Comparing Methods for Determining the Influence of Land Cover Type on Stream Water Quality in Sandy River Basin, Oregon

Molly Awram, Robert Bolduc, and Sayantani Karmakar
Instructor Geoffrey Duh, Ph.D., GEOG 592 Spring 2016 Term Project
Portland State University

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ABSTRACT

- We applied methods from Grabowski, et. al (2015) to examine the adaptability of their model for assessing spatial and non-spatial relationships between an index of stream temperature metrics (dependent variable) an index of landscape parameters (independent variable) related to water quality. Two of the four model equations use non-spatial techniques, and two use distance-weighted techniques for determining average parameter values in 7 sub-watersheds in the Sandy River Basin (SRB). We hypothesized that the distance-weighted averaging techniques will yield stronger correlations with the temperature index compared to the non-spatial techniques.
- The non-spatial average CN within a 1 km buffer of the gage station produced the greatest positive correlation value with temperature. The non-spatial average EL within a 1 km buffer produced the greatest negative correlation with temperature. Correlation was positive with all methods for the CN parameter, while all other methods and parameters produced negative correlation.
- The adaptability of this model allows for multivariate analysis of watersheds with the hope that application can yield a more significant understanding of how landscape variation affects hydrologic systems.

INTRODUCTION

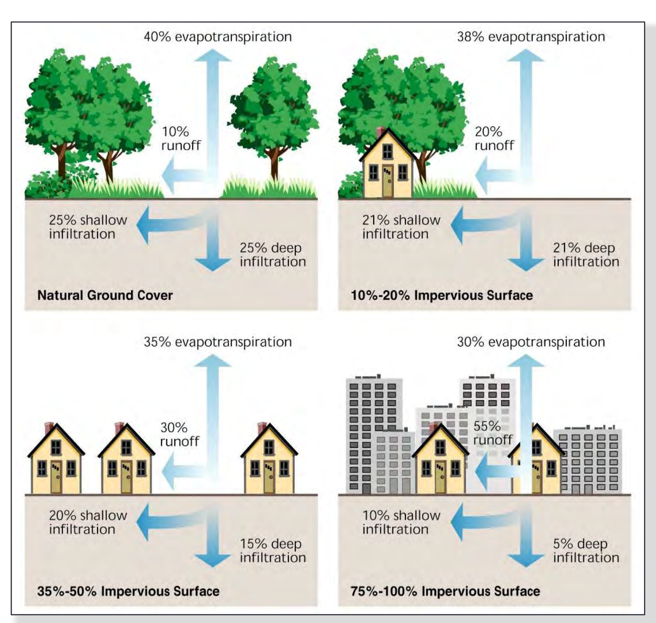

Figure 1. Illustration of how increased proportions of impervious surfaces relate to changes in shallow infiltration. Image courtesy of USDA.

Stream temperature, land cover, soil conditions, slope, and elevation are all used to characterize water quality (Montgomery, 1999; Allan, 2004). Changes in land use, especially increases in impervious surfaces, can alter the natural hydrology of the terrain by increasing the rate at which stormwater is delivered to streams. Additionally, impervious surfaces retain heat which transfers to stormwater as it travels over the surface, delivering warmer water to streams (Beechie et. al, 2010). Thermal characteristics of water bodies are well-researched, and it is understood that water temperature deeply influences the suitability of streams as salmon habitat (US EPA, 2001). As development increases in many parts of the country, concern for the effects is expected to increase interest in new methods for effective targeting of at-risk areas.

STUDY AREA

The Sandy River Basin encompasses 1315 square km in northwestern Oregon with a large variety of land cover types and uses, as well as wide ranges of population distributions. It is home to the Sandy River, which has annual spawning runs of Chinook and Coho salmon, and Steelhead trout. These runs were at risk for extinction during the 1990s, and have since triggered expensive ongoing efforts to stabilize the fish populations (ODFW, 2012).

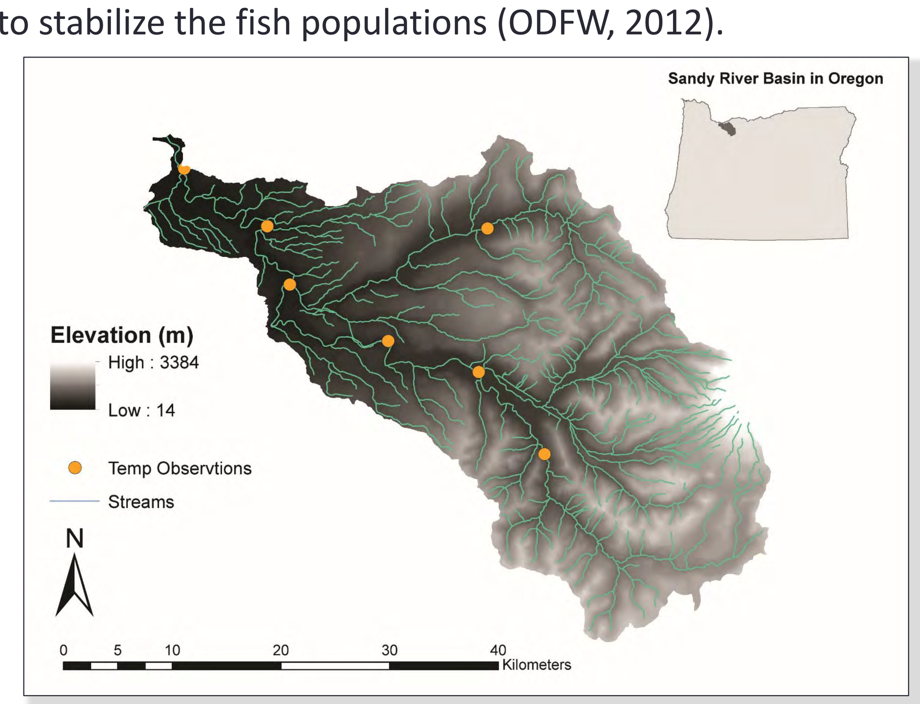

Figure 2. DEM of study area with points indicating monitoring stations, which serve as pour points for 7 delineated sub-watersheds.

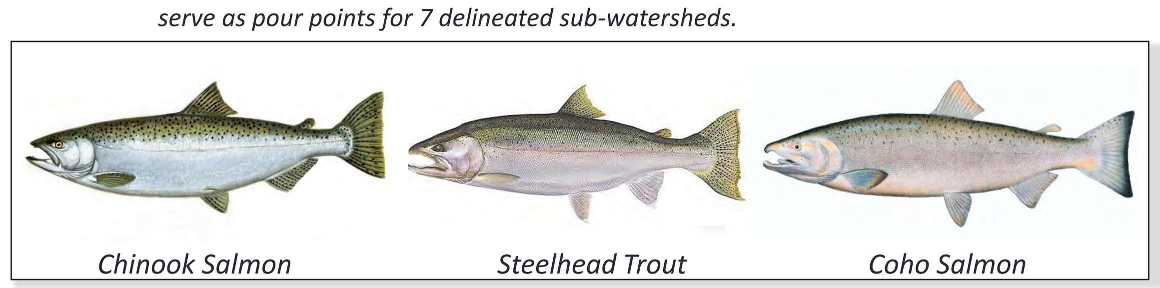

Figure 3, Images Courtesy of ODFW.

METHODS

- We obtained continuous temperature data at all available sample points (n = 7) throughout the Sandy River Basin (SRB) from the US Geological Survey (USGS) and the Department of Environmental Quality (DEQ). The temperature data were compiled into a temperature index consisting of values for each sub-basin, including average daily, 7-day average maximum, 7-day average minimum temperatures, and number of days where the temperature exceeds 12°C. The US EPA states that 12°C is a common temperature threshold for impairment of juvenile salmon species, and warmer stream temperatures can prevent the fish from feeding (2001).

Table 1. Temperature Index (Dependent Variable)

Subwatershed	Avg. Temp (°C)	7DAD (max)	7DAD (min)	No. Days (>12 °C)
1308	18.12	21.25	12.96	18
2654	10.84	13.26	7.25	5
5006	5.71	6.56	5.19	0
5007	4.69	5.11	4.11	0
5017	5.29	5.73	5.03	0
5019	13.92	17.31	9.16	15
5027	15.93	17.45	13.33	18

- An 80m DEM of the study area was obtained from the USGS and by using ArcMap 10.3 flow direction and flow accumulation tools, we delineated the SRB into 7 sub-basins that drain to each gage station. We used the flow length calculator in ArcMap's Hydrology toolset to determine the distance between a gage station and each raster cell in that gage's sub-basin. This flow length is the distance variable in the distance-weighted models.

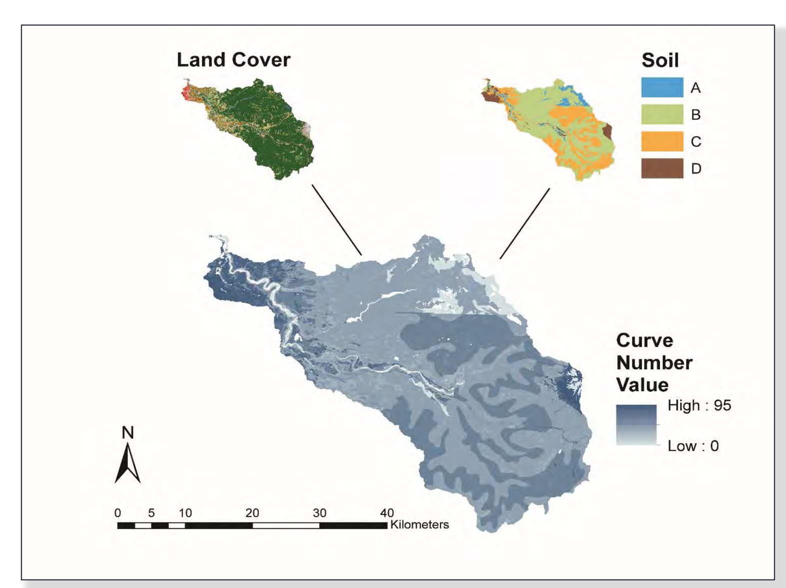

Figure 4. Illustration of the creation of CN raster by combining land cover and soil data in ArcMap. Created by Robert Bolduc.

- The US Department of Agriculture's (USDA) National Land Cover Datasets (NLCD) were included in our analyses as well as soil data for the watershed from SSURGO to generate a raster of curve numbers (CN) in the watershed, and we used the DEM to generate slope (SL) and elevation (EL) rasters. The "per-pixel values" in the raster datasets are values for the given parameter in each raster cell, and are used to compare four different model equations.

- Two of the model equations consist of non-spatial techniques for determining the parameter of interest: the areal sub-basin average, and average within a 1km buffer around each gage station. The other two methods involve applying distance-weighted averages: the inverse-distance weighted (IDW) average, and the exponential decay (ED) average of each raster cell to the gage station. Using statistical testing, we calculated a correlation coefficient for each parameter in order to determine whether spatial or non-spatial methods were better for explaining the variation of our temperature index.

$$Average\ K = \Sigma\,\frac{K_i}{n}$$

$$Average\ K_{1km} = \Sigma\,\frac{K_i}{n_{1km}}$$

$$IDW\ \ K = \Sigma\,\frac{(\frac{1}{d_i} * K_i)}{n}$$

$$ED\ K = \Sigma\,(\frac{e^{d_i} * K_i}{n})$$

Table 2. Parameter Index (Independent Variable)

Non-Spatial	Areal Average		
Subwatershed	CN	SL	EL (m)
1308	71.3	9.9	224.1
2654	47.9	47.2	855.5
5006	61.2	46.7	1225.4
5007	57.4	59.9	1600.5
5017	54.9	34	741.2
5019	59.0	37.2	692.3
5027	60.5	32	667.3

Spatial	IDW Average		
Subwatershed	CN	SL	EL (m)
1308	88.1	16.3	368
2654	33.5	33	598.6
5006	56.9	43.4	1139.8
5007	73	76.2	2036.7
5017	50.6	31.4	683.7
5019	82.4	52	966.9
5027	56.6	45.8	955.3

Non-Spatial	Areal Average within 1km buffer		
Subwatershed	CN	SL	EL (m)
1308	63.6	7.2	70.4
2654	52.9	13.4	453.9
5006	48.4	38.5	707.3
5007	50.4	16.4	506.6
5017	55.6	15.8	329.4
5019	50.25	8.9	190.3
5027	56.8	13.9	152.4

Spatial	ED Average		
Subwatershed	CN	SL	EL (m)
1308	71.5	10	224.6
2654	48	33	856.4
5006	56.9	47.5	1226.7
5007	57.5	61	1602.9
5017	55	34.6	742.2
5019	59.1	37.8	693.4
5027	60.6	32.5	668.4

RESULTS

Correlation Coefficient, $$r = \frac{n\sum xy - (\sum x)(\sum y)}{\sqrt{n(\sum x^2) - (\sum x)^2}\sqrt{n(\sum y^2) - (\sum y)^2}}$$

Table 3. Correlation Coefficient between Dependent and Independent Variables

Non-Spatial	Areal Average	
Corr Coeff (CN and Temp)	Corr Coeff (SL and Temp)	Corr Coeff (EL and Temp)
0.504027863	-0.757415094	-0.814644917
Non-Spatial	**Areal Average within 1km buffer**	
Corr Coeff (CN and Temp)	Corr Coeff (SL and Temp)	Corr Coeff (EL and Temp)
0.665065088	-0.620174796	-0.831721467
Spatial	**IDW Average**	
Corr Coeff (CN and Temp)	Corr Coeff (SL and Temp)	Corr Coeff (EL and Temp)
0.390809149	-0.471317893	-0.576648721
Spatial	**ED Average**	
Corr Coeff (CN and Temp)	Corr Coeff (SL and Temp)	Corr Coeff (EL and Temp)
0.600931203	-0.785531437	-0.814515171

The non-spatial average CN within a 1 km buffer of the monitoring station produced the greatest positive correlation value with temperature. The non-spatial average EL within a 1 km buffer produced the greatest negative correlation with temperature. Correlation was positive with all methods for the CN parameter, while all other methods and parameters produced negative correlation.

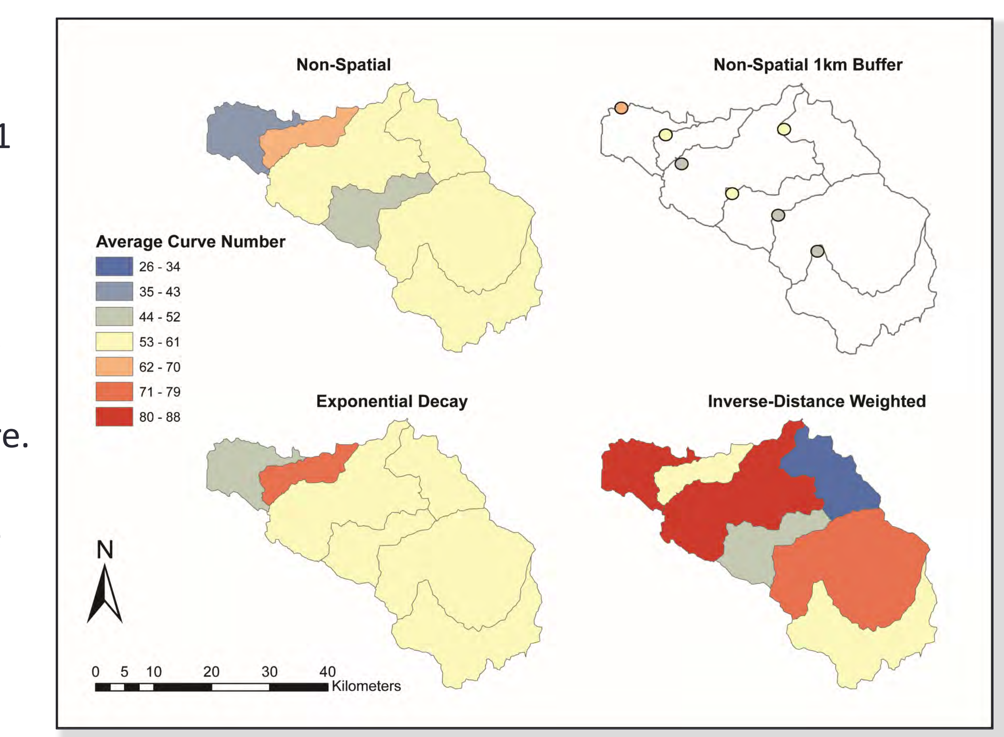

Figure 5. Illustration of an example output of each averaging method for the CN parameter assessed in ArcMap. Created by Robert Bolduc.

CONCLUSION

We hypothesized that the distance-weighted averaging techniques will yield stronger correlations with the temperature index compared to the non-spatial techniques based on Tobler's Law: everything is related to everything else, but near things are more related than distant things. Our results yielded a correlation that was positive with CN, and negative with SL and EL. This result makes sense because we would expect that as curve number increases, potential for runoff also increases and delivers more and warmer water to streams. Sub-watershed 1308 contained the greatest amount of impervious surfaces and also produced the warmest temperatures, further supporting this result. The negative correlations with SL and EL are also logical, especially considering the sub-watersheds in the southeastern portion of the basin, where snowmelt from Mt. Hood greatly influences the average temperatures. In an ideal study, an area this large would contain dozens of continuous monitoring stations that could provide a more detailed assessment of correlation between our indices, but due to constraints of publicly-funded data, our continuous resources were limited. However, this study supports the attempt made by Grabowski et. al (2008) to create a method that could be adapted to any watershed, while allowing researchers to create many combinations of water quality indicators and land cover characteristics. Further research with this approach can provide valuable insight to developers and environmental managers in order to better understand effects of land development and the hydrologic systems in the most at-risk areas.

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