Linking land use characteristics and water quality for targeted watershed management and restoration

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Sugar Creek Watershed

Located in east-central Ohio, the Sugar Creek drains to the Muskingum River, which is the largest contributing watershed to the Ohio River, and contributing to hypoxia conditions in the Gulf of Mexico. Draining 357 mi^2, the watershed lies within portions of glaciated and unglaciated Ohio. The glaciated portion is characterized by rolling hills and valleys, while the unglaciated portion has steeper topography with coal and clay deposits. The watershed has significant diversity in terms of physiographic, cultural and social structure, agricultural practices, and stream-reach health.

The landscape is dominated by agriculture with patches of second-growth forest, some riparian corridors, and small to moderate sized municipalities. The overall condition of the Sugar Creek watershed is typical of agricultural landscapes in the eastern U.S. A 1998 Ohio EPA Total Maximum Daily Load (TMDL) study determined the Sugar Creek watershed was one of the most degraded in the state, with 93% of the main stem not achieving full aquatic use designations. The watershed was severely impaired due to sedimentation, habitat alteration , and nutrient enrichment. Non point source pollution was assumed to comprise much of the problem due to the agricultural nature of the watershed. The study concluded that while seriously impaired, the watershed had moderate to high restoration potential due to the nature of the impairment sources.

Following the TMDL study, state and county agencies, as well as researchers and citizens, have begun to work towards improved watershed health and sustainability. **The research presented here is one tool utilized to focus initial management and restoration activities.**

North and South Fork

Two subwatersheds of the Sugar Creek are the North and South Forks. The North Fork lies within glaciated Ohio, is comprised of a mix of dairy and row crop operations, and culturally has both Amish and Non-Amish farms. The village of Kidron is situated in the upper reaches of the North Fork.

The South Fork lies within unglaciated Ohio, and as a result of the terrain is mainly dairy operations. The South Fork is predominately Amish farms. The lower reaches of the South Fork run through New Philadelphia, a city of 17,000 people.

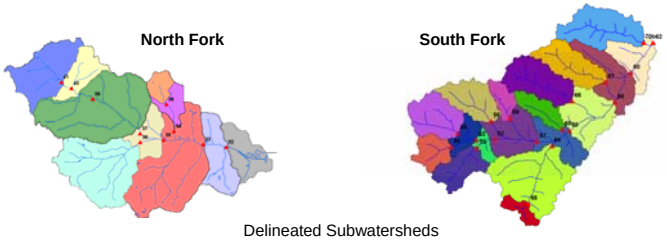
Water Quality

Water samples were collected June 2002 through June 2004 a ten locations in both the North and South Forks. The samples were preserved and chilled before laboratory analysis for concentrations of nitrate-nitrogen (NO_3^--N) and ammonium-nitrogen (NH_4^+-N) by a modified indophenol blue technique, and soluble available phosphorus (PO_4-P) by spectrophotometry.

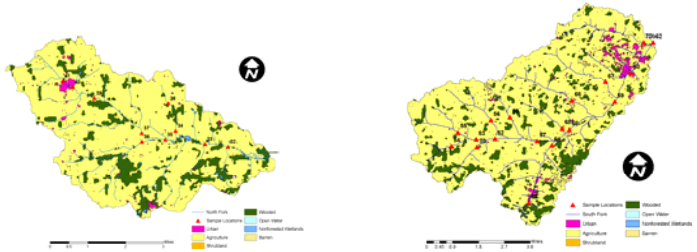
To elucidate seasonal variations in water quality, mean values of each nutrient at each location were calculated for three seasonal periods: year-round, the growing season (May 1- October 15), and the dormant season (October 16- April 30).

Land Use Characteristics

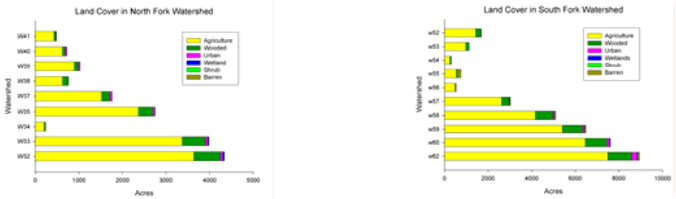
Using a geographic information system (ArcGIS®, ESRI), subwatersheds were delineated above each sample location in both the North and South Forks. Land cover data (Ohio Department of Natural Resources 1994) was clipped for each subwatershed to determine contributing area landscape characteristics above each sample location. Land cover classes included: percent urban, agriculture, wooded, shrubland, wetland, open water, and barren. Stream and road density were also determined for each subwatershed. We determined percent forested buffer by creating a 50 foot buffer around the stream network and clipping all wooded land cover inside the buffer.



Delineated Subwatersheds



Land Cover

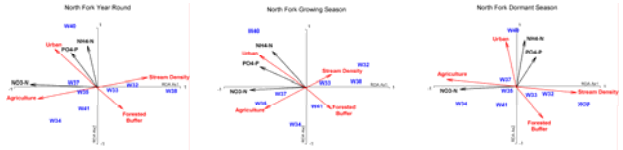


Land Cover for each Subwatershed

Acknowledgements Salaries and research funds were provided by the State of Ohio through an Ohio EPA 319 Implementation Grant to the Ohio Agricultural Research and Development Center (OARDC).

Linking land use and water quality

To analyze relationships between contributing area land use characteristics and water quality results, redundancy analyses (RDA) were used. A separate RDA was conducted for each of the three seasonal periods for both the North and the South Forks.



North Fork Relationships

While agriculture dominates the landscape, PO_4-P and NH_4-N concentrations are strongly related to percent urban and Wsd 39 and 40. Wsd 39 was removed from RDA analysis because it dominated the ordination. These watersheds are downstream from two point sources: the village of Kidron and a poultry facility. Percent agriculture consistently has a strong relationship with NO_3-N, but during the dormant season is strongest. This may indicate leaching or excessive winter manure applications. NO_3-N is negatively related to stream density indicating that the nutrient is not compounding downstream. Percent forested buffer is negatively related to all nutrients as well as percents agriculture and urban, indicating that the few forested buffers in the North Fork are functioning.

North Fork Redundancy Analysis

Season		Cumulative % Species Variance Explained	Monte-Carlo Permutation Pseudo-F
Year Round	Ax 1	31.4	12.000
	Ax 2	18.3	6.000
Growing	Ax 1	28.8	17.000*
	Ax 2	15.2	17.000*
Dormant	Ax 1	34.8	19.000*
	Ax 2	18.4	10.000

South Fork Relationships

Percent urban and PO_4-P are strongly related, especially in the lower subwatersheds where point sources have high phosphate discharge. Additionally there is a positive relationship between PO_4-P and stream density because of point sources in the watershed. Percent agriculture is positively related to NO_3-N, particularly in the growing season where there may be over-application of fertilizer or leaching. NH_4-N is related to both agriculture and urban in the South Fork, indicating a possible livestock or human waste problem. There is minimal wooded land cover in the watershed and the few forested buffers are functioning as shown by the negative relationships.

South Fork Redundancy Analysis

Season		Cumulative % Species Variance Explained	Monte-Carlo Permutation Pseudo-F
Year Round	Ax 1	[illegible]	[illegible]
	Ax 2	[illegible]	[illegible]
Growing	Ax 1	[illegible]	[illegible]
	Ax 2	[illegible]	[illegible]
Dormant	Ax 1	[illegible]	[illegible]
	Ax 2	[illegible]	[illegible]

Management and Restoration Implications

While both of these watersheds are predominately agriculture, the few urban areas have a significant impact on water quality. Already some improvements have been made including a WWTP for the village of Kidron in the North Fork and meetings with point source facilities in the South Fork about improving discharge water quality. Additionally, watershed groups have been formed in each watershed and have begun to address hotspots for poor water quality as well as implementation of best management practices. Further research is planned to discern specific agricultural practices leading to high NO_3-N concentrations in the watersheds.