Modeling Food, Water, and Energy Nexus in The Connecticut River Watershed

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Introduction

The Connecticut River Watershed is a region rich with history of agriculture, exploration, and natural beauty. It is also the longest river in New England at 410 miles long. This has led the Connecticut river to be used as a hub for human activity, with over 2 million people residing here today. Since its emergence over 10,000 years ago, the river has had a history of production, pollution, and recovery. It has now been listed as one of 14 American heritage rivers as well as the first national blueway. As more and more people live among this watershed, it is increasingly important to look at how human life can impact the region. Looking at how human activity such as farming and damming can impact a river helps us understand how the river will impact its surrounding environment. This research can allow humans to continue utilizing these resources in a responsible and sustainable way for years to come. For this reason, this project explores the connection between the river and human life along it in the forms of food and energy.

Objective and Hypothesis

Hypothesis: Food, water, and energy are deeply connected and an imbalance of one can throw off the entire watershed dynamic.

Objective: Create data visualizations using GIS software to better understand the connection of food, water, and energy within the Connecticut River Watershed

Background

The Connecticut River Watershed flows through a large portion of western New England including major cities such as Springfield and Hartford. The Watershed has a long history of human life, from the Mohegans, Nipmucs, Pocumtucs, Pequots, and many more native peoples who called the river home, to the British colonists who laid claim to lands here as early as the 1600s. Since then, it has become one of the most heavily dammed rivers in America. These dams were used to power mills, generate electricity, store drinking water, and irrigate farmland. This began the long, interwoven relationship between humans and the Connecticut River.

Now, as food and water insecurity is a reality faced by more and more people every day, a need to explore the interconnectedness of these resources has become imperative for the future of the Connecticut River and the life that relies so heavily on it.

Agriculture consumes the majority of freshwater on the planet and Hydroelectric energy makes up roughly 29% of renewable energy production in the US. Moreover, rivers and streams such as the Connecticut River are lifelines for many regions of the country. Thus, my research focuses on the relationship between the Connecticut River and its tributaries to food and energy usage and vice versa.

Methods

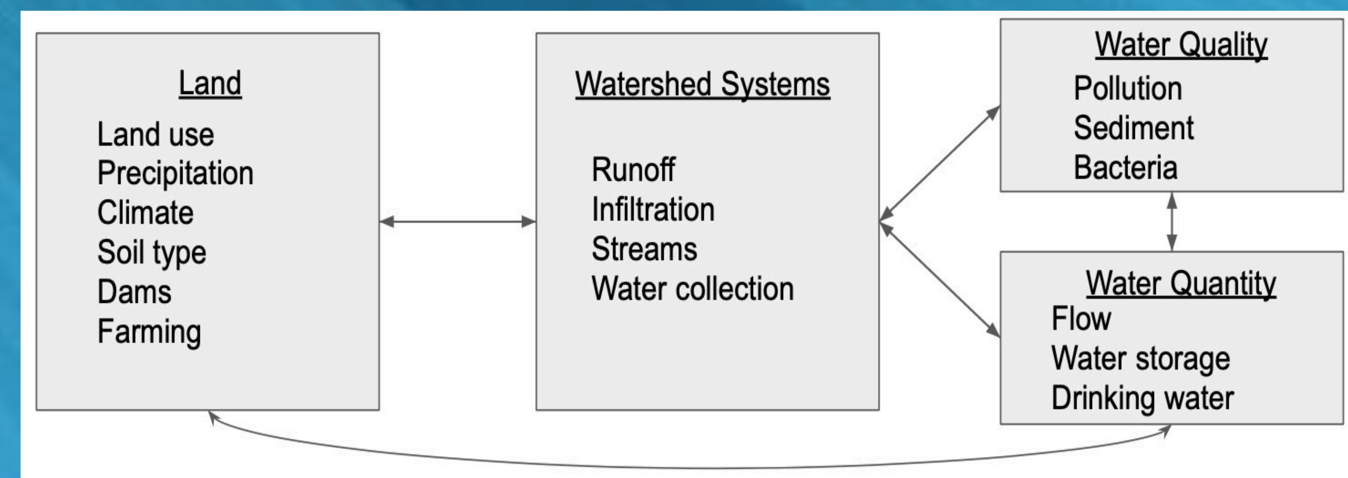

Figure 1. Concept map showing connections within a watershed

The methodology of this research involves a compilation of data from various sources using GIS technology. These sources include The US Census of Agriculture, US Energy Atlas, and The Connecticut River Conservancy. This was mapped out using ArcGIS to generate visuals. These maps were transformed into Excel data which allowed me to do my own calculations regarding energy and agricultural production. Lastly, I used a software called BASINS to perform a PLOAD model and used Model my Watershed to perform a GWLF-E analysis to look at pollution, land, and stream data.

Programs used: ArcGIS Pro, BASINS, EXCEL, Model My Watershed

Results/Discussions

Figures 1 and 2 below show the results of the PLOAD analysis that was done for this project. They are calculated largely using land cover data for the region and each map depicts the lower Connecticut River as the highest in pollution load per acre, this is largely due to farming in the region and high land development. To go along with data, you can also see table 1, which dictates the pollution that is distributed from over 140 point sources in the region.

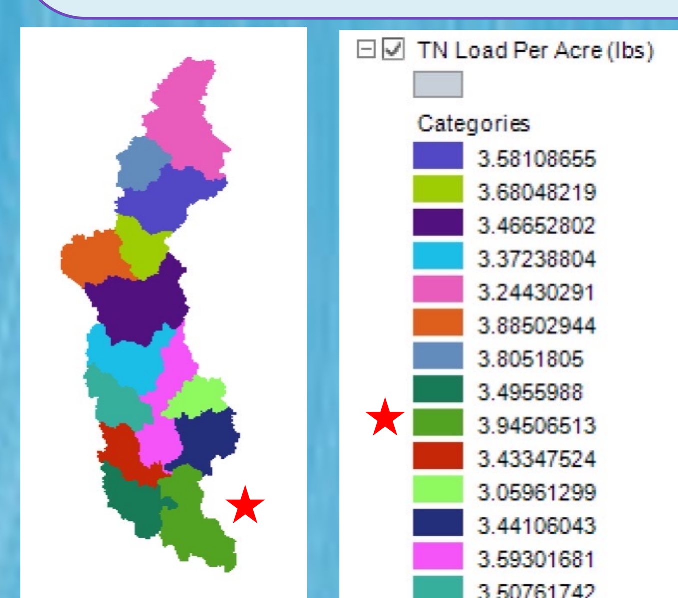

Figure 2. Total Nitrogen Load Per Acre Map & Legend

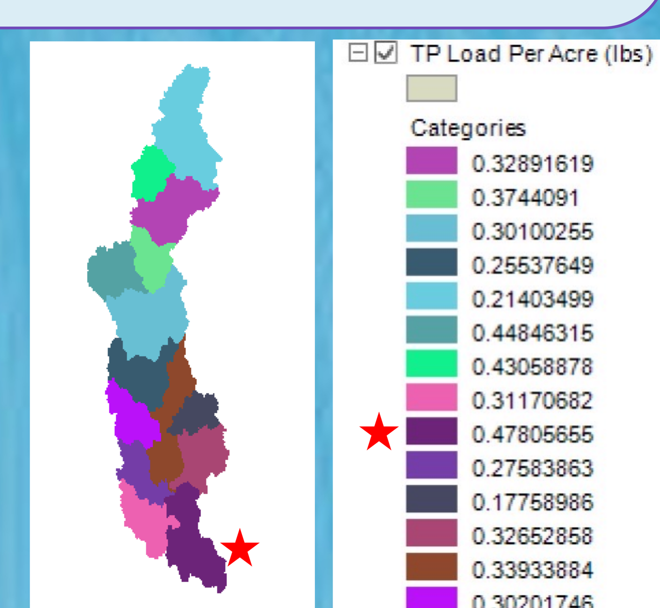

Figure 3. Total Phosphorous Load Per Acre Map & Legend

Table 1. Pollution Discharge, Total Nitrogen Load, and Total Phosphorous Load

NPDES	Discharge (m³/d)	TN Load (kg/yr)	TP Load (kg/yr)
Total For Area of Interest	564,783.44	1,168,844.00	59,237.00

Table 2. Top: Stream Order, Middle: Land Coverage, Bottom: Mean Precipitation & Temperature

Stream Order	Total Length (km)	Mean Channel Slope (%)
1st	11,809.66	4.14%
2nd	3,708.51	1.80%
3rd	1,989.90	0.84%
4th	1,016.37	0.45%
5th	672.07	0.22%
6th	366.64	0.03%
7th	0	No Data
8th	0	No Data
9th	0	No Data
10th	0	No Data
Other	170.84	No Data
Combined	19,734.00	2.94%

Type	Area (km²)	Coverage (%)	Active River Area (km²)
Open Water	600.65	2.1	571.5
Perennial Ice/Snow	0	0	0
Developed, Open Space	1,340.93	4.69	398.94
Developed, Low Intensity	910.9	3.19	306.65
Developed, Medium Intensity	618.23	2.16	222.37
Developed, High Intensity	177.34	0.62	75.79
Barren Land (Rock/Sand/Clay)	53.31	0.19	16.87
Deciduous Forest	8,981.63	31.42	1,104.21
Evergreen Forest	3,980.09	13.93	938.86
Mixed Forest	7,984.05	27.93	1,382.15
Shrub/Scrub	384.31	1.34	51.12
Grassland/Herbaceous	168.52	0.59	39.26
Pasture/Hay	1,343.51	4.7	385.18
Cultivated Crops	270.22	0.95	164.8
Woody Wetlands	1,638.74	5.73	1,088.09
Emergent Herbaceous Wetlands	127.6	0.45	103.12
Total	28,580.02	100	6,848.91

Month	Mean Precip. (cm)	Mean Temp. (°C)
January	8.2	-7.1
February	7.5	-6.5
March	9	-1.2
April	9.1	5.6
May	9.7	12.2
June	10.5	17
July	10.6	19.7
August	10.4	18.5
September	10.1	14.5
October	9.6	8.5
November	9.7	2.2
December	9.2	-4.5
Annual	113.6	6.6

Table 2 depicts the results of GWLF-E analysis which was conducted across the watershed. We can see that the majority of the land cover is forested at roughly 73%. Agriculture makes up roughly 5.5%, and developed space covers about 10.5%. This land coverage dictates the amount of pollution that will run off into streams and potentially into the water supply. Furthermore, the analysis gave stream order of the watershed which shows that roughly 60% of the streams that make up the watershed are first order. These first order streams are fed simply from runoff and precipitation Although we mostly think of the main stem of the river when we think of a watershed, the many streams that flow into it are just as important when it comes to monitoring water resources. Lastly, this analysis gave precipitation and temperature data which shows that the region has a humid continental climate with constant precipitation.

During this project I compiled all my ArcGIS data regarding energy and agriculture into a spreadsheet which includes the data for the watershed and all HU10 and HU12 sub basins. The 15-mile falls dams provide the most energy of all dam projects and this data reflects that. When it comes to agriculture the Manhan River-Connecticut River sub basin generated the most money from agricultural sales. This sub basin contains Amherst and some of the surrounding towns and is highly productive due to its location within the floodplain.

Table 3. Maximum Energy and Agriculture Production in HU10 & HU12 Sub-Basins

Most Efficient HU10 Basins	
Energy: Stevens River - Connecticut River	740,026.7 mWH
Agriculture: Manhan River - Connecticut River	32,706,354 USD
Most Efficient HU12 Basins	
Energy: Comerford Station Dam - Connecticut River	354,921.6 mWH
Agriculture: Headwaters White River	11,808,101 USD

Table 4. Annual Agriculture & Hydroelectric Energy Production for Watershed

Agriculture Sales (in USD)	579,431,878
Annual Hydroelectric Production (mWH)	2,371,715.20

Figures 3 and 4 depict data visualizations of agricultural sales and hydroelectric energy for the watershed. These visuals were made by using national data and compiling it into the shape of the Connecticut River Watershed. The most agriculturally productive areas tend to be to the south where the river meanders and creates vast floodplains of fertile soil as seen by the darker color in figure 3. Figure 4 highlights the fact that most energy produced by rivers in the watershed comes directly from the main stem of the Connecticut River. Certain tributaries such as the Deerfield river and Chicopee river also have a large number of dams.

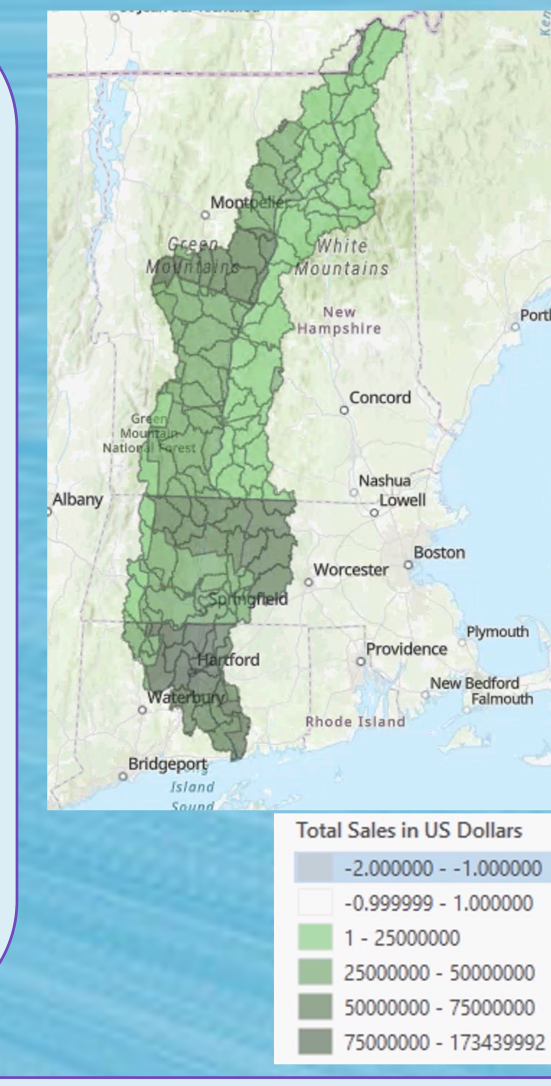

Figure 4. HU10 Map of Agricultural Sales via Census Data

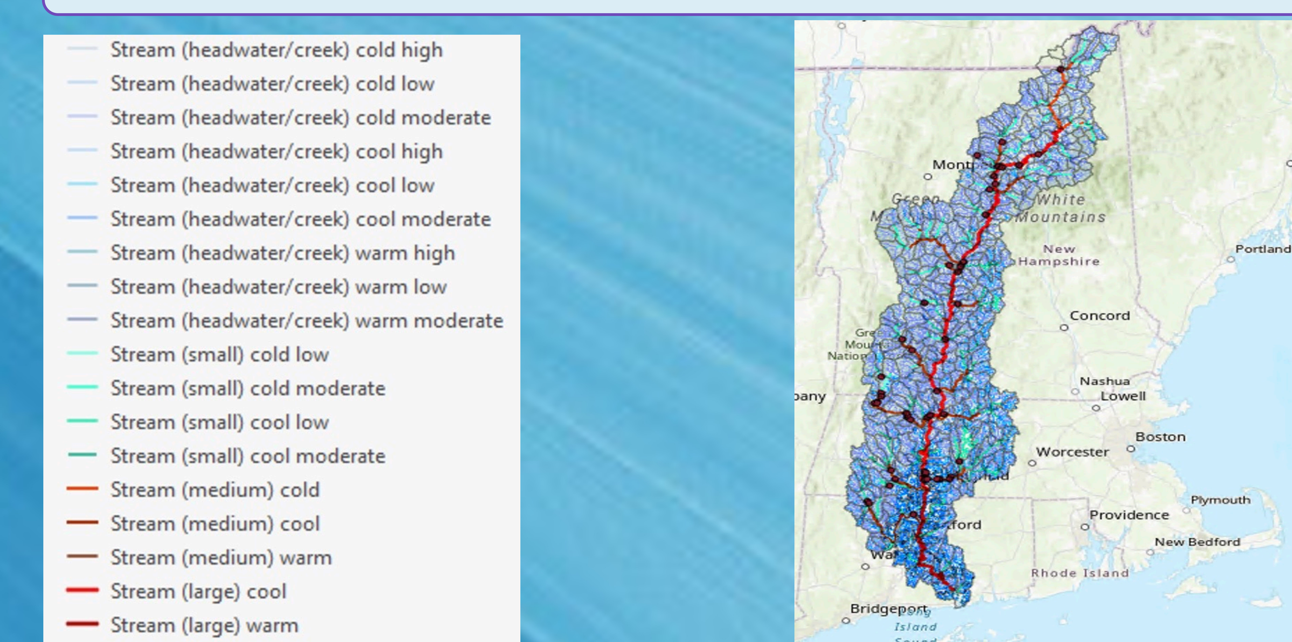

Figure 5. Map of Hydroelectric Power Plants

Conclusions

To conclude, the biggest takeaway I had from this project was that it is highly possible to reverse certain effects of pollution if action is taken early. This watershed was once riddled with sewage and industrial waste and is now the backbone of clean energy and agricultural production within New England. I also learned the importance of data visualization tools such as GIS. GIS can tell the story of an entire region with a simple map, allowing all to learn the intricacies of environmental conservation.

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