Geodesign for Water Quality Sustainability on Lac Courte Oreilles

Lake Lac Courte Oreilles (LCO) is one of only five lakes of Wisconsin's 15,089 lakes that sustains cold-water whitefish and cisco (lake herring). This two-story stratified fishery is facing tragedy from excessive nutrients, in particular Phosphorus (P), that are fueling growth of aquatic invasive species (i.e. curly leaf pondweed) and nuisance species (i.e. filamentous algae). As these plants die and decay over the summer, the process consumes dissolved oxygen (DO2) and suffocates cisco and whitefish inhabiting the cold-water strata. Furthermore, climate change warms LCO's waters so that these fish no longer have an escape hatch to reach oxygen rich waters in the autumn months. July 2016 marks a massive whitefish and cisco die off on LCO. The death of whitefish and cisco are tragic early warning signs of declining water quality.

LCO is part of the 125-square mile Upper Couderay River Watershed (UCRW) that contributes approximately 12 billion gallons of water annually – almost all of which eventually flows into LCO. To improve water quality on LCO, COLA knows that it must address issues at the watershed scale. With educational assistance from the UW-Stevens Point GIS Center, COLA is employing Geodesign methods and GIS techniques to analyze the potential vulnerability of agricultural lands to erosion. The analysis summarizes indicators of soil erosion by individual tax parcels. The results provide conservationists a tool to identify landowners and future collaborators in the fight to limit erosion and keep nutrients on agricultural fields and out of LCO.

A Geodesign Fix for Excessive Phosphorus (P)

Nutrient-laden sediments have been building on LCO over the long term and from various sources. Dredging and treating existing sediments to bind P offer a few short-term fixes. A Geodesign approach first looks to science and land management practices. Not long ago, farmers commonly prepared their soils for seed by turning plant residues under the soil with a moldboard plow and tilling with a disc harrow – a practice known as clean tillage. Soil science process models reveal that this practice oxygenates the soil and activates microorganisms that accelerate the breakdown of crop residues and soil organic matter. It also disturbs the creation of a soil substance named glomalin. Glomalin is a protein produced by a type of beneficial soil fungi that acts as a glue binding soil particles tightly to each other. Glomalin is present in undisturbed and no-till systems as compared to conventionally clean-tilled soils (NRCS) (Ohio State). No-till or conservation tillage is an example of Agricultural Best Management Practices (BMPs) designed to keep the nutrients on the land where they benefit the crop and producer and out of nearby waterways. Furthermore, Geodesign exploits modern GIS technology and data to identify agricultural lands potentially most vulnerable to erosion. These areas offer producers and conservationists the greatest water quality and economic improvement gains from implementing BMPs.

GIS Tools and Techniques – the Erosion Vulnerability Assessment for Agricultural Lands

The Erosion Vulnerability Assessment for Agricultural Lands (EVAAL) is a set of GIS techniques designed by the Wisconsin Department of Natural Resources (WDNR) to identify agricultural lands potentially most vulnerable to erosion. EVAAL does not measure actual erosion, but rather offers a relative index that ranks vulnerable areas within a specified area. Geospatial data used for EVAAL is available for all of Wisconsin and most of America, however, EVAAL recommends the use of LiDAR elevation data, which was not available for the project area and is limited nationally.

EVAAL offers scripts and tools for ESRI's ArcGIS software platform. Investigators exploited ArcGIS version 10.3 for this project. EVAAL guides analysts through the a process of: 1) conditioning a digital elevation model (DEM), 2) creating internally draining areas, 3) estimating gully erosion, and 4) estimating sheet and rill erosion, and finally, 5) normalizing and adding the results of gully and sheet and rill erosion into a single erosion index.

Geography Major and GIS Center Intern, Kyle McNair was responsible for executing the EVAAL model for the UCRW under the supervision of Douglas Miskowiak. Overcoming the limitations of the 10-meter DEM within an oversized watershed was most challenging. Improving how EVAAL modeled the natural flow of water proved cumbersome. Kyle manually inspected the DEM to place culverts that would break digital dams, such as raised roadbeds and bridges that digitally restricted flow of water. From DEM conditioning to the final erosion index, Kyle documented each step of the process with maps. The maps can downloaded from http://www.uwsp.edu/cols-ap/GIS/Pages/COLA.aspx .

EVAAL culminates by creating the erosion vulnerability index (EVI), a combination of the stream power index (3) and soil loss potential (4) into a single indicator of potential erosion vulnerability. EVAAL normalizes SPI and soil loss to a common measurement scale before adding them together. The index excludes areas considered internally draining (2). The EVI identifies areas in the landscape that are potentially most vulnerable to erosion.

Aggregate the Index to the Tax Parcel – The Unit of Land Management

Ultimately, the EVI was aggregated at the tax parcel level as a means to support pragmatic land planning and management. Importantly, landowner information (name and address) is explicit and identifies the individuals or entities responsible for land management and the potential partner to keep soil on land and out of water. Next, each parcel receives an aggregated score, normalized by area. The single score helps conservationists identify parcels most and least vulnerable to erosion and a means to prioritize conservation efforts where they can do the most good. Finally, the details about how the aggregated score was calculated is also attached to the parcel. The details help conservationists and producers understand, "Is erosion likely due to slope, crop rotations, soil type, or a combination of these factors?" The details are anticipated to help choose agricultural BMPs custom tailored to fight erosion for each parcel of land. The aggregated EVI has only just been shared with conservationists (January 2017) and its ability to educate land owners and negotiate effective land management strategies and implementation has not yet been evaluated.

Conclusion

LCO offers a classic narrative illustrating the tragedy of the commons. People acting rationally to maximize their own self-interests, whether it be for leisure, profit, or to minimize effort, consume a resource beyond its carrying capacity, until it is diminished of value. LCO is a commons resource owned by every citizen of Wisconsin and the United States by way of the Wisconsin State Constitution and the Public Trust Doctrine. Instead of tragedy by use of the commons or taking something from the commons, the tragedy on LCO is born by deposit of something damaging to the commons. Excessive nutrients and atmospheric carbon are deposits to the LCO commons that has diminished habitat (well oxygenated, cold water) capable of sustaining cisco and whitefish. The die off of whitefish and cisco on LCO is an early indicator of tragedy. Whitefish and cisco are the most vulnerable species and the first affected by polluted waters and a warming atmosphere.

The sciences that describe how and why natural systems functions in the way they do is sound. Humans have a solid scientific understanding of fisheries, climate, soils, biology, chemistry, physics, and other sciences that describe how the world and the things on or near its surface function. How humans respond to manage the commons is now in question. Technical fixes for the problem such as dredging or treating LCO are short term fixes that do not treat the source of the problem. LCO requires a fix designed with greater imagination and collaboration among many human stakeholders. Fortuitously, the fix that limits P from agricultural sources benefits all stakeholders. Implementation of BMPs keep soils and nutrients on the land where producers want them and need them to grow crops and out of LCO where they degrade water quality and fish habitat. With Geodesign and GIS, investigators have identified priority zones where implementation of BMPs are anticipated to have the greatest effect. With the tax parcel, conservationists can identify actors and develop the human partnerships necessary to negotiate other fixes that address the source of the problem.