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GIS-BASED TRENDING ANALYSIS OF CROPLAND ASSOCIATED WITH RIPARIAN FROM 2008 TO 2018 IN WISCONSIN

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GIS-BASED TRENDING ANALYSIS OF CROPLAND ASSOCIATED
WITH RIPARIAN FROM 2008 TO 2018 IN WISCONSIN

By

Yanyun Li

A THESIS

Submitted in partial fulfillment of the requirements for the degree of

MASTER OF SCIENCE

In Applied Ecology

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2020

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This thesis has been approved in partial fulfillment of the requirements for the Degree of
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College of Forest Resources and Environmental Science

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List of abbreviations

RBDM	Riparian Buffer Delineation Model
USGS	U.S Geological Survey
CDL	Crop Data Layer
HUC	Hydrological Unique Code
FGDB	File Geodatabase
GDB	Geodatabase
DEM	Digital Elevation Model
NHD	National Hydrological Dataset
NWI	National Wetlands Inventory
GIS	Geographic Information System
DNR	Department of Natural Resources
NASS	National Agricultural Statistics Service
WBD	Watershed Boundary Dataset

Abstract

One of important characteristics of riparian area is to protect surface and underground water from nutrient contaminated runoff from nearby farmland. Comparing with the traditional fixed-width riparian buffer delineation, the Riparian Buffer Delineation Model (RBDM) to be used in this study, is a GIS-based tool designed to map variable-width riparian buffers by taking into consideration the watercourse and its associated floodplain. As the use of biofuels increases especially derived from corn, riparian areas are often converted to agricultural fields due to the nutrient rich soils and flat topography commonly found in these locations. Meanwhile, it also gives rise to nonpoint source pollution since massive amounts of fertilizer applied to corn yearly, excess nitrogen and phosphorus commonly wash into adjacent streams and lakes. Wisconsin (WI) is one of the states with this typical issue of planting plenty of corns, so how does the corn acreage changes over years and how does it relate to the riparian area function? This study developed two tools utilizing Python and ArcMap GIS were coded to facilitate geoprocessing and to insure and maintain data correctness. To illustration how to visualize the crop acreage changes in riparian area, nine watersheds with highest increase in corn acreage from 2008 to 2018 were selected as samples for analysis. The results indicate if corn acreage continuous to grow, the use of petroleum based fertilizer will also grow as well as soil erosion.

1 Introduction

The definition of a riparian area varies with different management and regulatory purposes. Referring to several federal agency definitions for a riparian area given by the National Research Council (2002), the dominant characteristic defining riparian area is location. It is located between a waterbody and upland. Additionally, soil characteristics and vegetation are two important indicators to help differentiate the riparian area from the upland area. Riparian areas are commonly thought of as ecotones along streams, rivers, lakes, and ponds. They are three-dimensional transitional areas from aquatic to terrestrial ecosystems, which can extend from the smallest headwaters to the largest rivers (Oakley et al., 1985), down into groundwater and up above the canopy (Verry et al., 2004). Due to their proximity to a watercourse, the riparian area usually has a high water table and moist soil conditions. This poor drainage ability benefits increases water storage and sediment accumulation. Additionally, riparian areas also include well-defined flora and fauna communities adapted to this unique landscape.

Over decades of research, riparian areas have been shown to provide ecological and social benefits. The riparian plant community is dominated by trees and other rooted herbaceous plants. These plants normally have very strong root networks which assist in maintaining channel complexity, control water flow rate, and prevent bank erosion. Meanwhile, riparian areas are helpful in the release and fixation of essential elements such as nitrogen, adjusting climate and preserving a sustainable and diverse habitat.

An important characteristic of riparian area is to protect surface and underground water from nutrient contaminated runoff from nearby farmland. This runoff makes its way into streams, sending sediments and excessive amounts of nitrogen, phosphorus and other contaminants such as herbicides into waterways. These nutrients can potentially contribute to algae blooms that deoxygenate the watercourse ecosystem. Riparian vegetation works efficiently in “intercepting” most of the nutrients discharged from cropland; thereby preventing them from directly flushing into watercourses. Riparian forests uptake approximately 89% of available nitrogen compare to nitrogen retention of adjacent cropland (only 8%). Similarly, 80% of phosphorus uptake by riparian forests is double that of adjacent cropland (~40%) (Peterjohn, 1984).

Social benefits are also important, as approximately 75% of outdoor recreation (hiking, fishing, etc.) in the United States occurs in the riparian area (Jones, 2008). Riparian areas also have esthetic values in improving the surrounding landscape.

According to the Revised Land and Resource Management (United States Forest Service, 2004), riparian is termed as a management prescription area. This management prescription area aims at maintaining riparian functions and values with specific management practices. Traditionally riparian areas were delineated via fixed width strip buffer. Previous studies recommended that reasonable buffer widths range from 3 to 100 meters, depending management objectives (Hawes et al., 2005). Fixed-width buffers are the easiest method to implement. However, these buffers tend to over and under estimate

the actual riparian area since the fixed-width calculation fails to consider the actual function related to the riparian area (Palik et al., 2000). Instead, it focuses on the watercourse itself and ignores the influences of other riparian area indicators. Palik et al. (2000) suggest a variable-width method since it incorporates both soil characteristics and flooding probability. The advantages of variable-width buffers are also noted by Wenger and Fowler (2000), when they noted highly correlated variables (slope, presence of wetlands, width of floodplain etc.) influence riparian area boundaries.

Mapping a comprehensive and accurate riparian buffer is challenging, since the watercourse and its associated floodplain are dynamic. GIS analysis functions link together multiple spatial predictors for delineating riparian areas. Incorporating hydrologic and geomorphological information into a variable width buffer model allows accurate boundary delineation. The Riparian Buffer Delineation Model (RBDM) developed by Abood et al., (2011) is a GIS-based tool, designed to map variable-width riparian buffers by taking into consideration the watercourse and its associated floodplain. The model utilizes ArcGIS Pro (ESRI, 1999-2018). This GIS model was initially developed by Mason et al., (2007), and is an accurate variable-width buffer zone utilizing 50-year flood heights and digital elevation models (DEMs). Abood further refined this model to better delineate the variable-width riparian zone "...along moving watercourses by hydrologically defining riparian ecotone to occur at the 50-year flood height utilizing the varying spatial resolution of DEMs" (Abood, 2011). Also, the RBDM can be used to delineate more comprehensive riparian areas by incorporating additional spatial data such as wetlands, soil drainage classes and land cover. The RBDM processes individual watersheds at any HUC (hydrologic unit code) scale within the area of interest utilizing file geodatabases (GDBs).

As the use of biofuels increases, particularly biofuel derived from corn, concern has arisen as to whether or not corn acreage has increased in riparian areas. Riparian areas are often converted to agricultural fields due to the nutrient rich soils and flat topography commonly found in these locations. Corn is the most important row crop in Wisconsin (WI) because of its productivity and high yields. In addition to biofuel production (ethanol), corn is important for animal feed and human consumption. Although corn is an important and highly productive crop, there are several serious drawbacks to consider. Roughly 76% of annual corn production fuels cars and feeds livestock instead of feeding people (Foley, 2013). Corn production consumes a huge amount of resources such as petroleum based fertilizers and diesel driven farm equipment in addition to being a row crop which can experience soil erosion and nutrient loss. As a result of the massive amounts of fertilizer applied to corn yearly, excess nitrogen and phosphorus commonly wash into adjacent streams and lakes are a serious source of nonpoint source pollution.

1.1 Site Description

The study area for this project was the Wisconsin River watershed. The Wisconsin River (HUC 6) is a tributary of the Mississippi River in WI, at approximately 692 kilometers /

430 miles. It is the longest river in WI with its headwaters located just across the border in Michigan (Figure 1-1). This area is characterized in the north by extensive forest cover, and slowly transitions to agricultural activities with intensive row cropping as it proceeds south.

Figure 1-1. Wisconsin River watershed. Scale is 1:4,000,000.

The watershed is subdivided into 77 HUC 10 sub-watersheds (Figure 1-2) which are the units used for this study.

Figure 1-2. The 77 10-digit HUC watersheds at a scale of 1:1,800,000.

1.2 Data Inputs

Delineating the 77 sub watersheds with the RDBM requires the inputs listed in Table 1-1. Comprehensive riparian areas, as opposed to basic riparian areas, are required; hence soils drainage classes and mapped wetlands are also needed inputs.

Table 1-1. Data inputs for the RDBM

Data	Data Source
Watershed	The national map https://viewer.nationalmap.gov/basic/
Lakes & Ponds	The national map
Rivers & Streams	The national map
Wetlands Data	National Wetlands Inventory (NWI) https://www.fws.gov/wetlands/data/Mapper.html
Stream Gauge Data	USGS https://waterdata.usgs.gov/nwis/sw
gSSURGO Data	Geospatial Data Gateway https://datagateway.nrcs.usda.gov/
10-meter Elevation Data	The nation map

After riparian area delineation, the cropland dataset (CDL) is integrated to assess agricultural land cover change between 2008 and 2018. This timeframe was chosen to provide a consistent land cover classification scheme for the CDL. Annual geospatial CDL thematic layers from 2008 to 2018 are accessible on the CropScape website (<https://nassgeodata.gmu.edu/CropScape/>). These datasets include detailed agricultural crop data for the U.S., including corn. Corn grown within riparian areas is separated from upland area corn. Graphically displaying the acreage through an animated time series helps visualize yearly changes in area spatially. The coordinate system of choice was: NAD 1983 2011 Wisconsin Transverse Mercator.

2 Methodology

2.1 Data Preprocessing for RBDM

2.1.1 Watershed Preparation

Watershed boundary dataset (WBD), referred to the watershed. HUC 6 watershed with code of 070700 and its nested HUC 10 watersheds were download from The National Map Viewer (<https://viewer.nationalmap.gov/basic/>).

2.1.2 Streams & Rivers Preparation

2.1.2.1 NHD Flowline Data Issues

NHD flowline streams and rivers, was also downloaded from the National Map Viewer website. The completeness of the NHD data varies from watershed to watershed. A critical attribute missing from the sub-watersheds is stream order, and this information is required to calculate the variable 50-year flood height. Determining stream order was accomplished using the Hydrology Toolbox in ArcMap GIS (Figure 2-1).

New flowline feature classes with calculated stream order were derived from the input DEM to eliminate sinks, and flow direction and flow accumulation were also calculated. A threshold value (4,500) for determining the surface flow path was chosen by comparing the newly created flowline data which spatially best matches the original NHD flowline. Stream order was determined by the Strahler method to assign numeric orders to the linear flow path segments. The raster flowline data was then converted from raster to vector data format.

Figure 2-1. Workflow creating new flowlines with a calculated stream order attribute field.

Figure 2-2 shows two flowline datasets in a subset of a HUC 10 watershed. The blue line is the newly created flowline dataset with a calculated stream order. The red line is the original NHD flowline dataset. The newly created flowline feature class now has a stream order attribute, but is lacking the official Reach Code attribute which provides a unique identifying number for each stream segment. This unique number also provides the link for joining various standalone tables associated with the streamflow data. To maintain the integrity of flowline shape features and useful attribute fields, the ideal approach would be to join the stream order field from the new created flowline feature to the original NHD flowlines.

However, there are no common fields between the two flowline datasets, and join by common attribute was not an option. Spatial Join, which utilizes spatial x, y coordinates, overcomes the issue by using spatial location to assign the reach code. Figure 2-2 shows that the overall line distribution of the newly created flowline lines up with the original NHD flowline very well, and the “Closest” match option was chosen. Some upstream NHD flowlines (red) failed to overlay with the newly created flowlines (blue). For these locations, the stream order was entered manually. Most of these upstream segments had a stream order of 1. An example of stream and rivers (NHD) coded with stream order in Figure 2-3.

Figure 2-2. Comparison between digitized new streams (blue) and NHD flowline (red) at 1:31,500.

Figure 2-3. NHD flowline and associated stream order for one of HUC 10 sub-watersheds, at a scale of 1:130,000.

2.1.2.2 Estimate 50-year Flood Height

There are 21 USGS stream gauges with at least 10 years of data providing both annual statistics and field measurements needed to calculate the 50-year flood height. The calculation follows the formula developed by Mason (2007). Using the latitude and longitude location coordinates for each station, a gauge station location feature class was created and added to the GDB. The calculated 50-year flood height data was entered into the flowline feature class as a new attribute.

Abood (2015) showed the importance of determining flood height by stream order rather than applying one 50-year flood height to the entire HUC 10 watershed. By overlaying the NHD flowline with stream gauge locations and using linear regression, the relationship of flood height to stream order can be determined. Figure 2-4 and Table 2-2 illustrate this and show how flood height increases with increasing stream order.

In Figure 2-4, the X-axis represents stream order and the Y-axis represents the calculated 50-year flood height (meters). Stream order begins with 1 and is referred to as a headwater. The deeper and wider a watercourse is, the higher stream order it has. Points represent gauge stations and their associated stream orders. The plotted line is calculated by utilizing the regression equation with the highest R-squared value. Calculated flood heights are added as an attribute field to the NHD flowline based on stream order.

Figure 2-4. Scatter plot of estimated 50-year flood height V.S. stream order.

Table 2-1. Stream order and estimated 50-year flood height from Figure 2-4.

Stream Order	Flood Height (meters)
1	0.106
2	0.177
3	0.297
4	0.499
5	0.838
6	1.407
7	2.361

2.1.3 Lakes and Ponds Preparation

NHD waterbodies, referred to as lakes and ponds, were downloaded from the National Map Viewer website and subset to the area of interest.

2.1.4 Wetland Data Preparation

Mapped wetlands data adjacent to waterbodies are important indicators of extended riparian areas. National Wetland Inventory (NWI) dataset can be downloaded from the U.S. Fish & Wildlife Service website, and used as input in RBDM. Riparian buffers derived from just the 50-year flood height and DEM are referred to as basic riparian buffers. The inclusion of wetlands and soils information (noted below) are referred to as comprehensive riparian buffers.

2.1.5 Soils Data Preparation

Wet soils indicators, such as drainage class, are also serve as an input into the model to delineate a more comprehensive riparian area. Ten-meter gSSURGO soils data in raster format was released in 2016 for the study site. Compared with the traditional vector format SSURGO soils data, gSSURGO has improved capability in combined analysis with other gridded national data (such as DEMs) and shorter processing times (gSSURGO User Guide, 2016). A new table was added to the gSSURGO data, the National Value Added Look Up (Valu1) which contains information on potential wetland soils. According to four criteria suggested by Palik et al. (2004) to determine riparian areas, wet soils must meet all of the following criteria:

- (1) Soils with potential wetland soil landscapes (PWSL, Version 1) must have a value ≥ 80 , indicating over 80% percent of map unit is classified as potential wet soil;
- (2) Soils must have a drainage class of “Poorly drained”, “Somewhat poorly drained” or “Very poorly drained”;
- (3) Soils must have a very slow infiltration rate when thoroughly wet, indicated by a hydric group of “C”, “D”, “A/D”, “B/D” or “C/D”; and
- (4) Soils with a hydric rating of “Yes”, or “Unranked” with a and “PWSL ≥ 80 ” are classified as hydric soils.

2.2 Create FGDB for RBDM and Import Data

The RBDM processes each HUC 10 watershed independently. As noted previously, the Wisconsin River Watershed is made up of 77 HUC 10 watersheds. Individual FGDBs are created for each. Since all of the HUC 10 watersheds have the same inputs, a Python workflow script was written to automate the data input process and ensure the correct data is affiliated with its appropriate GDB. Figure 2-5 shows the input command window developed for ArcMap. The code is in Appendix A.

Figure 2-5. Data preparation tool designed for RBDM in ArcMap. The outputs are automatically named as “watershed”, “lakes_ponds”, “streams_rivers”, “wetlands”, “soils”, and “DEM”.

Required inputs include:

- (1) Input watershed is the full watershed area of interest;
- (2) Input lakes and ponds are the NHD waterbody data;
- (3) Input streams and rivers are the NHD flowline with stream order and 50-year flood height included in the attribute table;
- (4) Wetlands and soils data are optional inputs;
- (5) Input DEM and soil data should be larger than the study area; 300 meters buffer suggested; and
- (6) Output folder asks the user to specify an output folder name to store the individual FGDBs.

The name for each GDB is created automatically by taking the order of ObjectID in the attribute table for the HUC 10 watershed. The names of outputs in each GDB are created automatically as well, hence all FGDB names are uniform and avoids future typo issues. Figure 2-6 shows an output example of a GDB for one of the HUC 10 watersheds. Figure 2-7 shows the consistent labeling of the GDBs.

Figure 2-6. An example FGDB of one of the HUC 10 watersheds.

Figure 2-7. Partial list of the HUC 10 GDBs naming convention.

2.3 Riparian Area Delineation

Once all the required data are imported as standalone feature classes into each of the 77 GDBs, the RBDM is ready to run in ArcGIS Pro. The riparian area output is a polygon (Figure 2-8).

Figure 2-8. Riparian buffer delineated for a portion of a HUC 10 watershed at 1:20,000.

2.4 Integrated with Cropland Data

Geospatial cropland data layer (CDL) is available online from 2008 to the present. It provides information about land cover for specific agricultural crops. The classification scheme of the CDL is presented in Figure 2-3 and shows the newest color legend of the 2018 CDL dataset. The legend for other years can be found at https://www.nass.usda.gov/Research_and_Science/Cropland/sarsfaqs2.php#Section1_8.0.

To assess the change in corn acreage planted for the 11 year period (2008 - 2018) required upland planted corn to be separated from corn growth within riparian buffers. To facilitate this operation a Python script (Appendix B) was developed to efficiently process the 77 HUC 10 watersheds. The script is capable of comparing any crop within the CDL data.

Figure 2-9. 2018 continental United States land cover categories (by decreasing acreage) from USDA NASS.

Multiple years' data can be input simultaneously with two raster datasets created for each year (Figure 2-10). Secondly, the tool converts the raster dataset to a vector feature class, and then combines them into a time-embedded vector feature class. Converting to vector format facilitates change detection analysis within ArcMap.

Figure 2-10. CDL info extract and conversion within riparian and upland tool in ArcMap.

2.4.1 Tool Description

- (1) **Input CDL Data** is one or multiple CDL data layers in consecutive years for the area of interest;
- (2) **SQL Sentences** specifies which crop (s) are selected. "Class_Name = 'Corn' " selects all of corn within the watershed and separates it in upland and riparian buffer corn;
- (3) **Working Folder** specifies the folder containing all HUC 10 watershed GDBs;
- (4) The **Raster Output Only** box determines the final output format. If checked, this tool only creates raster outputs for each year, and the output is named automatically as crop name + year, like "Corn_2008"; if unchecked, output is in vector format;
- (5) The **Output Name of the Combined Vector in Riparian** specifies an output name for the combined vector data. If the raster only box is checked, this input is optional; and
- (6) The **Output Name of the Combined Vector in Upland** specifies an output name for the combined vector data within the upland area. If the raster only box is checked, this input is optional.

2.4.2 Data Requirements

- (1) Existing folder includes all GDBs; one for each HUC 10 watersheds. Make sure they are named in sequential order (For example ID01.gdb, ID02.gdb...ID77.gdb), this can be done by following the processes in section 2.2;
- (2) The riparian area is generated by the RBDM in advance and exported to each GDB, and must have a common name "riparian";
- (3) The name of all-year CDL dataset must include four-digit numbers of the corresponding year. For example, CDL of 2008 should be named as "CDL2008";
- (4) The common field of "Class_Name" is required in all-year CDL data, this field contains a list of crop categories.

2.4.3 Other Explanations

- (1) All outputs are written into the corresponding FGDB. This tool will automatically loop through all FGDBs.
- (2) The raster outputs within riparian are named as "Crop Name_RYear". For example, the corn within the riparian area of 2008 will be named as "Corn_R2008".
- (3) The raster outputs within upland are named as "Crop Name_UYear". For example, the corn within the upland area of 2008 will be named as "Corn_U2008".
- (4) The vector outputs within riparian are named as "Crop Name_RYear_vec". For example, the corn within the riparian area of 2008 will be named as "Corn_R2008_vec".
- (5) The vector outputs within upland are named as "Crop Name_UYear_vec". For example, the corn within the riparian area of 2008 will be named as "Corn_U2008_vec".
- (6) Only the combined vector is named by users.

2.4.4 Flowchart

As Figure 2-11 shows, the Python logic behind the tool to automation tool is based on the nested for loops. Nested loop means an inner loop within the body of the outer one. As the outer loop, the Condition 1 starts with reading the first FGDB in the working folder. The first pass of the outer loop will trigger the inner loop, here it is Condition 2. The inner loop starts to work with the first year CDL dataset.

Under the inner loop, Statement A extracts corn data from CDL and delineates them as riparian buffer or upland corn. Figure 2-12 shows a brief workflow of the statements logic. After separating the corn data, a new field called "Year" is added to the attribute table. The calculation of the "Year" field is according to the input CDL name, and this is the reason for the requirement mentioned in section 4.2.3 (3). The final outputs are in polygon format, and the inner loop will execute multiple times until it cycles through the last year of data.

After the completion of the inner loop, the process moves back to the outer loop. Statement B is to merge and dissolve multi-year corn data within riparian buffer and upland respectively. Figure 2-13 shows a brief workflow of Statement B. As the results of Statement B, one polygon represents the 11-year corn planted in riparian, another one represents the 11-year corn planted in upland. The outer loop will be executed multiple times till it processes the last GDB.

Figure 2-11. Nested loop flowchart

Figure 2-12. Workflow for Statement A

Figure 2-13. Workflow for Statement B

3 Results and Analysis

Time is an important component when analyzing spatial data as it provides the fourth dimension for analyses. Geospatial data visualization enables users to directly connect data with geographic location and assess trends. Once the vector feature classes are embedded with the time field generated by running CDL Info Extract and Conversion within Riparian and Upland tool, three types of outputs are created to develop an understanding of how the spatial extent of corn changes through time.

The first output is a statistic table, which quantitatively presents the overall trend of corn coverage from 2008 to 2018. It also gives insight as to the magnitude of change within riparian buffers as well as upland areas. The second output is the map comparison between 2008 and 2018. The primary advantage of the map is to show when and where corn acreage changes at the same time. These maps show where corn is most frequently located and whether it increases or decreases during the decade of study. The last outputs take advantage of a bar chart and map to create a time animation in a video format. The animation consists of 11 keyframes for each year, and every frame displays the corn coverage map in that specific year. In this study, time animation visualizes the corn changing dynamically, it highlights hotspots of change and predicts potential future trend. Time animation are easily understood by non-expert GIS person and can be easily shared via email or website.

Time animation is achieved by Time Slider in ArcMap. Time Slider allows a set of keyframes of tracking data to be played in a common video format which is easily shared via uploading to websites or attaching to an email. Other functions in ArcGIS work similarly, such as Animation Function in ArcGIS Pro, and Tracking Analyst in ArcMap GIS.

Within the Wisconsin River watershed, planted corn acreage has been increasing. To illustrate the advantages of geospatial visualization for this project, the nine HUC 10 watersheds with the highest increase in corn acreage from 2008 to 2018 (Table 3-1) are discussed. Figure 3-1 shows the location of these 9 watersheds (in yellow).

Table 3-1. Corn case study watershed information.

ID	Watershed Name
3	Hoosier Hollow-Mill Creek
8	Little Baraboo River-Baraboo River
23	Fourmile Creek
33	Big Roche a Cri Creek
53	Headwaters Kickapoo River
54	Willow Creek
56	Fourteenmile Creek
65	Tenmile Creek

Figure 3-1. Locations of watersheds with largest corn acreage increase between 2008 and 2018. Watershed names are listed in Table 3-1.

3.1 Output: Area Results

Yearly total corn area (km²) for the riparian buffer and upland areas (Appendix C) are directly exported from the feature class attribute tables. The results show upland corn area increasing from 2008 to 2018 for all watersheds, with minor yearly fluctuations. These fluctuations are normally due to abnormal weather conditions (extremely wet or cold temperature, etc.) and weight measurement errors. Unlike upland area, riparian buffer corn area remains stable through years. Each year 90% of grown corn is located in upland fields.

3.2 Outputs: Map Comparison & Time Animation

Figures 3-2 to 3-10 show the locations of corn fields between 2008 and 2018 for the 9 selected watersheds. Yellow areas indicate corn located in upland fields, and red areas indicate corn located within riparian buffers. Green highlights the delineated riparian region within the watershed. The animations show changes in corn acreage from year to year and where they are located (see attached AVI format files). These visualization support the yearly total acreage numbers and show the overall trend of corn acreage steadily growing with minor fluctuations between years.

The Mill Creek (ID3) watershed (Figure 3-3) is located west of Richland Center, with the village of Boaz near the center of the watershed. The northwestern corner extends into Forest Township. Wider riparian buffers are located next to higher-order streams. Upland corn fields in Eagle Township are larger and more extensive than the rest of watershed. Watching the video shows the upland corn acreage is constantly changing. This is due in part to crop rotation. While there is no significant change of corn acreage in the riparian areas, most upland corn fields are adjacent to them.

[AVI_ID03.avi](#)

Figure 3-2. Corn comparison between 2008 and 2018 of Hoosier Hollow-Mill Creek watershed (ID3). Scale is 1:210,000.

The Little Baraboo River-Baraboo River (ID8) watershed (Figure 3-4) has additional and more extensive upland corn fields being planted during the study period, with much of the increase area adjacent to higher order streams. These are found near the villages of Union Center, Wonewoc, Ironton, and Cazenovia. According to the video, we can see that the overall corn coverage in this watershed increases steadily from 2008 to 2018 except in the townships of La Valle and Winfield.

[AVI_ID08.avi](#)

Figure 3-3. Changes in corn field locations between the years 2008 and 2018 for Little Baraboo River-Baraboo River watershed (ID8). Scale is 1:290,000.

The Fourmile Creek (ID23) watershed is the last HUC10 watershed before the Wisconsin River enters the Mississippi River. Comparing the 2008 acreage to 2018 maps, it is apparent corn plantings increased in both upland fields and riparian buffer areas. Riparian buffer acreage occurs in Buena Vista township. The upland acreage increases throughout the entire watershed except for Grand Rapids township. Watching the video shows the overall trending increasing steadily except in Plover township in 2014, and then corn coverage increases dramatically from 2017 to 2018.

[AVI_ID23.avi](#)

Figure 3-4. Changes in corn field locations between 2008 and 2018 of Fourmile Creek watershed (ID23). Scale is 1:210,000.

Big Roche a Cri Creek (ID33) watershed (Figure 3-6) is located on Petenwell Lake in the townships of Richfield, Deerfield, and Leola. This watershed contains large contiguous wetland riparian areas. Upland corn sees large acreage increases in the western (Strong's

Prairie Township) and easternmost parts (surround the city of Hancock) of the watershed. Looking the riparian buffer acreage for 2018, most of the increase is located between large adjacent upland corn fields. This may indicate the narrow riparian buffers were dry during the planting season and were simultaneously planted with the upland planting.

[AVI_ID33.avi](#)

Figure 3-5. Changes in corn field locations between 2008 and 2018 of Big Roche a Cri Creek watershed (ID33). Scale is 1:250,000.

Headwaters Kickapoo River (ID53) watershed (Figure 3-7) is located in Wisconsin's Driftless Area which has never been glaciated. It is composed of narrow valleys, steep ridges and a dendritic drainage pattern. Fields area located on hillshades and run

perpendicular to the slope to reduce soil erosion. Yearly crop rotation is a widely accepted farming practice for this area. This is highlighted in the video. Note that the locations of corn fields are constantly changing.

[AVI_ID53.avi](#)

Figure 3-6. Changes in corn field locations between 2008 and 2018 of Headwaters Kickapoo River watershed (ID53). Scale is 1:200,000.

Willow Creek (ID54) watershed (Figure 3-7) is located east of the village of Richland Center. This watershed is also located in the Driftless Area. Riparian buffers are narrow as there are no extensive wetlands. Where the buffers widen is due to the serpentine pattern of the streams with numerous oxbows. Where the buffers are not wooded, fields

run to the edge of the stream and are periodically planted to corn when adjacent upland fields are corn.

[AVI_ID54.avi](#)

Figure 3-7. Changes in corn field locations between 2008 and 2018 of Willow Creek watershed (ID54). Scale is 1:160,000.

Fourteenmile Creek (ID56) watershed is located between the Village of Plainfield to the east and southwest of the city of Nekoosa. As Figure 3-9 shows, the watershed has extensive contiguous riparian areas. Where corn is grown within riparian areas, the fields usually ditched and drained to promote drainage. One of concern is the expansion of corn fields in riparian areas in central Leola Township. Google Earth imagery from 2013 shows wooded riparian areas which have since been cleared and converted to agriculture.

[AVI_ID56.avi](#)

Figure 3-8. Changes in corn field locations between 2008 and 2018 of Fourteenmile Creek watershed (ID56). Scale is 1:190,000.

Tenmile Creek (ID65) watershed (Figure 3-10) is located immediately east and north of Fouteen Mile Creek watershed and southeast of the city of Nekoosa. Most corn fields are

in the eastern half of the watershed which is located on the lakebed of glacier Lake Wisconsin. Crop rotation is common in this area and many fields are irrigated with central pivot irrigation. According to the video, we can see corn field changes more dramatic outside of the riparian area especially in Oasis Township.

[AVI_ID65.avi](#)

Figure 3-9. Changes in corn field locations between 2008 and 2018 of Tenmile Creek watershed (ID65). Scale is 1:340,000.

Pine River (ID70) watershed has Richland Center as its center and is located on the eastern border of Mill Creek watershed. The watershed is located in the Driftless Area. Figure 3-11 indicates the distribution of the riparian areas in this watershed is quite

uniform and is located in valleys. Very few riparian areas are planted to corn. Watching the video shows increasing corn acreage. Similar to all of the above watersheds, there is no obvious change for the corn areas within the riparian area from 2008 to 2018.

[AVI_ID70.avi](#)

Figure 3-10. Changes in corn field locations between 2008 and 2018 of Pine River watershed (ID70). Scale is 1:300,000.

4 Conclusion

Riparian zones within the Wisconsin River watershed were mapped accurately using the RBDM based on the 50-year flood height affiliated with stream order, NWI, and digital soils data. The buffer zones were integrated with CDL data from 2008 through 2018 to ascertain if corn acreage had increased for the 11 year period. The time frame is important as corn prices rose (and fell) dramatically, and demand for corn for ethanol production rose as additional plants were built (Figures 4-1 and 4-2) (RFA, 2019).

Figure 4-1. New and existing ethanol biorefineries in the United States as of 2019 (Renewable Fuels Association, 2019).

Figure 4-2. Ethanol fuel production between 1980 and 2018. Note the rapid climb starting in 2008 and continuing to the present (Renewable Fuels Association, 2019).

Two new tools utilizing Python and ArcMap GIS were coded to facilitate geoprocessing and to insure and maintain data correctness. In the first function, the data input process and ensures the correct data is affiliated with the appropriate GDB before running the RBDM. For a study area this large, data input is tedious and prone to error. The second code separates user-specified cropland (corn for this study) between riparian and upland areas. Then convert the resulting feature classes to a time-embedded vector dataset. Time contributes the 4th dimension to spatial data as it gives us additional insight into understanding the data by recognizing changes in spatial distribution of the corn crop.

Petroleum based fertilizer applied to corn is the primary source of nitrogen entering and contaminating the nation's water resources. Previous research has demonstrated that riparian areas provide an effective means for reducing nitrogen as well as phosphorus in surface and groundwater (Schilling, 2007). Riparian buffers are especially good at trapping these soluble pollutants and sediments from nearby agricultural land.

Woody vegetation has a very strong and deep root system which facilitates the infiltration of soluble nutrients into the soil, and dense grasses are effective in trapping particulates. It is recommended that riparian buffer consist of multi-species combinations of stiff

grasses and woody vegetation to improve pollutants and sediment removal (Lee, 2003). During periods of intensive rain, groundwater also contributes water to the stream course due to rising water table and may increase harmful soluble nutrients. This is called baseflow. Shallow-rooted cornfields contribute more baseflow than woody forest and grassland (Schilling, 2007) and pose a threat to adjacent streams. In our study, it is noted the corn area within riparian areas remains fairly consistent from 2008 to 2018 for the nine sample watersheds. However, it is also noted the overall corn acreage is increasing over time and many of fields area adjacent to existing riparian areas.

Corn has food, seeds and industrial (FSI) uses, and the FSI has been increasing dramatically by adding approximate 5000 million bushels between 1998 to 2018 according to the ERS Feed Outlook 2019 (USDA). Ethanol is one of the primary products in FSI. To achieve the target set by Renewable Fuel Standard (RFS) aiming to achieve 36 billion gallons of renewable fuel by 2022, it is predictable for corn acreage to increase in order to meet ethanol production expectations.

If corn acreage continuous to grow, the use of petroleum based fertilizer will also grow as well as soil erosion. These increases will create burdens for existed riparian areas to remove nutrients and trap sediments. As we knew, the riparian delineation model RBDM does not take specific vegetation into account as this information is very difficult to obtain, especially over an area as large as the Wisconsin River watershed. However, a question to consider is: if corn acreage increases and we rely on riparian areas to help reduce nonpoint source pollution, should the vegetation within riparian areas be more closely managed? Also, should management guidelines be established for agricultural practices on fields adjacent to riparian areas?

5 Copyright Documentation

Ethanol Industry Outlook. Power with Renewed Energy. 2019. Renewable Fuels Association.

Federal standards and procedures for the National Watershed Boundary Dataset (WBD), 2013; TM; 11-A3; Section A: Federal Standards in Book 11 Collection and Delineation of Spatial Data; U.S. Geological Survey; U.S. Department of Agriculture; Natural Resources Conservation Service

Foley, J., 2013. It's Time to Rethink America's Corn System. Scientific American. <https://www.scientificamerican.com/article/time-to-rethink-corn/>

Gridded Soil Survey Geographic (gSSURGO) Database User Guide. 2016. National Soil Survey Center. Natural Resources Conservation Service. United States Department of Agriculture.

Hawes, E., Smith, M., 2005. Riparian buffer zones: Functions and recommended widths. Eightmile River Wild and Scenic Study Committee, 15, p.2005.

Ilhardt, B. L., Verry, E. S., Palik, B. J., 2000, 'Defining riparian areas', in E. S. Verry, J. W. Hornbeck and C. A. Dolloff (eds.), Riparian Management in Forests of the Continental Eastern United States, Lewis Publishers, Boca Raton, FL, pp. 23–42.

Jones, G, 2008. Social and economic value of riparian environments. Finch, Deborah M. Rocky Mountain Riparian Digest. Rocky Mountain Riparian Digest. Fort Collins, CO: U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station. p. 3-4.

Lee, K. H., Isenhardt, T. M., Schultz, R. C., 2003. Sediment and nutrient removal in an established multi-species riparian buffer. Journal of Soil and Water Conservation 2003 58(1):1-8

Mason, L., 2007. GIS Modeling of Riparian Zones Utilizing Digital Elevation Models and Flood Height Data: An Intelligent Approach. M.S. Thesis, Michigan Technological University, Houghton, Michigan, 75p.

NHD Help Portal. Available online at: https://usgs-mrs.cr.usgs.gov/NHDHelp/WebHelp/NHD_Help_Portal.html#NHD_Help_Portal_1.html

National Research Council. 2002. Riparian Areas: Functions and Strategies for Management. Washington, DC: The National Academies Press. <https://doi.org/10.17226/10327>.

Oakley, A.L., Collins, J.A., Everson, L.B., Heller, D.A., Howerton, J.C., Vincent, R.E., 1985. Riparian zones and freshwater wetlands. Management of wildlife and fish habitats in forests of western Oregon and Washington, pp.57-80.

Palik, B., Tang, S. M., Chavez, Q., 2004. Estimating riparian area extent and land use in the Midwest, General Technical Report NC-248, U.S. Department of Agriculture, Forest Service, North Central Research Station, St. Paul, MN, pp. 28.

Peterjohn, W., Correll, D., 1984. Nutrient Dynamics in an Agricultural Watershed: Observations on the Role of A Riparian Forest. *Ecology*, 65(5), 1466-1475.
doi:10.2307/1939127

Seaber, P. R., Kapinos, P. F., Knapp, G. L., 1994. Hydrological Unit Maps. U.S. Geological Survey, Water Supply Paper 2294.

Soil Survey Division Staff, 1993. Soil survey manual. Soil Conservation Service. U.S. Department of Agriculture Handbook 18. Available online at:
https://www.nrcs.usda.gov/wps/portal/nrcs/detail/?cid=nrcs142p2_054253

Soil Survey Staff, Natural Resources Conservation Service, United States Department of Agriculture. Web Soil Survey. Available online at <http://websoilsurvey.nrcs.usda.gov/>. Accessed 03/25/2016.

Schilling, K., 2007. Water table fluctuations under three riparian land covers, Iowa (USA). *Hydrological Processes*. 21. 2415 - 2424. 10.1002/hyp.6393.

U.S. Senate (2019) Renewable Fuels, An Overview, an Energy Efficiency Act of 2019 (U.S. Senate, Washington, DC, September 4, 2019).

USDA National Agricultural Statistics Service Cropland Data Layer. 2008-2018. Published crop-specific data layer [Online]. Available at <https://nassgeodata.gmu.edu/CropScape/> (accessed 05/06/2018). USDA-NASS, Washington, DC.

U.S. Geological Survey, 2019, National Water Information System data available on the World Wide Web (USGS Water Data for the Nation), accessed [Dec 10, 2016], at URL [<http://waterdata.usgs.gov/nwis/>].

United States Forest Service. 2004. Revised Land and Resource Management Plan: Jefferson National Forest. Appendix A. [Atlanta, GA]: U.S. Dept. of Agriculture, Forest Service, Southern Region.

Wenger, S. J., Fowler, L., 2000. Protecting stream and river corridors: creating effective local riparian buffer ordinances.

A Appendix A

```
#####  
###      Data Pre-processing for RBDM (ArcMap Desktop Version)      ###  
#####  
  
# This tool is designed for data preparation of RBDM, creating multiple FGDBs and  
# having all required data for running RBDM clipped to the same spatial extent.  
  
# Import arcpy and other support modules:  
  
import arcpy, os, sys, traceback  
  
import arcpy.mapping as mapping  
  
  
  
# check out the Spatial Analyst Extension (Code will not run, with the extension being  
# checked out)  
  
arcpy.CheckOutExtension ("Spatial")  
  
  
  
# Allow script to overwrite existing feature classes  
  
arcpy.env.overwriteOutput = True  
  
  
  
# Define different input data for processing  
  
watershed = arcpy.GetParameterAsText(0)  
waterbody = arcpy.GetParameterAsText(1)  
flowline = arcpy.GetParameterAsText(2)  
wetland = arcpy.GetParameterAsText(3)  
soil = arcpy.GetParameterAsText(4)  
inraster = arcpy.GetParameterAsText(5)  
output = arcpy.GetParameterAsText(6)
```

```

# Get total watersheds number within original data
count = arcpy.GetCount_management(watershed)
num = int(count.getOutput(0))

# Make temporary feature layers
arcpy.management.MakeFeatureLayer(watershed, "watershed_lyr")

# Run a loop for each watershed
time = 1
while True:
    if time <= num:
        # Create new file geodatabase
        out_name = "ID{0}.gdb".format(time)
        arcpy.CreateFileGDB_management(output, out_name)
        arcpy.AddMessage("Generating No. {0} geodatabase...").format(time)

        # Set new workspace path
        arcpy.env.workspace = os.path.join(output, out_name)

        # Create a query and select layer by attribute
        qry = ' "OBJECTID" = {0} '.format(time)
        arcpy.management.SelectLayerByAttribute("watershed_lyr", "NEW_SELECTION",
        qry)

```

```

# Clip waterbody, wetlands, flowline
arcpy.Clip_analysis(waterbody, "watershed_lyr", "lakes_ponds")
arcpy.Clip_analysis(flowline, "watershed_lyr", "streams_rivers")

arcpy.Buffer_analysis("watershed_lyr", "watershed_lyr_buf", "300 Meters")

try:
    # Extract the buffered Soil
    soils = arcpy.sa.ExtractByMask(soil, "watershed_lyr_buf")
    soils.save("soils")
    arcpy.Clip_analysis(wetland, "watershed_lyr", "wetlands")
except:
    pass

# Extract the buffered DEM
dem = arcpy.sa.ExtractByMask(inraster, "watershed_lyr_buf")
dem.save("DEM")

# Export selected watershed as a new feature class
arcpy.management.CopyFeatures("watershed_lyr", "watershed")

# Delete non-required feature class
arcpy.Delete_management("watershed_lyr_buf")

time += 1

```

else:

break

B Appendix B

```
#####  
###      CDL Info Extract and Conversion within Riparian and Upland      ###  
#####
```

```
# Import arcpy and other support modules:
```

```
import arcpy, os, sys, traceback
```

```
import arcpy.mapping as mapping
```

```
from arcpy.sa import *
```

```
import re
```

```
# check out the Spatial Analyst Extension (Code will not run, with the extension being  
checked out)
```

```
arcpy.CheckOutExtension ("Spatial")
```

```
# Allow script to overwrite existing feature classes
```

```
arcpy.env.overwriteOutput = True
```

```
# Define different input data for processing
```

```
cdl = arcpy.GetParameterAsText(0)
```

```
qry = arcpy.GetParameterAsText(1)
```

```
working_en = arcpy.GetParameterAsText(2)
```

```
ischecked = arcpy.GetParameterAsText(3)
```

```
cdl_all_years_rp = arcpy.GetParameterAsText(4)
```

```

cdl_all_years_up = arcpy.GetParameterAsText(5)
cdlYearList = cdl.split(";")

# Set workspace path
arcpy.env.workspace = working_en
workspaces = arcpy.ListWorkspaces("*", "FileGDB")

cntr = 1

for FGDB in workspaces:

    arcpy.env.workspace = os.path.join(working_en, os.path.basename(FGDB))

    arcpy.AddMessage("Working on No." + str(cntr) + " File Geodatabase...")

# Loop through all years CDL data

cntr_1 = 1

for cType in cdlYearList:

    arcpy.AddMessage("Processing the No." + str(cntr_1) + " year " +
os.path.basename(cType)+ "...")

# Extract crop from attribute table

attExtract = ExtractByAttributes(cType, qry)

attExtract.save("EBA")

# Clip selected crop within riparian area

try:

    croplist = qry.split("")

    crop = croplist[1]

```

```

        crop_name = filter(str.isalnum, str(crop))
except AttributeError:

    crop_name = "crop"

year = re.findall("\\d+", os.path.basename(cType))[0]

crop_year_1 = crop_name + "_R" + year

outExtractByMask = ExtractByMask("EBA", "riparian")

outExtractByMask.save(crop_year_1)


# Clip selected crop in upland area

crop_year_2 = crop_name + "_U" + year

arcpy.Erase_analysis("watershed", "riparian", "upland")

outExtractByMask = ExtractByMask("EBA", "upland")

outExtractByMask.save(crop_year_2)


if str(ischecked) == 'true':

    pass

else:

    # Process: Raster to Polygon

    try:

        crop_year_poly_1 = crop_year_1 + "_vec"

        arcpy.RasterToPolygon_conversion(crop_year_1, crop_year_poly_1,
"NO_SIMPLIFY", "Class_Name")

        arcpy.AddMessage("Processing: Raster to polygon for area in riparian")


        crop_year_poly_2 = crop_year_2 + "_vec"

```



```

        arcpy.RasterToPolygon_conversion(crop_year_2, crop_year_poly_2,
"NO_SIMPLIFY", "Class_Name")

        arcpy.AddMessage("Processing: Raster to polygon for area in upland")

# Process: Add Field

in_feature = crop_year_poly_1

add_field = "Year"

out_feature = crop_year_poly_1

arcpy.AddField_management(in_feature, add_field, "TEXT", "", "", "", "",
"NULLABLE", "NON_REQUIRED", "")

arcpy.CalculateField_management(out_feature, "Year", year, "PYTHON_9.3")


in_feature = crop_year_poly_2

add_field = "Year"

out_feature = crop_year_poly_2

arcpy.AddField_management(in_feature, add_field, "TEXT", "", "", "", "",
"NULLABLE", "NON_REQUIRED", "")

arcpy.CalculateField_management(out_feature, "Year", year, "PYTHON_9.3")


# Create a list to store all crop polygons

if cntr_1 == 1:

    poly_list_1 = [crop_year_poly_1]

    poly_list_2 = [crop_year_poly_2]

else:

    poly_list_1.append(crop_year_poly_1)

```

```

        poly_list_2.append(crop_year_poly_2)

    except:

        pass

    cntr_1 = cntr_1 + 1

# Merge from start year to the end year polygon and dissolved by Class_Name
try:

    # For cdl in riparian

    arcpy.Merge_management(poly_list_1, "lyr_Merge_RP")

    arcpy.AddMessage("Processing: Merge all years data in riparian")

    in_feature = "lyr_Merge_RP"

    field = ["Class_Name", "Year"]

    out_feature = cdl_all_years_rp

    arcpy.Dissolve_management(in_feature, out_feature, field)

    arcpy.AddField_management(cdl_all_years_rp, "Location", "TEXT", "", "", "", "",
"NULLABLE", "NON_REQUIRED", "")

    arcpy.CalculateField_management(cdl_all_years_rp, "Location", "riparian",
"PYTHON_9.3")

    arcpy.AddMessage("Processing: Dissolved by year")

    arcpy.AddMessage("Processing: Add location field for riparian area")


# For cdl in upland

    arcpy.Merge_management(poly_list_2, "lyr_Merge_UP")

```

```

    arcpy.AddMessage("Processing: Merge all years data in upland")

    in_feature = "lyr_Merge_UP"

    field = ["Class_Name", "Year"]

    out_feature = cdl_all_years_up

    arcpy.Dissolve_management(in_feature, out_feature, field)

    arcpy.AddField_management(cdl_all_years_up, "Location", "TEXT", "", "", "", "",
"NULLABLE", "NON_REQUIRED", "")

    arcpy.CalculateField_management(cdl_all_years_up, "Location", "upland",
"PYTHON_9.3")

    arcpy.AddMessage("Processing: Dissolved by year")

    arcpy.AddMessage("Processing: Add location field for upland area")


except:

    arcpy.AddMessage("Warning: Only raster formate was generated!!!")

    pass


# Delete non-required feature class

arcpy.Delete_management("EBA")

arcpy.Delete_management("upland")

arcpy.Delete_management("lyr_Merge_RP")

arcpy.Delete_management("lyr_Merge_UP")


cntr=cntr+1

arcpy.AddMessage("-----")

```

C Corn Area in Square Kilometers

C.1 Hoosier Hollow-Mill Creek (ID3)

Year	Corn Area (km²)	
	Riparian Buffer	Upland
2008	2.41	19.65
2009	2.97	22.70
2010	2.83	22.78
2011	2.79	24.67
2012	3.04	25.27
2013	2.46	21.70
2014	2.64	25.08
2015	3.03	25.00
2016	3.06	27.77
2017	2.67	26.02
2018	2.93	26.74

C.2 Little Baraboo River-Baraboo River (ID8)

Year	Corn Area (km²)	
	Riparian Buffer	Upland
2008	4.20	49.42
2009	3.52	52.00
2010	3.39	47.69
2011	3.48	57.75
2012	3.64	62.66
2013	2.50	60.74
2014	3.45	60.00
2015	4.18	65.00
2016	4.04	72.50
2017	3.95	68.57
2018	3.22	65.09

C.3 Fourmile Creek (ID23)

Year	Corn Area (km²)	
	Riparian Buffer	Upland

2008	1.93	27.30
2009	3.30	25.64
2010	4.05	29.76
2011	4.89	30.74
2012	4.41	35.41
2013	4.82	38.93
2014	4.15	27.32
2015	5.93	33.32
2016	4.55	33.25
2017	6.21	75.56
2018	8.06	71.53

C.4 Big Roche a Cri Creek (ID33)

Year	Corn Area (km²)	
	Riparian Buffer	Upland
2008	1.61	14.21
2009	1.68	12.74
2010	3.50	17.05
2011	2.80	19.24
2012	2.62	21.32
2013	3.50	26.19
2014	1.81	19.45
2015	2.37	18.92
2016	1.89	18.26
2017	5.29	33.10
2018	5.61	34.13

C.5 Headwaters Kickapoo River (ID53)

Year	Corn Area (km ²)	
	Riparian Buffer	Upland
2008	2.53	26.97
2009	2.30	27.48
2010	2.53	26.43
2011	2.53	28.65
2012	2.60	34.94
2013	2.06	28.90
2014	2.55	30.28
2015	2.59	34.64
2016	2.76	35.32
2017	2.70	34.90
2018	2.47	35.93

C.6 Headwaters Kickapoo River (ID54)

Year	Corn Area (km ²)	
	Riparian Buffer	Upland
2008	1.99	12.89
2009	2.55	16.13
2010	1.75	13.41
2011	2.22	17.93
2012	2.34	18.36
2013	1.91	17.01
2014	2.13	17.12
2015	2.30	18.92
2016	2.58	21.41
2017	2.63	19.59
2018	2.06	18.50

C.7 Fourteenmile Creek (ID56)

Year	Corn Area (km ²)	
	Riparian Buffer	Upland
2008	2.09	7.62
2009	2.21	7.32
2010	4.10	10.93
2011	3.20	12.88
2012	2.86	10.87
2013	3.40	14.73
2014	2.23	9.50
2015	3.51	10.93
2016	3.39	15.00
2017	4.42	22.11
2018	3.69	22.89

C.8 Tenmile Creek (ID65)

Year	Corn Area (km ²)	
	Riparian Buffer	Upland
2008	0.90	50.87
2009	0.58	42.48
2010	1.23	45.29
2011	0.69	56.50
2012	1.13	57.05
2013	1.04	66.30
2014	0.93	51.04
2015	0.99	53.03
2016	1.45	62.03
2017	1.42	78.43
2018	1.54	78.92

C.9 Pine River (ID70)

Year	Corn Area (km ²)	
	Riparian Buffer	Upland
2008	5.53	37.35
2009	5.99	43.25

2010	5.48	38.06
2011	6.35	48.97
2012	6.26	49.35
2013	5.64	47.16
2014	6.08	45.48
2015	6.83	52.15
2016	6.56	49.13
2017	6.34	53.03
2018	6.01	50.68