The Effects of Granularity:

Comparing Soil Erosion Predictions Using Two Elevation Datasets

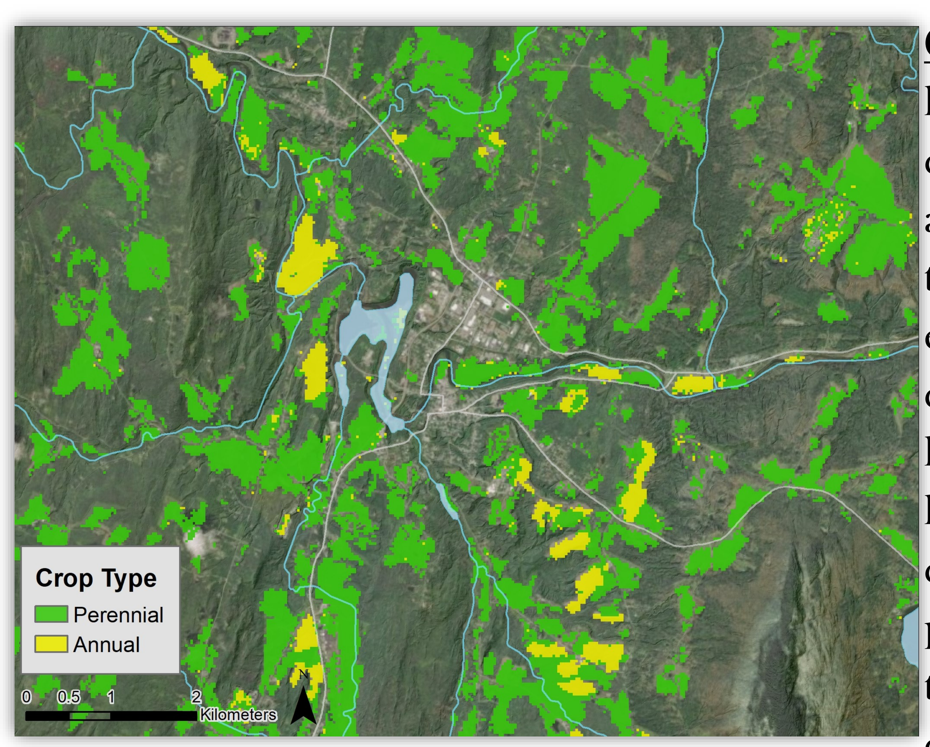
Introduction

Despite Vermont's idyllic beauty, it suffers from the eutrophication of its waters, which is primarily driven by phosphorus runoff from fertilized farm fields. Because phosphorus is tightly bound to soil particles, its movement can be estimated through the use of erosion models. The standard method to estimate the quantity of soil erosion is by using the RUSLE model, which takes numerous management and inherent geological factors into account. In this study, I will estimate erosion risk for the town of Morrisville Vermont using soil, crop type, and slope data. I'll use two different elevation data layers to see how sensitive erosion models are to elevation granularity; one is a very fine-grained 1-meter resolution dataset, and then other is a coarser 1/3 arc-second resolution (with cell size of about 9x9-meters). The results of this will tell us how sensitive erosion models are to elevation granularity.

I chose Morrisville for this study, because it is located within the Lake Champlain watershed (which suffers from excess phosphorus) and was one of surprisingly few locations that was covered by all of the data layers I wanted to use for this study. Because I wanted to explore granularity, I chose to use a very small study area, about 100 square kilometers.

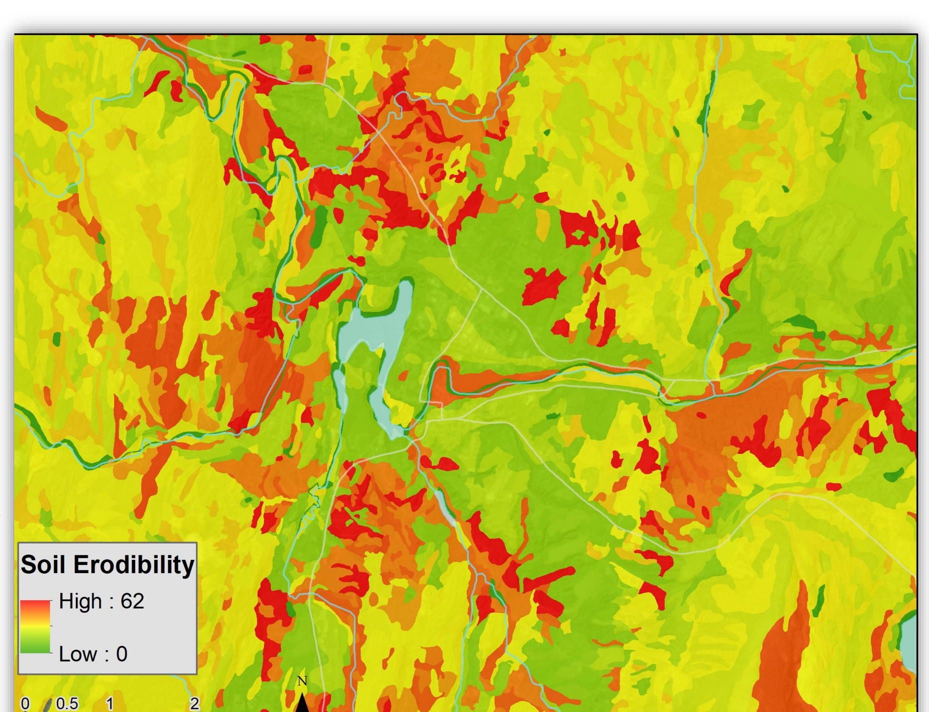
Methods

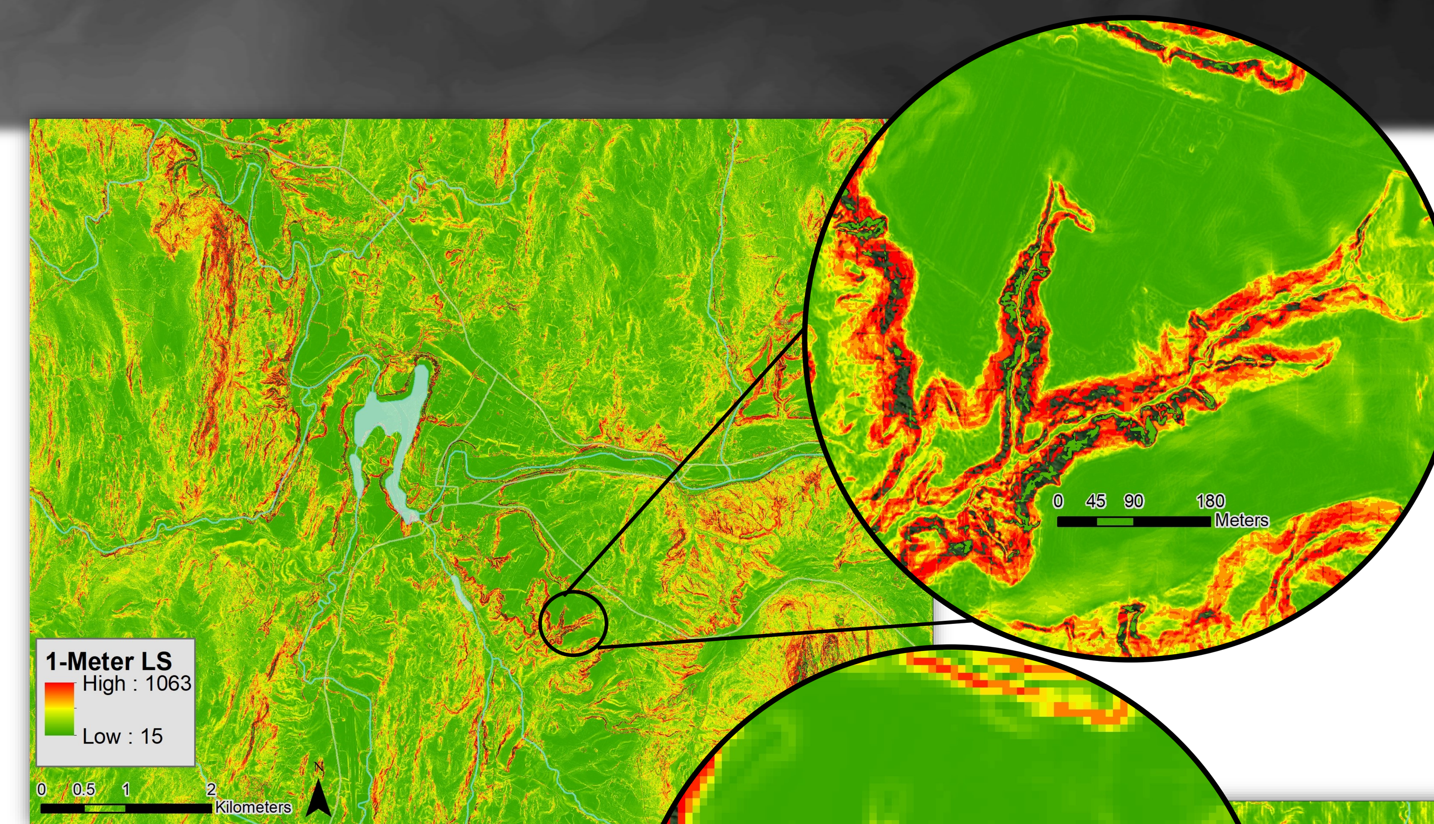
For this study, I wanted to estimate erosion levels by approximating the RUSLE model, focusing exclusively on cropland. Although RUSLE is a complicated model with numerous inputs, I simplified it to three: crop type (C-Factor), inherent soil erodibility (K-Factor), and slope (LS-Factor). Instead of deciding how to weight each factor myself, which felt too likely to be arbitrary, I instead used actual numbers from the RUSLE equation. Because ArcMap sometimes struggles with values less than 1, I multiplied each of the factors by 100 to obtain integers.

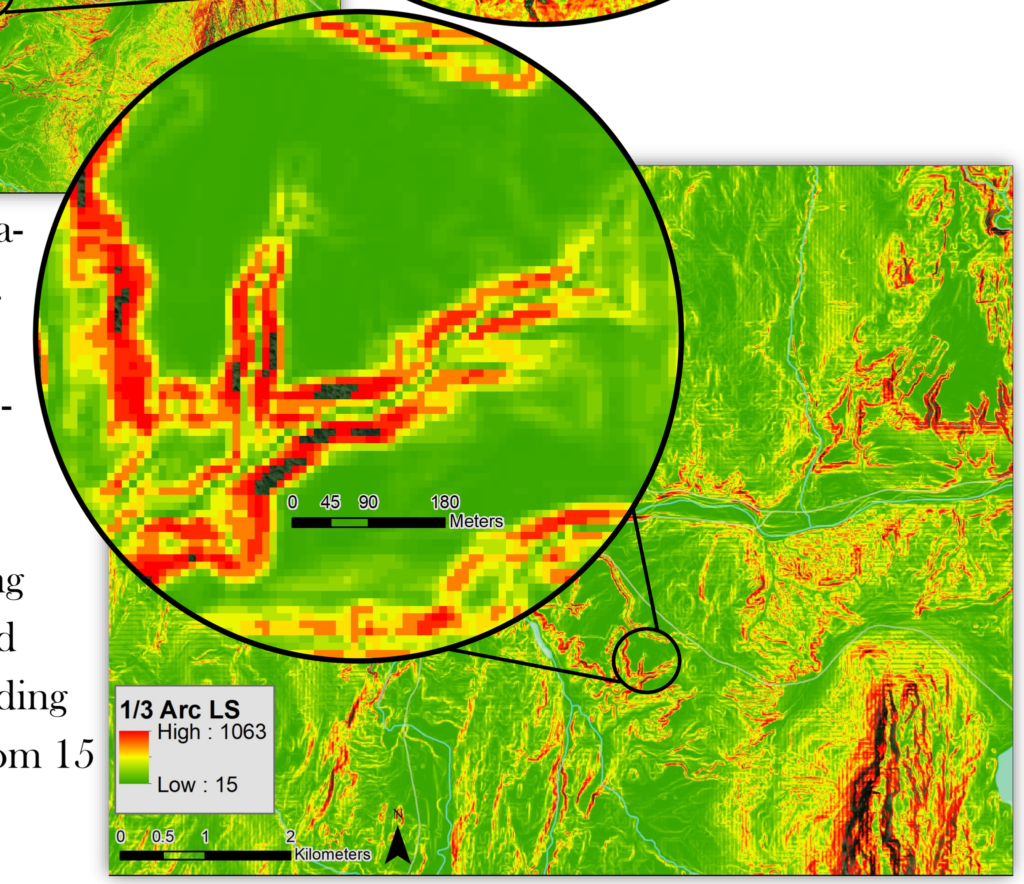


Crop Type: Using USDA's CropScape layer (satellite imagery, 30x30-meter cells), I reclassified it into perennial and annual crops. Because annual crops are typically tilled at least once per year, erosion rates are higher than perennial crops. RUSLE sets the C-factor to 2 for hay, and to 50 for silage corn. I used silage corn as a stand-in for all annual crops, and grass hay as a stand-in for perennial crops—I felt confident about these values since these are the predominant crops for the area. Unfortunately, there is no information about whether or not farmers are employing conservation practices such as reduced tillage, which would affect the estimates of erosion rates.

Soil Erodibility: I used USDA soils data, which has a 10x10-meter cell size. K-Factor is one of the available layers, which shows inherent soil erodibility based on soil composition. The K-Factor ranges from 0 (very stable) to 69 (very erodible).



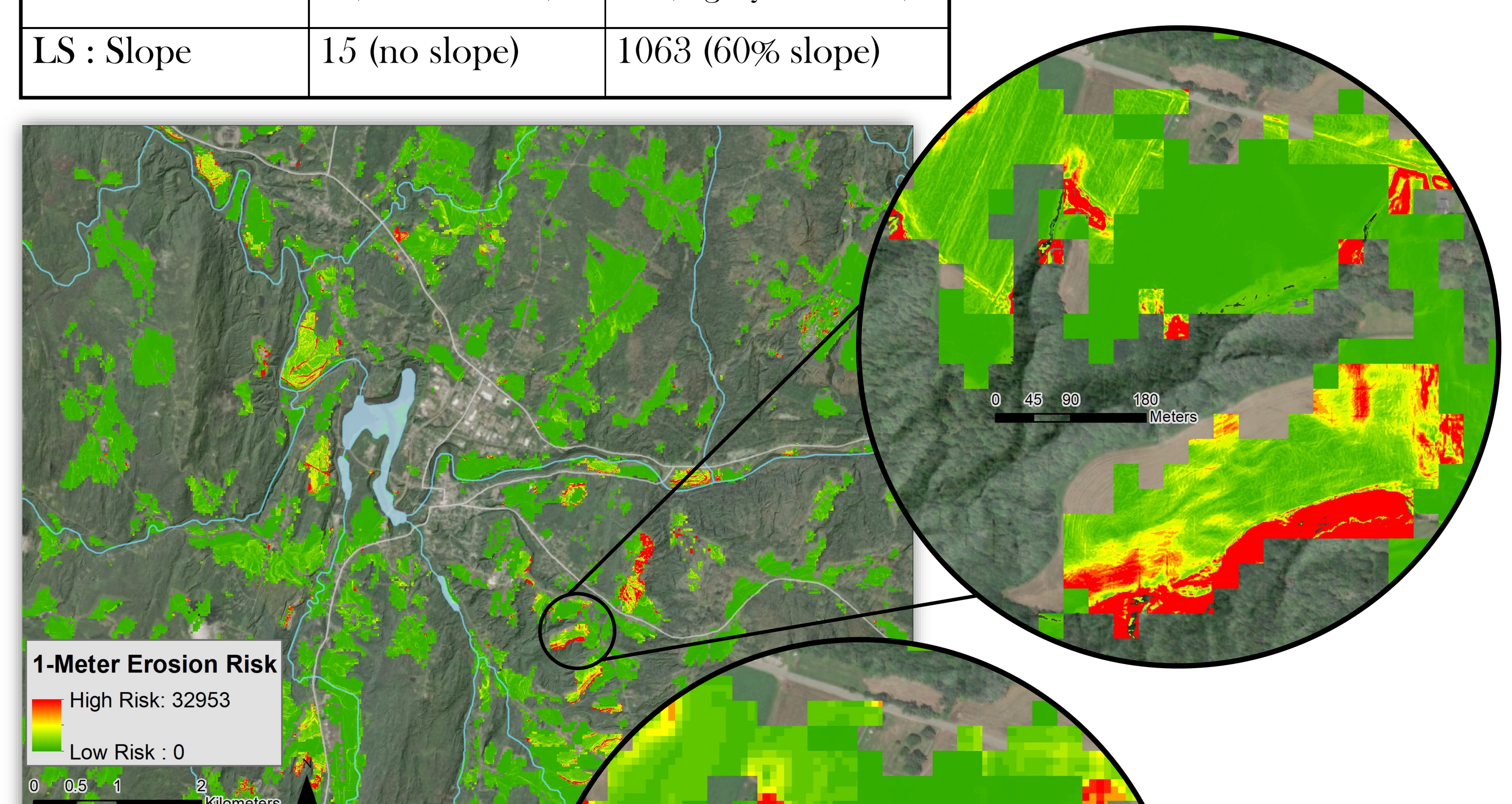


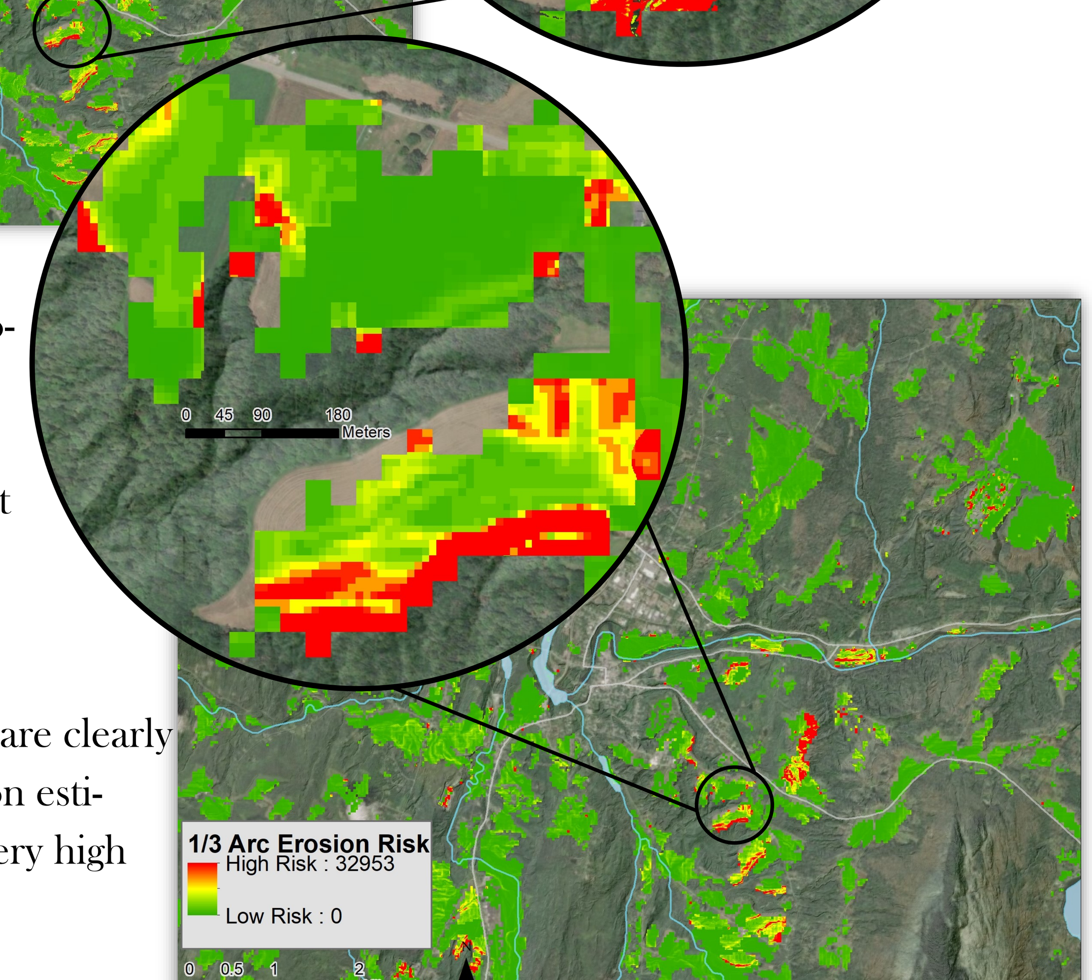


Elevation: I used two elevation datasets for slope, or the LS-Factor. Magnification shows the difference in granularity between the 1-meter resolution and the 1/3 arc-second, which has cells approximately 9x9-meters long. Assuming 100 foot-long slopes, I reclassified percent slope into the corresponding LS-Factor values, which range from 15 (flat) to 1,063 (very steep).

Erosion Factor	Lowest Value	Highest Value
C : Crop Type	2 (perennial)	50 (annual)
K : Soil	0 (not erodible)	69 (highly erodible)
LS : Slope	15 (no slope)	1063 (60% slope)

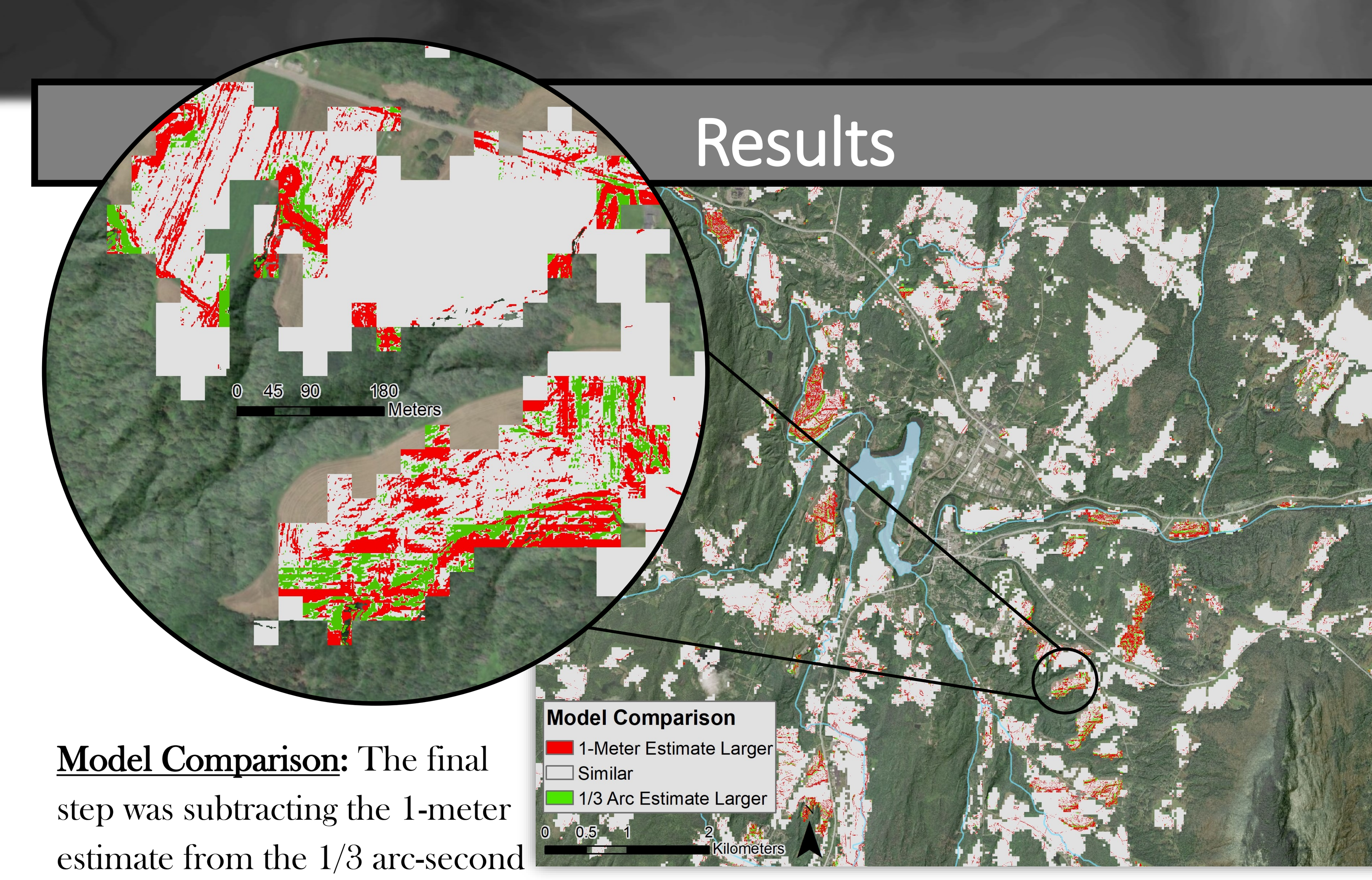
Erosion = (C * K * LS) / 100





Erosion Risk: To obtain erosion estimates, I calculated (C*K*LS)/100, running the model twice for the different elevation layers. Here, we can see the differences between them: the estimates made with the 1-meter data are clearly much more detailed. Erosion estimates range from 32,953 (very high risk) to 0 (very low risk).

Results



Model Comparison: The final step was subtracting the 1-meter estimate from the 1/3 arc-second estimate to determine the difference in predictions for each individual cell. Results ranged from –31,682 (1-meter > 1/3 arc-second estimate) to +30,473 (1/3 arc-second > 1-meter estimate). Overall, 91% of the predictions were similar (± 200 points from 0), while the 1-meter data gave larger predictions (< - 200) for 7% of cells, and the 1/3 arc-second gave larger (> +200) predictions for 2%. Essentially, while the models were similar, the model using fine-grained elevation data was more likely to estimate higher levels of erosion than the coarser-grainer data. It is possible that predictions made with coarser elevation data could be under-estimating soil-loss estimates, which has wide-reaching implications for agricultural conservation and water quality.

Similar Cells (-200 - +200)	91%
1-meter Larger (< -200)	7%
1/3 Arc Larger (>+200)	2%

Conclusion and Limitations

There are several important limitations to this study: 1. The soils and crop data are both relatively chunky, with 10 and 30-meter cells, respectively, which means they could fail to classify areas up to 30x30 and 90x90 meters 2. Partly because of that granularity, and partly because both datasets rely on satellite imagery, there are also clear areas of omission (areas where there are holes in one or more data layers) and commission (e.g. forested areas that CropScape classified as corn). 3. It was surprisingly difficult to find numeric values for the C and LS factors, since RUSLE is generally run as a computer model with many more inputs. Because of that, I had to simplify the C factor to two values (for hay and silage corn) and most importantly, I could only include slopes up to 60%. Although it's extremely unlikely that any farm fields would exceed a 60% slope, it's possible that my models excluded some areas.

In conclusion, despite these limitations, I believe that this study not only provides a solid estimate of relative erosion risk in Morrisville, it also highlights the sensitivity of erosion models to elevation granularity, which is very important for accurate estimations, especially since RUSLE weights LS-factor relatively heavily compared with C and K-factors.

References

Emily Liss, Fundamentals of GIS. Poster submitted December 21, 2018.

Projection: NAD 1983 Vermont

Crop data: National Agricultural Statistics Service, "CropScape." 2017.

Soils: United States Department of Agriculture NRCS, Soil Survey Geographic Database, downloaded from ArcGis.com

Elevation: United States Geological Survey, National Map Elevation Data. 1-meter and 1/3 arc-second resolution. 2018.

Background (hydrography, imagery, roads): ESRI, 2017.

LS Factor Conversions: Ontario Ministry of Agriculture, Food, and Rural Affairs. 2012. Link here.

C Factor Conversions: Five Counties Conservation Program. 2012. Link here.