is cut in half by the Oak Openings, a forested area on mainly sandy soils.

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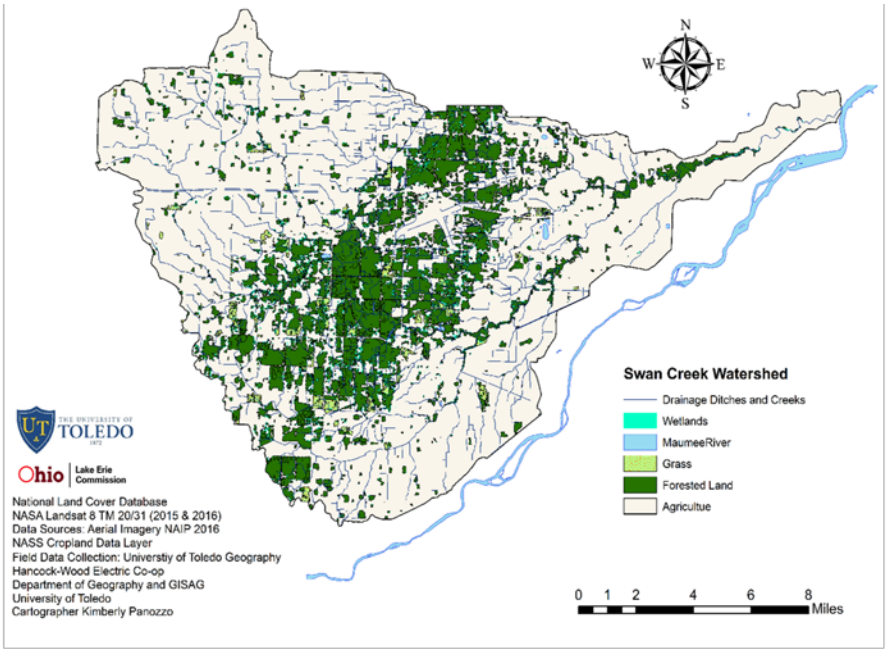

Figure 1 Map of Swan Creek Watershed with land cover classifications

The layer creation process involved three steps, identification of BMPs, creation and incorporation of index values and interpolation. BMP layers were created using remotely sensed data and other GIS layers. Figure 2 shows which data were used to create each layer.

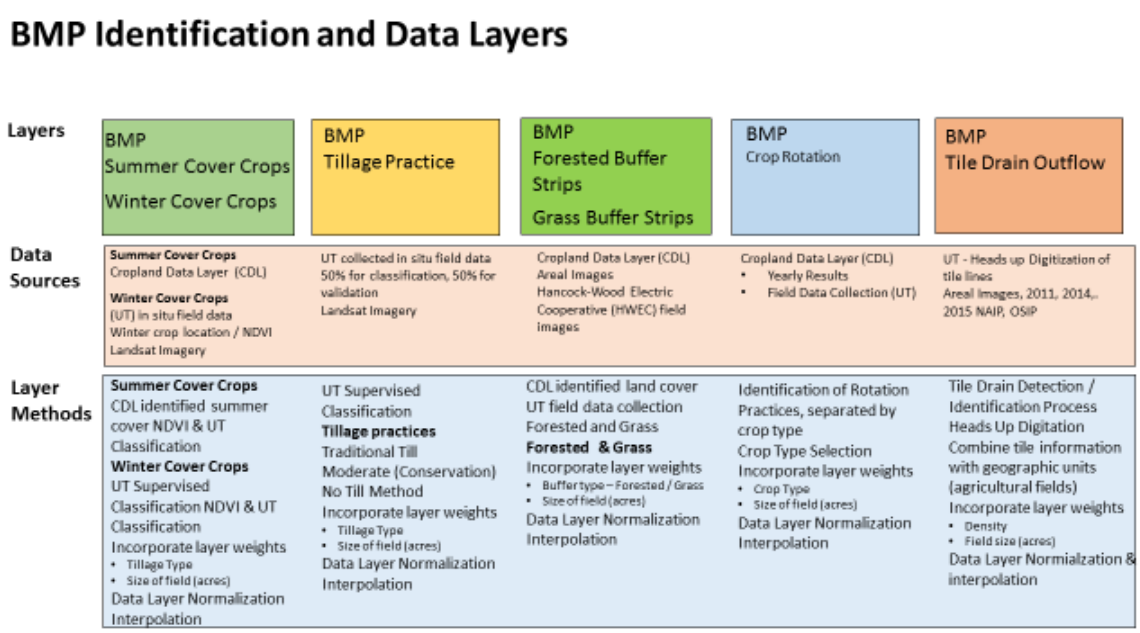

Figure 2 Individual Layer- Data Sources and Methods to create each layer

BMP Interpolation

Once the data layers were completed, they were interpolated to smooth the layers so that individual fields could not be identified. Multiple techniques of interpolation were tested to evaluate the most appropriate method. We found that if we used a Fishnet grid to subsample

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the layers and the applied an Inverse distance weighting (IDW), the best results were achieved. We tested three distances, 500 m, 1000 m, and 3000 m, to interpolate the results. We found that a IDW distance of 500 meters produced the most visually acceptable results. The same IDW was applied to all of the data layers so that the layers could be combined together to create the final hotspot layer.

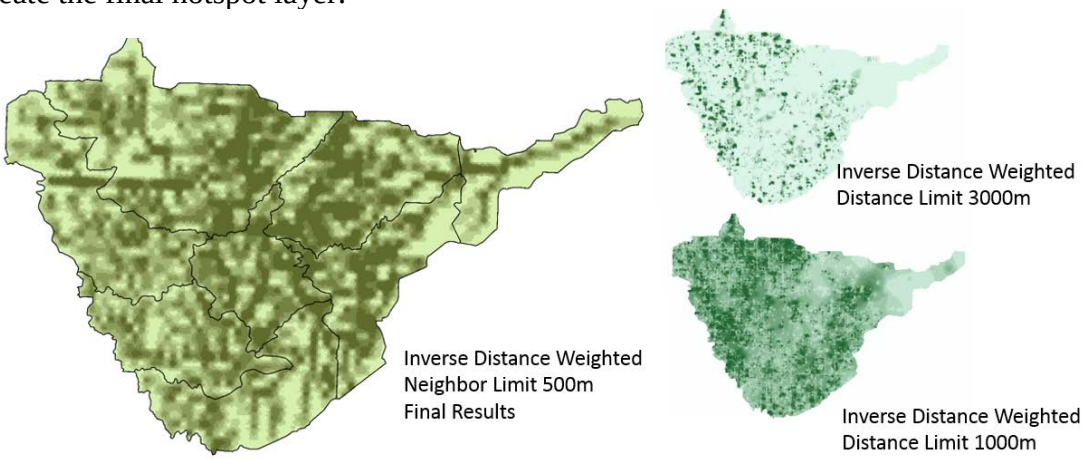

Figure 3 Inverse Distance Weighted interpolation examples are shown with neighboring values set to 500 meters, 1000 meters and 3000 meters.

Cover Crops

Cover crops are being used by farmers in the winter months to keep soil on their fields and can help to manage nutrients. Cover crop identification was performed using the Cropland Data Layer (CDL) and Landsat Imagery (Figure 4).

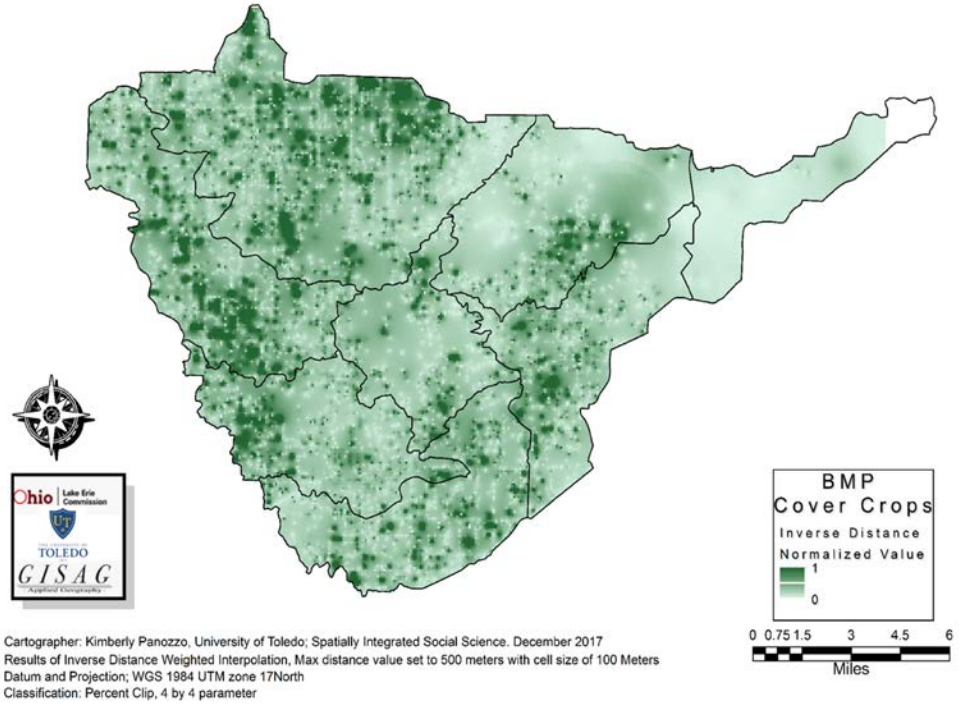

Figure 4 Interpolated cover crops layer for Swan Creek

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The University of Toledo's *in situ* field data from 2016 was used as training sets and will be used for validation of the data layer in future projects. Each year students drive transects within the Maumee River Watershed to evaluate green cover for both spring and fall. The Normalized Difference Vegetation Index (NDVI) and a color composite image were created using Landsat 8 imagery. NDVI is an index from -1 to 1 where 1 is complete and dense vegetation cover. A supervised classification was completed to determine the cover crops for both late fall 2015 and early spring 2016. CDL data was incorporated to include fields that contained winter wheat. The accuracy of the CDL for winter wheat is very high – 96% (Panozzo, 2016).

Tillage Practice

The process of identifying tillage practice was similar to steps undertaken for locating cover crops. Landsat 8 satellite imagery on multiple days was combined for both the start and end of the growing season. Although tillage practice has been mapped from remote sensing in the past, it is fairly difficult to pull out of the satellite imagery (South 2004). A supervised classification for crop type and the associated tillage practice was created using the University of Toledo *in situ* transect collection discussed earlier. During the transects, UT students would collect information about tillage and take pictures of over 800 fields within the Maumee River watershed. The students note whether the residue on the field is between 0 and 30 % that is traditional tillage, 30-90 % representing conservation tillage and 90—100 % for no till. The field observations were used as training sets for the remote sensing classification. To be able to identify tillage practice, a class had to be created for each crop type and tillage practice. Therefore, the classification uses classes or corn, traditional tillage, corn, conservation tillage and corn, no till. The same things was done for winter wheat and soybeans. The results for each tillage type were then combined into the three classes (Figure 5).

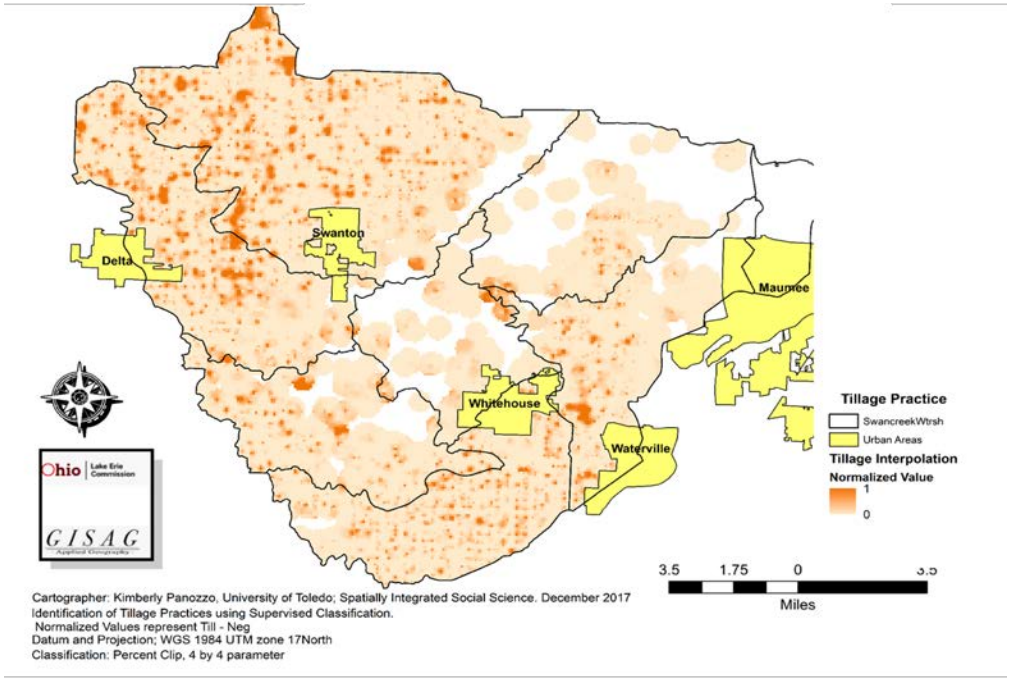

Figure 5 Interpolated tillage practices layer for Swan Creek

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Buffer Strips (grassy and wooded)

Identification of buffer strips within the watershed required a straightforward approach using aerial imagery with one meter spatial resolution (Benedict 2007). A hydrology layer was collected showing waterways and drainage ditches within the Swan Creek watershed. The first step was to create a land use classification of grass and wooded areas. Multiple buffers around all waterways and ditches were created within ArcGIS at 10 meters, 20 meters and finally, 30 meters. All grass and wooded areas that fell within the buffers were selected as buffer strips.

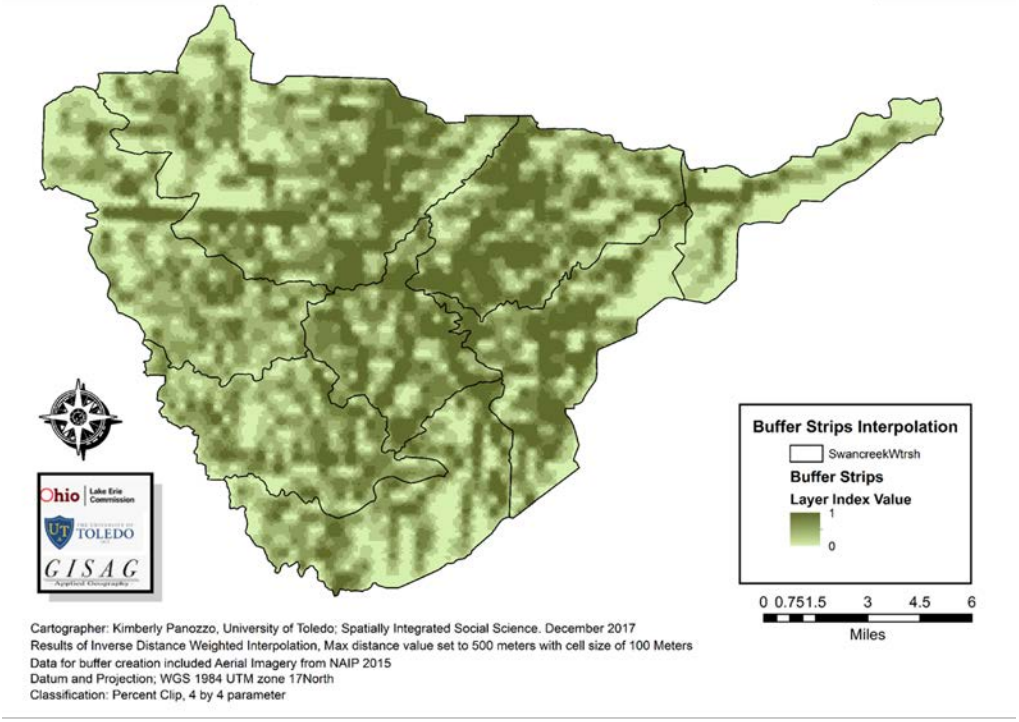

Figure 6 Interpolated buffer strips (grassy and wooded) layer for Swan Creek

Crop Rotation

Corn, soybeans and winter wheat are the three main crops grown on fields in the Swan Creek watershed. Identification of crop rotation was created using the USDA National Agricultural Statistics Service (NASS) CDL layers of crop type for ten years, 2007 to 2016. The number of years of planted corn was summed for each field (Figure 7). Corn was used because it is the crop type that produces the most DRP runoff. Some areas had corn planted a lot including some where corn was planted all ten years of the study. The layer was then normalized and smoothed using the techniques previously described.

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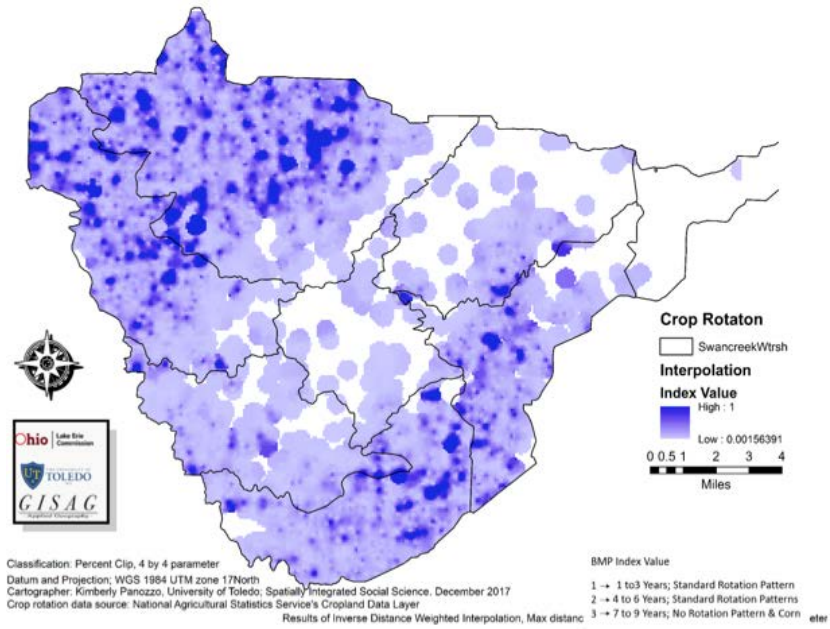

Figure 7 Interpolated crop rotation layer for Swan Creek

Tile Drain Density

Tile drain mapping began at the University of Toledo under a project to investigate the fate of sewage sludge that was applied on agricultural fields (Czajkowski et al. 2010). Naz (2009) from Purdue University has used hyperspectral remote sensing to map tile lines. Identification of tile drain density was completed for this project through heads-up digitization of multiple years of aerial imagery available through the National Aerial Imagery Program (Figure 8). Tile drain density was calculated using the length per area for a given area. The layer was then smoothed using the IDW technique.

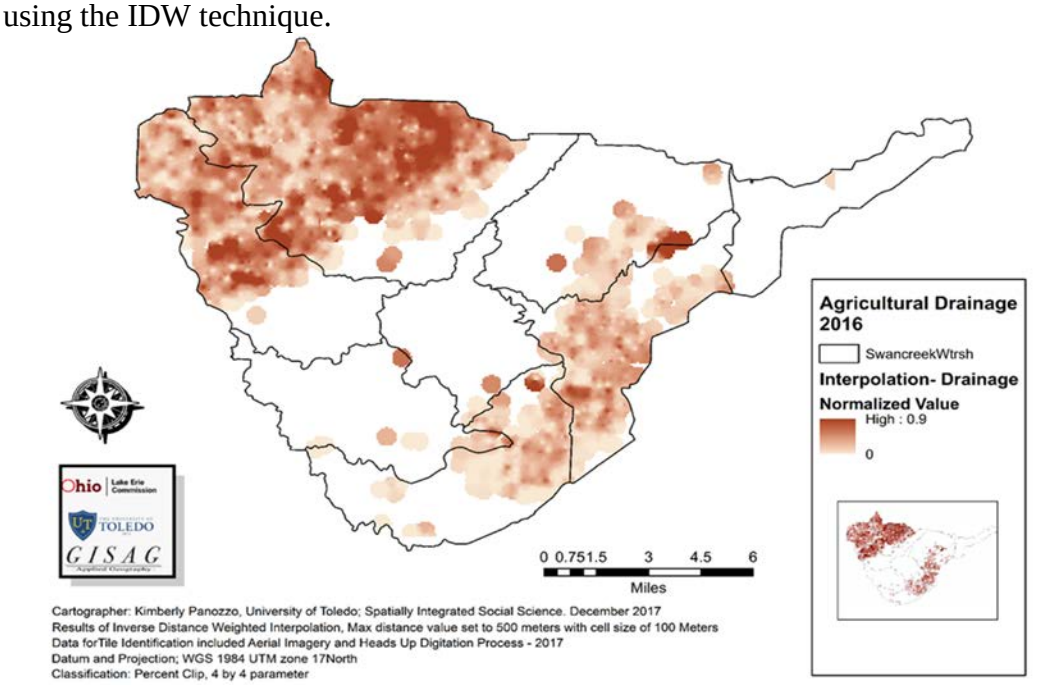

Figure 8 Interpolated tile drain density layer for Swan Creek

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BMP Index

In order to combine the data layers into one hotspot analysis, each later needed to be normalized. An index value was created for each individual layer using information gleaned from related literature (Kleinman et al. 2001; Muller et al. 1984; Shapely and Smith 1991; King et al. 2014) as well as from various stakeholders. Each BMP was evaluated on the basis of its ability to prevent or reduce DRP runoff. The stakeholders were given a survey asking them to rate each BMP and the parameters associated with that BMP using a scale from 1 to 3. A value of 1 represents a BMP that will reduce DRP runoff and 3 that represents BMPs that lead to high DRP runoff. Stakeholders were identified as persons who have in-depth knowledge of the impact of BMPs on DRP runoff into Lake Erie. For this pilot, only three stakeholders were surveyed. Each BMP layer weight can be seen in Tables 1 to 5.

In order to determine index values, the weights were averaged given all of the interview responses or literature sources for each category (or BMP).

Table 1 Buffer Strips & Tillage Practice Index. Literature sources included Kleinman et al. (2004), Mueller et al. (1984), and Shapely et al. (1991).

Layer	High		Low	Layer	High		Low
Buffer Strips	30 m	20 m	10 m	**Tillage**	No Till	Moderate Tillage	Conventional
Respondent 1	1	2	3	**Respondent 1**	1	2	3
Respondent 2	1	2	3	**Respondent 2**	1	2	3
Respondent 3	1	2	3	**Respondent 3**	1	2	3
Literature 1	1	2	2	**Literature 1**	3	2	1
Literature 2	1	2	3	**Literature 2**	3	2	1
Literature 3	1	2	3	**Literature 3**	3	2	1
Literature 4	1	2	3	**Literature 4**	3	2	1
Layer Index	1	2	3	Layer Index	2.1	2.0	1.9
****Dissolved Reactive P**	High BMP	Middle	Low BMP	****Dissolved Reactive P**	Low BMP	Middle	High BMP

Table 2 Cover Crops & Crop Rotation Index, Literature sources include Kleinman et al. (2004), Sharpley et al. (1991)

Layer	Highest			Lowest
BMP Cover Crops	Fall & Spring	Fall	Spring	None
Respondent 1	1	1	2	3
Respondent 2		1	2	3
Respondent 3	1		2	3
Literature 1		1	2	3
Literature 2		1	2	3
Literature 3	1	2	2	-
Layer Index	1	1.2	2	3

Layer	High		Low
Crop Rotation Patterns	Standard	Variable	Corn - No rotation
Respondent 1	1	2	3
Respondent 2	1	1	3
Respondent 3	1	2	3
Literature 1	1	2	3
Layer Index	1	2	3
****Dissolved Reactive P**	High BMP	Middle	Low BMP

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Table 3 Tile drainage Index, Literature source includes King et al. (2014).

Drainage	High Density		Low Density	None
Respondent 1	3	2	1	
Respondent 2	3	2	1	
Respondent 3	4	3	2	1
Literature 1	3	2	1	
Literature 2	3	2	1	
Totals	3.2	2.2	1.2	1
****Dissolved Reactive P**	Low BMP			High BMP

The cover crop index values were determined by the cover crop on each field. If cover was identified for both fall and spring, an index value of 3 was given. Areas identified as having cover crops in both fall and spring were given a value of 1. Alternatively, a fall only identified cover crop was given the value of 1.2 and spring was given a value of 2.

The buffer strip index values were set based on width of the buffer strip. The literature and responses from stakeholders were consistent that a wider buffer strip was better for DRP runoff. Larger buffer strips of 30 meters were set as 1 with the 10 meter buffer strips given a value of 3. The cover type of the buffer strip, grass versus wooded, was not differentiated in the final weighted layer.

Crop rotation patterns were similarly set to 1 for fields having many years of soy and wheat. A value of 2 was assigned to the typical Corn, soy, wheat rotation. A value of 3 was given to fields with four or more years of corn planted out of the tens years of data.

It was found that the literature and stakeholders disagreed on values that should be assigned to tillage practice. As a BMP, no till is considered good but some literature shows that no till can lead to high runoff of DRP. Ultimately, an average value of 2 was given to Tillage practice.

Tile drain density has a negative effect on DRP runoff. Fields with high density of tiles have more DRP runoff (King et al. 2014). Tile drain density index values were set as 1 for no drainage or low tile drain density to 3 for high tile drain density.

Layer combination

Figure 9 provides a visualization of the layers that were combined to produce the final BMP map. Each layer was then rank by the stakeholders and through the literature review (Figure 10). Buffer strips received a ranking of 1 indicating it was the most important and tillage practice received a value of 5 meaning it was deemed least important. Then, all of the layers were combined to create an overall BMP index with a scale from 0 – 1 (Figure 11).

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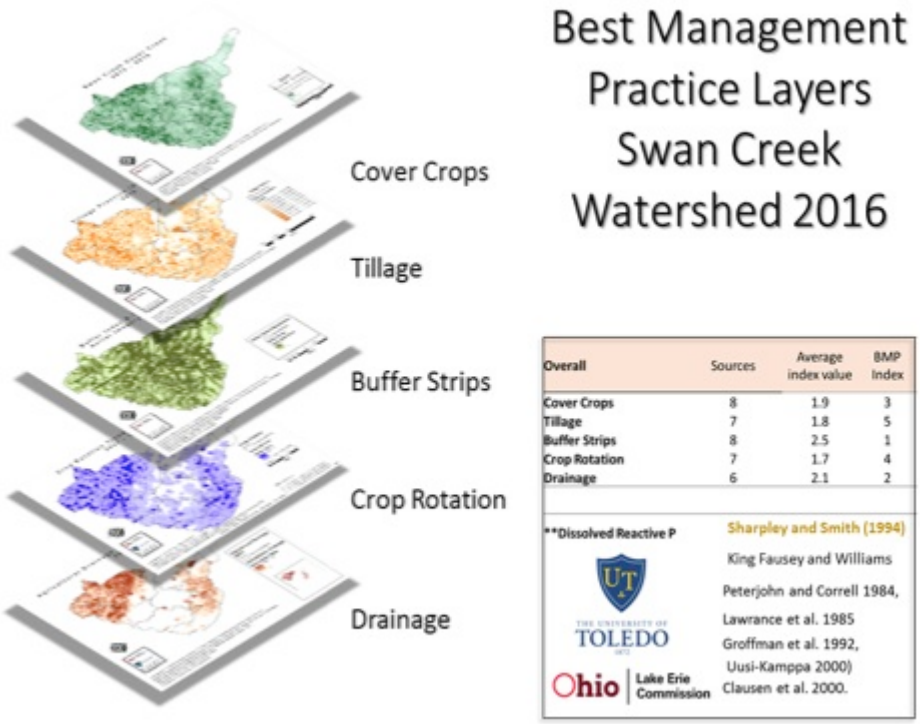

Figure 9 Combined BMP Layers. Each normalized, interpolated BMP layer was weighted and then combined to produce the final interpolated layer.

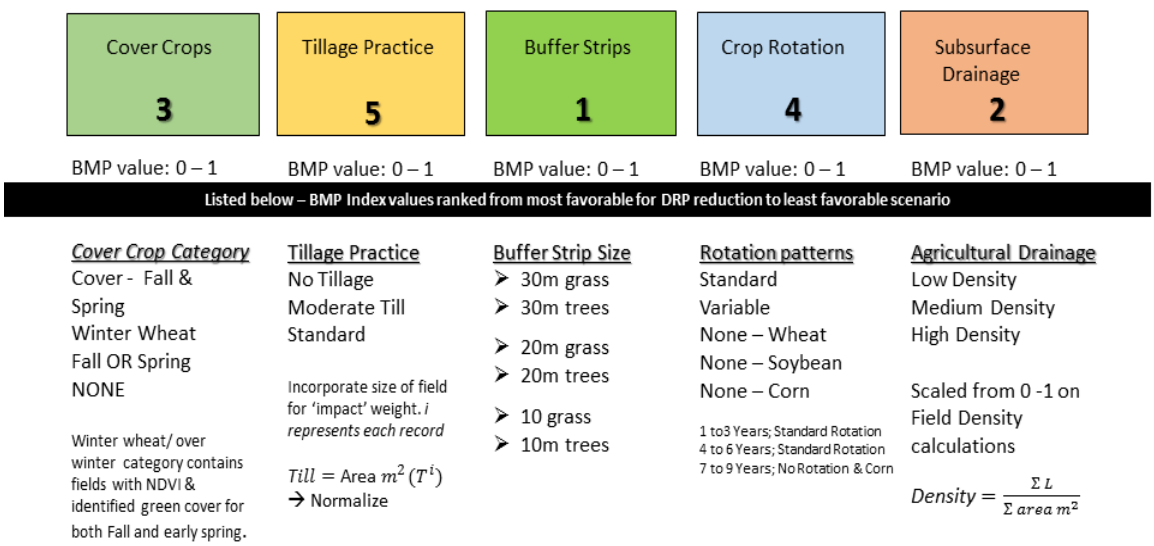

Figure 10 Overall Layer Index values and ranking.

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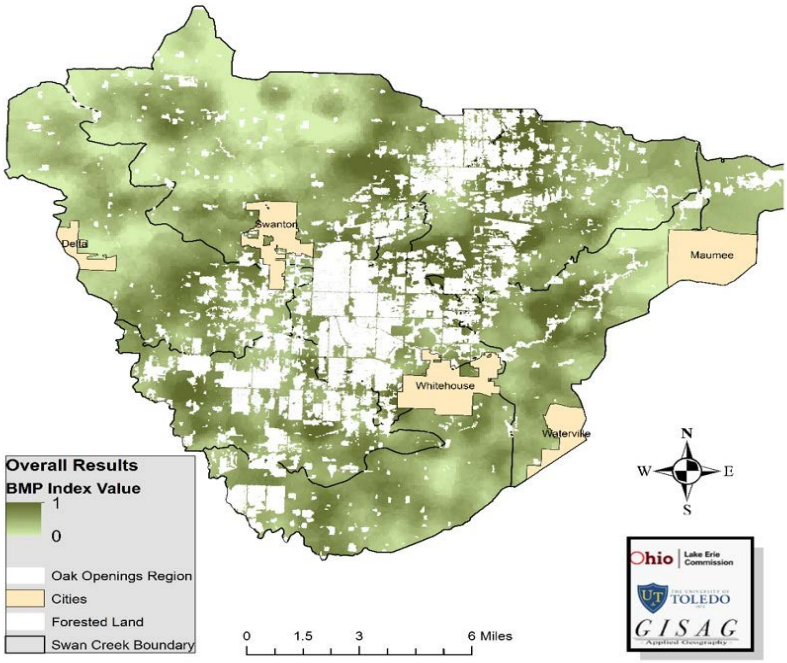

Figure 11. Final interpolated BMP index layer.

Results and Analysis

Spatial autocorrelation was tested using the Global Moran's I (Figure 12) and it was found that the BMP index layer had significant clustering within it. The statistics were applied using 0.01 to measure significance. The results indicated that the BMP index values were spatially clustered (Figure 13). Areas with darker shades represent higher BMP implementation.

Using hotspot analysis, we can determine what areas within the Swan Creek watershed contain areas of clustered BMPs for both high values (greater BMP use that is beneficial to DRP runoff) and low value clusters (lower adherence of BMP use that is detrimental to DRP runoff). The z score was derived using the Moran's I statistic and represents how intense the clustering of values is (only when it is statistically significant).

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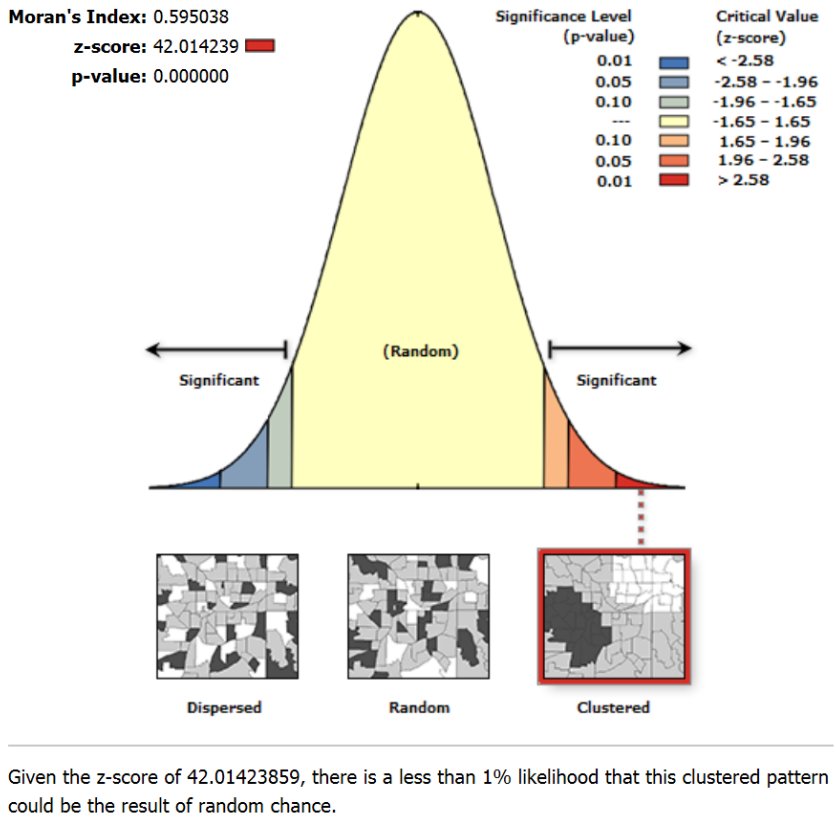

Figure 12. Statistical analysis was performed on each layer. Spatial autocorrelation was assessed using Moran's I global statistic to identify clustering.

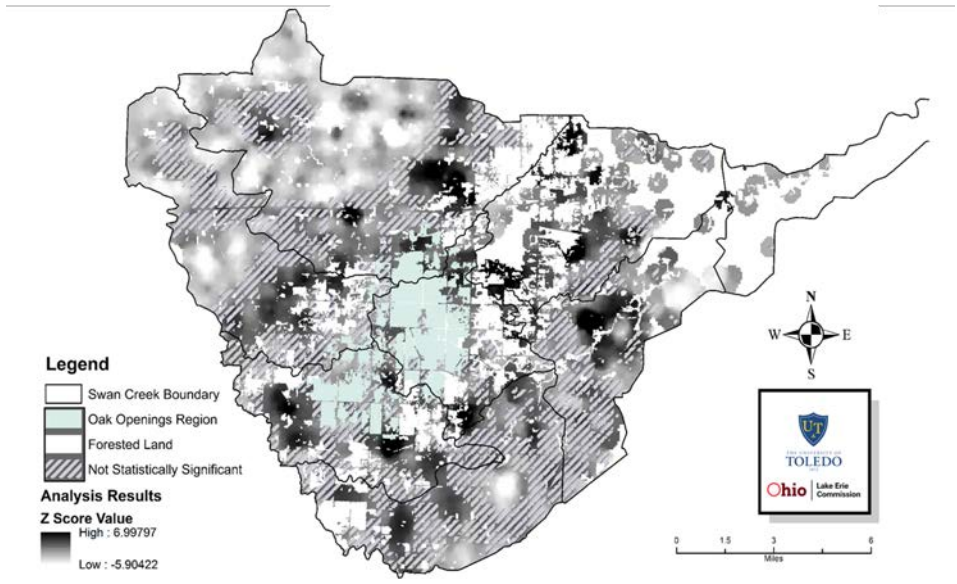

Figure 13. Moran's I Analysis Results. Dark areas indicated statistically significant high BMP implementation. Light areas are statistically significant low BMP implementation areas.

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Areas that are statistically significant at a 99% confidence level are shown in Figure 13 as the dark and light areas. Areas that were not statistically significant are shown in the diagonal stripes.

Implications

This research shows that agricultural practices can be identified and mapped using geographic information systems and remote sensing techniques. Furthermore, these layers can be used to evaluate spatial dependence and complete hotspot analysis.

Areas in close proximity to the Oak Openings region have a higher percentage of statistically significant BMP use. Conversely, areas with low BMP use are clustered in the northwestern portion of the watershed.

The BMP identification techniques have been validated in other projects however, at this time the Swan Creek layers have not been validated. Future work will evaluate the accuracy in order to incorporate these results into future modeling of the watershed.

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