Laura Alskog
June 1, 2011
GIS Certification Project
Final Paper

The Role of Sediments and Aquatic Plants in the Nutrient Budget of Spirit Lake at Mount St. Helens, WA

Introduction

The 1980 eruption of Mount St. Helens caused the bathymetry of Spirit Lake to change drastically, resulting in an increase in surface area and a decrease in average depth. Subsequently, Spirit Lake is experiencing an increase in productivity and primary succession is occurring in the surrounding watershed as the ecology of the area becomes reestablished. Since the eruption, the area has had virtually no human impact, which makes it a great resource to be used as control conditions when studying lakes, as it is an untouched, pristine environment. This analysis examines concentrations of carbon, nitrogen and phosphorus obtained from sediment samples collected over the summer of 2010, as well as aquatic plant height data, in order to identify sources of the lake's increasing productivity. The results of these analyses will be used as part of a larger nutrient-cycling model Jim Gawel has been building which examines changes in the lake over time. These results, along with the land cover color maps Danielle has created which identify vegetation types in the surrounding areas, are a very important step in the process of identifying the environmental conditions and sources in the surrounding area that would contribute to the lake exhibiting these specific nutrient conditions.

Objectives

The objectives of this analysis are to calculate sediment nutrient concentrations in areas of Spirit Lake that immediately surround watershed drainage basin entry points in order to identify major source areas of nutrient input from the surrounding drainage basins, and see whether a positive correlation exists between sediment nutrient concentrations and plant height. I am also looking to create interpolated surfaces of sediment carbon, nitrogen and phosphorus to determine total nutrients in the lake sediment by volume. The final goal of this project is to determine average plant height and total plant volume within the photic zone in order to determine the total concentrations of carbon, nitrogen and phosphorus in the system attributable to plant biomass.

Methods

Most of the data I needed to execute this project were available from Jim's X: drive files, so first I extracted what I needed from there. These files included Portland State University's point shapefile containing aquatic plant data, a point shapefile of the lake containing elevation data, a lake polygon shapefile, my sediment sampling results excel file, and the GPS waypoints excel files. From Matt I was given a stream layer and a LiDAR layer of the surrounding watershed was obtained from WAGDA. A geodatabase was created and within that, a feature dataset. The shapefiles were added to the feature dataset, and the geodatabase was projected in NAD_1983_UTM_Zone_10N. My first step was cleaning up and organizing my sediment sample data into workable tables, and adding a primary key to each sample in the sample results log, then exporting the tables to a new workbook. Eleven of the results in my table were from the same location, where a sediment core was taken. Because only the first ten centimeter of sediment are able to be caught in a sediment drudge sample, which is how the rest of the samples were obtained, I had to account for this. To do this, I averaged the top five core sample results for their C, N and P concentrations (sediment cores are cut up into 2 cm increments) and removed the rest, so the depth of sediment measured at this location was like that of the other locations for this data point. The lab who performed the nutrient analysis on my samples gave the nutrient results back in carbon % total, nitrogen % total and phosphorus mg/Kg, so I then converted all of these values into a standardized ppm concentration, and moved the ensuing table to a new book. The final nutrient table was added to ArcMap as a table. Next, I organized the GPS waypoint data and added a primary key to this table, which I then added as a table to ArcMap. The sediment and GPS tables were joined and then exported into the geodatabase in order to make the join permanent. The table was then added to the map using the add XY data tool and the point layer was then exported to the geodatabase to make permanent and added to the map. Next, I performed a Kriging interpolation using the GPS_Sediment_Concentration layer, and interpolated for each nutrient using the SL.Shore (lake polygon) as a mask. In the Kriging Interpolation tool I set the extent to be the lake polygon and interpolated for each nutrient. For phosphorus, I used cell size 2 and for carbon and nitrogen, I used cell size 10. The output of this was three raster grids for each C, N, and P. Next, I used the PSU point shapefile of the lake containing the elevation attribute to which I added a new field, Depth. I used field calculator and subtracted the contour field from the highest value, 1056, which in this case is the lake surface, which gave a lake surface value of zero. This data was collected using sonar over the lakes surface. This calculation gave me a field containing depth in meters. I symbolized this layer in 5 meter increments using depth column.

A raster layer of the lake was created called Spir1, using the bathymetry layer, and was then reclassified. The reclassify was done on the newly created lake polygon called SpiritGrid, in which GRIDCLASS 1 equaled depths of greater than 10 meters in depth, and GRIDCLASS 2 equaled areas of the lake less than or equal to ten meters in depth, the resultant raster had three classes, 0 (areas outside the lake), 1, and 2, classified by depth into each area. The raster to polygon conversion tool was used to convert the surface to a polygon, which was broken up into the photic and sub photic zones.

Because the plant data contained an enormous amount of sample points of which then the raster to polygon conversion tool was used to convert the surface to a polygon. This polygon many were highly inaccurate due to logs still lodged in the sediment from the eruption, much of this data had to be removed. The plant data was manipulated in excel, where canopy heights (plant heights) over two meters were removed from the data. The can_ht column was sorted, and values greater than or equal to two meters were selected and removed. Then, a new column was created called can_ht_med. In this column, to remove more inaccuracies, the median value of a group of about ten values in the plant height column was found using the median function, and pasted down the can_ht_med column to smooth out the data a bit more. This new plant excel file was then exported back into excel as a table, and added to the map as XY data, and exported to make permanent. An IDW interpolation was then done on the plant points, and a raster surface was created called plantheights. Next, the 10 meter deep and less "GRIDCLASS 2" reclassified lake polypon was selected out of the reclassified lake polygon in order to isolate the ten meter depth areas and a new layer was created called raster_reclass1selection. Then a clip was performed, with the input raster to be clipped as the plantheights raster and the output extent raster, the raster_reclass1selection raster and a new layer was created, plants_10m_zone. This layer contained plants in the photic zone (≤10 m deep) at a height of 2 meters of less.

The next step was attempting to create watersheds in order to obtain pour points using spatial analyst. Therefore, the WAGDA obtained LiDAR layer was added to the map, as was a streams layer, and everything but the lake layer turned off. Raster processing extents were set to "same as display" setting. In the hydrology toolbox, the Fill tool was used, with the LiDAR layer as the input and the output, the filled in LiDAR layer, named DEMFill1. Then the Flow Direction tool was used, with the input as DEMFill1and output FlowDir1. Then the flow accumulation tool was used, input FlowDir1, and output FlowAcc1. Spatial analyst calculator was used to determine the actual pathways of the rivers based on the raster layer. The calculation used was FlowAcc1> 5000. In the calculation layer, values of “0” were made transparent, and a raster layer of the river course to the lake was made. Using the newly created river course layer, a Pour Point shapefile was created. In ArcCatalogue, a new empty shapefile was created in the Feature Dataset and named PourPoint1, feature type “point”, and its coordinate system was set to NAD_1983_UTM_Zone10N. Using the Editor Toolbar with PourPoint1 in the target field with Create New Feature, Pour points were created using the sketch tool based on where the rivers intersected with the lake, and edits were saved. 200 m buffers were then created around the pour points and the buffered regions were clipped using the lake polygon as the extent. The Zonal Statistics as Table tool was run for each C, N, and P raster using the clipped buffer zones as the input zones and the input value rasters were the nutrient rasters. The Zonal Statistic as Table tool was also used to calculate zonal statistics for plants in the ten meter deep and shallower regions of the lake, and statistics for C, N and P were run for the entire lake, in order to find the total nutrients in the lake sediment by volume.

Results from the Analysis

The outputs of these analyses were my zonal statics tables for each C, N and P which contained the surface areas of the photic and sub-photic zones, and min, max, mean, range, sum and standard deviation values for the nutrient concentrations. My plant height zonal statics contained the same statistics for the photic zone of the lake only. Zonal statistics were also run for C, N and P concentrations in the sediment in the 200 meter buffer zones around each drainage basin pour point, allowing me to obtain average nutrient concentrations attributable to each drainage basin area, which are better indicators of nutrient source areas than the sediment surface interpolations values alone. Using these outputs, I have calculated total nutrients in the entire sediment surface of the lake by volume, as well as total nutrient concentrations contributed to the system by plant biomass. Zonal statistics were also run on plant heights per buffer zone to look at relationships between nutrient concentrations and average plant height to see if a positive correlation existed, for which I found it did not. These results will be used in conjunction with water column total nutrient data, stream nutrient input, and insect emergence and recapture data in the 2010 nutrient budget for Spirit Lake. The results of this study for aquatic plant heights were similar to a study done by Lehmann (1998) in which a GIS was used to look at the distribution of plants in the littoral zone (near shore) of Lake Geneva in Switzerland, in order to understand variables influencing distribution patterns of four different species, those variables being bathymetry, sediment nutrient concentrations, current, and pollutants. That study found the most influential factors on plant distribution to be bathymetry and light, as well as a weak correlation between nutrient gradients in the soil and plant distribution. Another study done by Oskarsdottir et. al (2010) looked at the spatial distribution of dissolved constituents in Icelandic river waters in Iceland, a volcanic island. This study used a GIS to map dissolved components of streams, including nitrogen and phosphorus, in order to realize spatial relationships between the surrounding land and the components of the waters. The results of the study found the highest concentrations of dissolved inorganic nitrogen and the dissolved in land areas where rivers drained from aged bedrock. The reason for this is believed to be nitrogen-fixing vegetation in the surrounding land. When Danielle's and my projects are combined together with more drainage basin data, it can be determined whether this finding applies to our study area as well.

Critical Analysis and Discussion of Project

I feel that my project was a success; it turned out to be a good amount of work and analysis, with results that are relevant and useful to the research community in the Spirit Lake area, and others interested in studying primary succession after a major disturbance event like the eruption of Mount St. Helens. My project went in a different direction than I was initially planning, which turned out to be really interesting, and ties into a lot of what Danielle has done with her project. These projects together lay a good foundation for future studies examining nutrient sources around the lake.

Sources

Lehmann, A . (1998). GIS modeling of submerged macrophyte distribution using Generalized Additive Models. Plant Ecology. 139(1), 113-124.

Oskarsdottir, S, Gislason, S, Snorrason, A, Halldorsdottir, S & Gisladottir, G. (2010). Spatial distribution of dissolved constituents in Icelandic river waters. Journal of Hydrology. 397(3), 175-190.