AN INVESTIGATION OF LAND USE CHANGE IN THE TUSCARORA CREEK WATERSHED OF MARYLAND

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ABSTRACT

The Tuscarora Creek, located in Frederick County, MD, flows under the Chesapeake and Ohio Canal (C&O) via a culvert and into the Potomac River. The culvert (culvert 71) is an original structure and the deterioration of this historic structure is directly tied to watershed processes within the small watershed of the Tuscarora Creek. One key variable that is important for understanding stream flow and sedimentation is land use. We therefore developed a database of land use classes by digitizing air photos from the years 1952, 1973 and 2011. Once the vector land use classes were complete they were then rasterized so that a cell by cell analysis could be performed by creating land cover change probability matrices. We analyzed land uses and land use change over this time period to provide insight into the current watershed impacts on culvert 71. What was found was that the watershed overall remained mostly forested and agricultural. There were small changes from forest and agriculture to developed land from 1973 to 2011. Since riparian buffers are important to evaluating the health of a stream, a 10 meter buffer of the streams were analyzed and another set land use change matrices were created.

Keywords: Chesapeake and Ohio Canal National Historic Park; Tuscarora Creek Watershed; Land use change

INTRODUCTION

Background

The Chesapeake and Ohio Canal National Historic Park (C&O Canal) is a piece of American history that should be preserved for future generations. The Tuscarora Creek watershed drains into the Potomac River but before the Tuscarora Creek reaches the Potomac it passes through an original culvert built during the canal's construction (High 2011). This culvert is already in poor condition(Figure 1) and it would be unfortunate for an original structure built during the construction of the C&O Canal to be lost.

Figure 1: Degraded Culvert 71, note loss of stonework on right side; photo Dec. 2011; credit Steve Dean

Objectives

The overall objective of this study is to establish a baseline dataset of land use change information for the Tuscarora Creek watershed. The first step to accomplishing this is to digitize and categorize current and historic air photos of the Tuscarora Creek watershed (D'Antonio and Jantz 2008). The second part of the dataset is to describe land use change by calculating a series of transition matrices. Finally, we will investigate land use changes in riparian areas since those are zones that are especially important for regulating stream flow and erosion.

STUDY AREA

Chesapeake and Ohio Canal

The C&O Canal was a man-made channel that stretched from just outside of Washington D.C. 184 miles to Cumberland, MD. The purpose of the canal was to facilitate the transportation of goods between these two cities and others in between. While the construction of the C&O took 22 years, from 1828 to 1850, to fully complete and was fraught with many damaging floods; the C&O Canal allowed for the transportation of millions of tons of coal until its use was discontinued in 1924 (National Park Service 2013).

Tuscarora Creek Watershed

The Tuscarora Creek watershed is located in eastern Maryland just to the west of the Potomac River (Figure 2). The majority of the watershed is located in Frederick County, Maryland. The watershed is a fairly small watershed and is about 24 square miles. The current land use within the watershed is mostly a mix of agricultural and forested land cover, with some low density developed areas.

Figure 2: Location of the Tuscarora Creek watershed

DATA AND METHODS

Digitizing

The digitizing for this project was completed with the same methods as described in the Pennsylvania Geographer (D'Antonio and Jantz 2008). The digitizing rules that were followed were: scale of 1:5000, ten acre minimum mapping unit, four lane roads or wider are digitized as polygons, single lane roads are include in the adjacent land use polygon if either side of the road is the same land use type, if there are different land use types on either side of the road each polygon goes to the middle of the road, forests must be a minimum of 50 meters wide. All of the digitizing was completed by Alexander Moats. The aerial photographs for 1952 and 1973 were provided by Frederick County Maryland's GIS department. The aerial imagery for 2011 was acquired from the United States Department of Agriculture's (USDA) National Agricultural Imagery Program (NAIP). When digitizing nine land use types were used to classify the watershed: forest, agricultural, transitional, open space, open water, road, heavy develop, medium develop and light develop.

Calculating Land Use Cover Change

In order to complete the transition matrices, the digitized land cover data needed to first be rasterized. Once the watersheds were rasterized, the combine tool from ArcGIS was used so that each cell could be analyzed to see what it changes from and changes to. Using Equation 1, percent change from each land use type to every other type is calculated for each transitional period (1952 to 1973 and 1973 to 2011). Equation 2a and equation 2b are used to calculate the annualized transition for transitional period since there is not a standard transition interval for this study. Equation 2a is used to calculate the transition when the first land use type does not equal the second land used type. Equation 2b is used to calculate the transition when the first land use type does equal the second land use type. In order to simplify the process of calculating the transition of each type, the data types heavy develop, medium develop and light develop were re-categorized to "developed". This simplifies the process since the 1952 dataset does not distinguish between types of developed land.

Equation 1: $$p_{i,j,\tau} = \frac{n_{i,j}}{\sum_{j=1}^{m} n_{i,j}}$$

$$\textit{Equation 2a:}\quad p_{i,j} = \frac{p_{i,j,\tau}}{\tau} \text{ when } i \neq j$$

$$\textit{Equation 2b:}\quad p_{i,j} = 1 - \sum_{j=1}^{n} p_{i,j} \text{ when } i = j$$

Calculating Land Use Cover Change in Riparian Buffers

Using the same methods as mentioned in the transition matrices section, the land use cover change was calculated for a 10 meter buffer of the streams in the Tuscarora Creek Watershed.

RESULTS

Digitized Data

Figure 3 shows the digitized datasets for 1952, 1973 and 2011. Figure 4 shows the total area of each land use type by year. As mentioned before the land use types heavy develop, medium develop and light develop were changed to a single class, "develop" to simplify the transition matrix calculations.

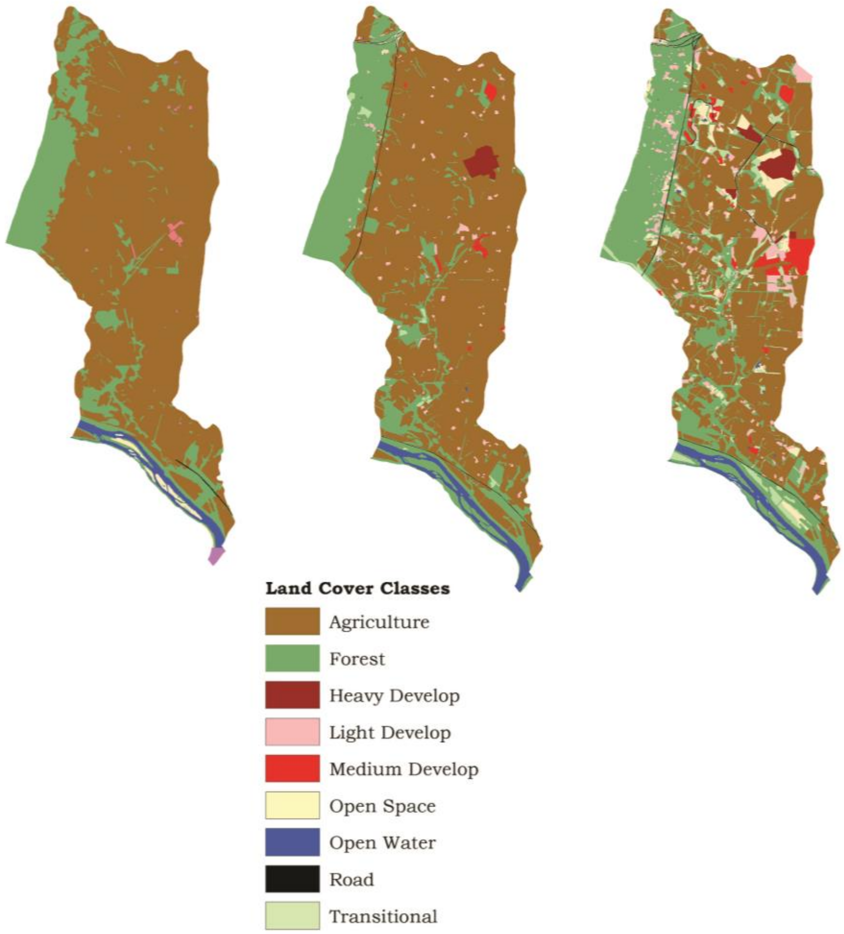

Figure 3: Digitized Land Use for 1952, 1973 and 2011 respectively

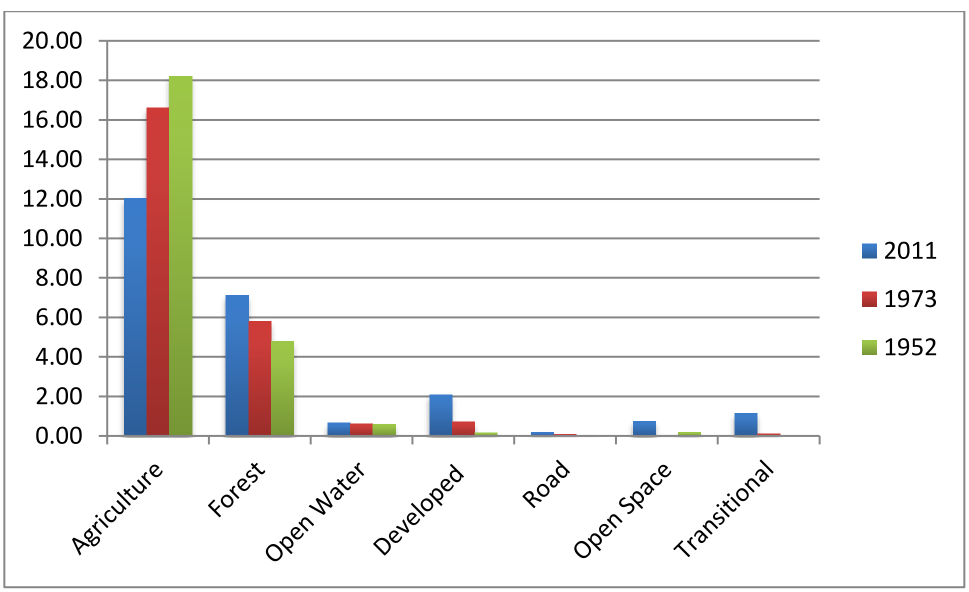

Figure 4: Graph that shows each land use type in square miles by year

Land Use Change Transition Matrices

These are the results from calculating land use change from the rasterized land use types. Table 1 shows the annualized transition between 1952 and 1973. Table 2 shows the annualized transition between 1973 and 2011.

Table 1: Annualized transition matrix for the watershed from 1952 to 1973

		TO 1973						
		Agriculture	**Forest**	**Open Water**	**Developed**	**Road**	**Open Space**	**Transitional**
FROM 1952	**Agriculture**	0.9940	0.0040	0.0000	0.0015	0.0001	0.0000	0.0002
	Forest	0.0064	0.9918	0.0004	0.0004	0.0004	0.0002	0.0003
	Open Water	0.0000	0.0081	0.9919	0.0000	0.0000	0.0000	0.0000
	Developed	0.0172	0.0037	0.0000	0.9790	0.0000	0.0000	0.0000
	Road	0.0089	0.0330	0.0000	0.0000	0.9581	0.0000	0.0000
	Open Space	0.0000	0.0431	0.0045	0.0000	0.0000	0.9524	0.0000
	Transitional	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000

Table 2: Annualized transition matrix for the watershed from 1973 to 2011

	TO 2011							
		Agriculture	Forest	Open Water	Developed	Road	Open Space	Transitional
FROM 1973	Agriculture	0.9922	0.0031	0.0000	0.0021	0.0001	0.0010	0.0014
	Forest	0.0013	0.9958	0.0005	0.0009	0.0001	0.0002	0.0011
	Open Water	0.0001	0.0030	0.9968	0.0000	0.0000	0.0000	0.0001
	Developed	0.0020	0.0027	0.0000	0.9933	0.0001	0.0013	0.0005
	Road	0.0002	0.0071	0.0000	0.0004	0.9908	0.0013	0.0002
	Open Space	0.0002	0.0140	0.0000	0.0032	0.0071	0.9754	0.0000
	Transitional	0.0032	0.0174	0.0002	0.0008	0.0000	0.0005	0.9780

Riparian Buffers Transition Matrices

These are the results from calculating land use change from the rasterized stream buffer. Table 3 is the annualized transition for the riparian buffers from 1952 to 1973 and table 4 is the annualized transition from 1973 to 2011.

Table 3: Annualized transition matrix for riparian buffers from 1952 to 1973

	TO 1973							
		Agriculture	Forest	Open Water	Develop	Road	Open Space	Transitional
FROM 1952	Agriculture	0.9899	0.0088	0.0000	0.0008	0.0002	0	0.0004
	Forest	0.0097	0.9890	0	0.0003	0.0001	0.0003	0.0005
	Open Water	0	0	0	0	0	0	0
	Develop	0.0204	0	0	0.9796	0	0	0
	Road	0	0.0476	0	0	0.9524	0	0
	Open Space	0	0	0	0	0	0	0
	Transitional	0	0	0	0	0	0	0

Table 4: Annualized transition matrix for riparian buffers from 1973 to 2011

TO 2011

		Agriculture	Forest	Open Water	Develop	Road	Open Space	Transitional
FROM 1973	Agriculture	0.9856	0.0100	0.0001	0.0009	0.0001	0.0013	0.0020
	Forest	0.0010	0.9970	0.0001	0.0004	0.0001	0.0001	0.0014
	Open Water	0	0	0.9737	0	0	0.0263	0
	Develop	0.0032	0.0048	0	0.9880	0	0.0008	0.0032
	Road	0	0.0088	0	0	0.9912	0	0
	Open Space	0	0.0263	0	0	0	0.9737	0
	Transitional	0.0029	0.0175	0	0.0015	0	0	0.9781

DISCUSSION

As can be seen in the results section, most of the Tuscarora Creek Watershed remains agricultural and forested. Most of the developed land occurred during the 1973 to 2011 transition period but still makes up less than 10% of the total area in the 2011 dataset. It should be noticed that in the annualized transition matrices for the riparian buffers for 1952 to 1973 that the transition from agriculture to forest was greater than forest to agriculture but for 1973 to 2011 annualized transitions, the reverse is the case (Figure 5). This is what is to expected with the improvement in agricultural practices such as including riparian buffers around streams and implementing stream fencing.

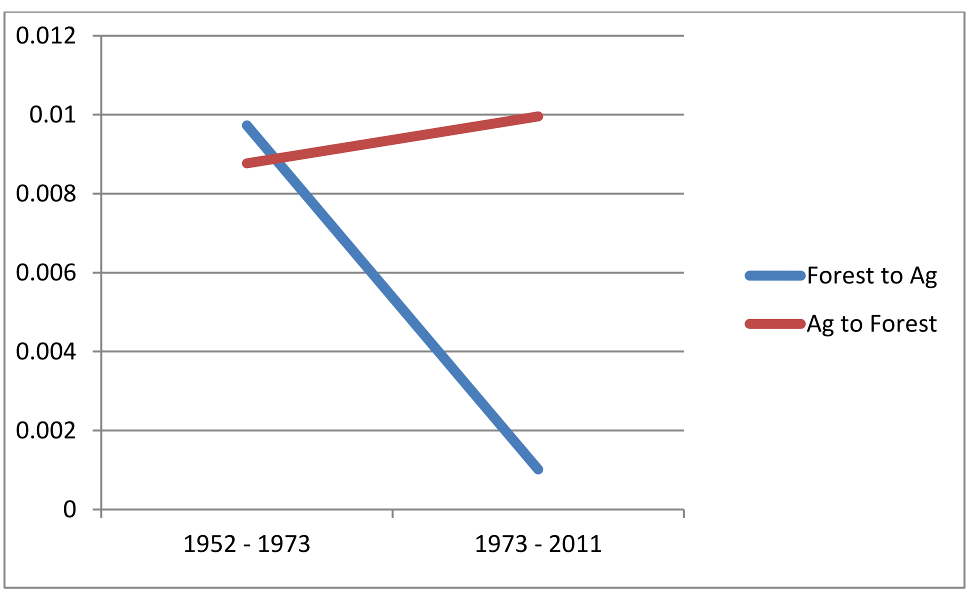

Figure 5: Graph showing the difference in the amount of transition from forest to Ag and Ag to forest between the transition between 1952 and 1973 and the transition between 1973 and 2011.

FUTURE RESEARCH

Now that an initial dataset has been developed and there is fair understanding of what might be occurring in the watershed and in the riparian buffers, more work can be done. Since the riparian buffers have transitioned the way that would be expected there could be some other source of sedimentation that could be investigated.

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