Final Project

Title: Spatial interpolation of Accumulated Growing Degree Day in North Dakota
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Project Repository: https://github.com/Samikshya036/GIS5571
Total Time Spent for project: Around 35 hours

Abstract

Farmers lack a model to forecast when their harvest will be fully grown. This study's goals is to calculate the number of accumulated growth degree days (AGDD) that crops would require (corn and wheat). Growing Degree Day (GDD) is a weather based indicator that is used to estimate plants growth and development during the growing season. Specific amount of heat is required for plants to grow from one stage of their lifecycle to another. The duration of the growing period from the first day of ideal planting conditions to the first day of ideal harvesting conditions is determined by weather, particularly heat and photoperiod. Farmers frequently use calendars for the prediction of plant growth and management. GDD provides farmers a more scientific framework of understanding the relationship between daily heat units and plant growth. Compared to using the calendar method of predicting plant growth and development, GDD is a far more accurate way to predict plant growth and development.

I selected Accumulated GDD for wheat and corn from NDAWN weather stations to complete this project. Here, I downloaded the historical climate data from web (NDAWN) through ETL pipeline in Jupyter Notebook and plotted interpolated map using interpolation technique for the accumulated GDD for several years (2018, 2019, 2020, 2021) in North Dakota.

Problem Statement

1. To compare Accumulated Growing Degree Day for Corn and Wheat in North Dakota in years 2018, 2019, 2020 and 2021
2. To build an ETL in ArcPro Jupyter Notebooks that downloads the Accumulated Growing Degree Day data for Wheat and Corn from NDAWN, use data into interpolated Growing Degree Maps by using interpolation techniques.

Table 1. Data requirement for GDD calculation

#	Requirement	Defined As	Attribute Data	Dataset	Preparation
1	Daily Temperature (Max/Min)	.CSV files from NDAWN	Temperature on Degrees/Fahrenheit	NDAWN Daily	Input predicted first planting date and ending date
3	Base temperature for wheat	Constant base temp	degrees	constant	No
4	Base Temperature for corn	Constant Base temp	degrees	constant	No

Input Data

The most common temperature index used to estimate plant development is growing degree days (GDD) which are calculated from the daily maximum and minimum air temperature. Growing degree days have proven useful for crop consultants, producers, and scientists who use them to predict plant development rate and growth stage. In certain crops this information is used to help plan crop management decisions such as irrigation or pesticide application timing, and for scheduling harvest.

Table 2: Table showing purpose of analysis of the data

#	Title	Purpose in Analysis	Link to Source
1	Annual Accumulated Growing Degree Day in North Dakota (2018-2021)	Spatial interpolation of annual Growing degree day of Corn and Wheat in North Dakota	NDAWN Daily

Study Area:
My study area includes all NDAWN weather stations in North Dakota. I selected North Dakota as my study area because data sets for annual Accumulated Growing Degree Days for Wheat and Corn are easily available in NDAWN website. I need to input planting start date and ending date for each crop in every year from 2018 to 2021. I did different analysis for both corn and wheat Growing Degree Day because their base temperature varies. (Corn Base: 10 degree Celsius, and Wheat base: 5.5 degree Celsius)

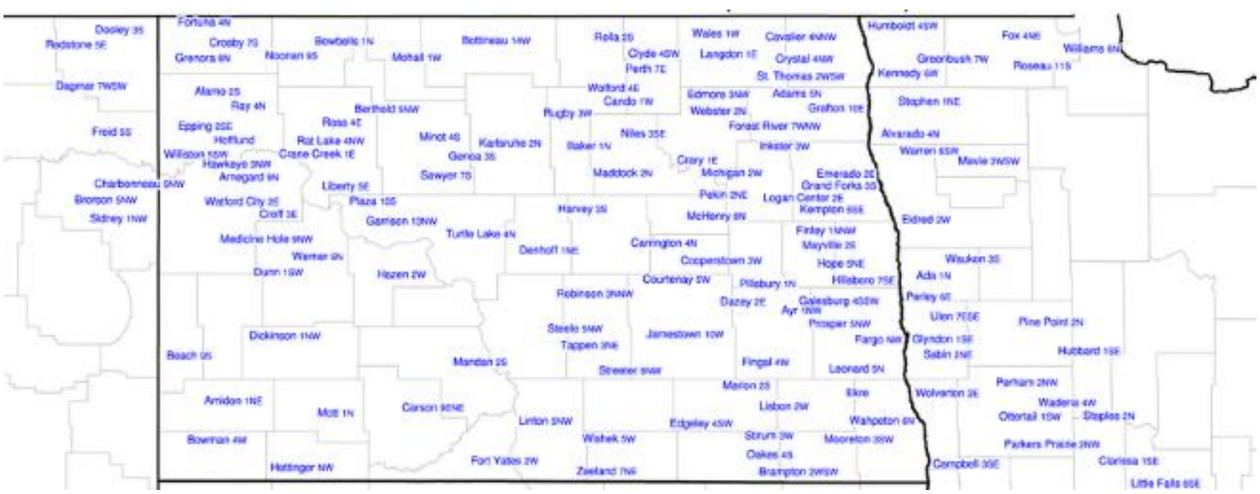

Figure 1: Figure showing study area for spatial interpolation of Annual accumulated Growing Degree Day (2018, 2019, 2020, 2021)

Methods

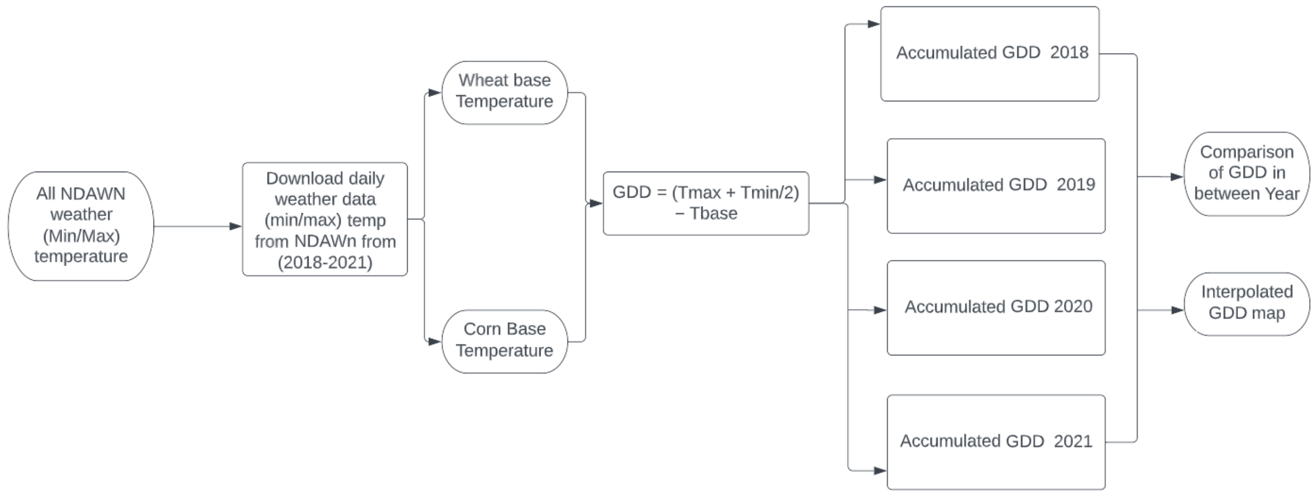

Figure 2: Figure showing workflow diagram for calculation of Accumulated Growing Degree Days.

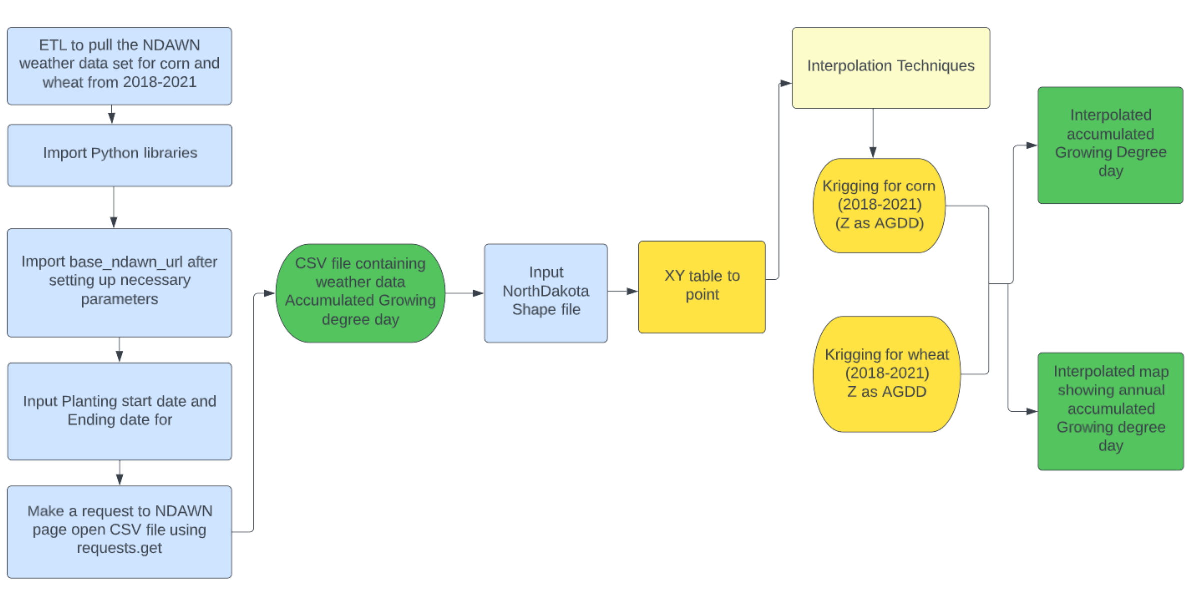

Figure 3: Figure showing data flow diagram for spatial interpolation of annual accumulated Growing Degree days.

Data retrieval Method

- Input planting start date and planting end date for each crop from year 2018 to 2021.
- Use requests.get to download Accumulated Growing Degree Day data from NDAWN website
- Get .CSV file containing includes Wheat and Corn Annual Accumulated Growing Degree Days (year 2018, 2019, 2020, 2021)

Interpolation Method

- Clip Study area and input North Dakota shape file (My study area)
- Use interpolation techniques (I tried IDW, Krigging and Spline). Krigging was best fit and map looked clear in Krigging technique, so I used Krigging for interpolation.
- Input Z as Accumulated Growing Degree days.
- Use Environment Manager code to fit Growing Degree Days in ND map
- Show the interpolated Annual accumulated Growing Degree Day map for Corn and wheat as a result.

Growing Degree day calculation:

Growing Degree Day (GDD) are calculated by taking the integral of warmth above a base temperature. Or simply, approximately equivalent to take the average temperature and minus base temperature in the following equation:

GDD = (Tmax + Tmin) /2 – Tbase

Tmax, Tmin, and Tbase are the daily maximum, daily minimum and base temperatures, respectively. Normally the maximum and minimum daily temperatures are pre-calculated before the above equation. If the maximum or minimum daily temperature is lower than the base temperature, then we set the maximum or minimum daily temperature equal to the base temperature.

For example, if the maximum daily temperature is 20, the minimum daily temperature is 5 and the base temperature is 10, we will have the GDD in the following equation: GDD = (20 + 10)/2 − 10 = 5

Base temperature: Base Temperature is the cool temperature at which a plant does not develop. At or below the base temperature, plants no longer develop or grow. Hence, Base temperature for all crops are always constant.

Table 3: Examples of Base temperature for the application of growing degree day model for different crops

Crop	Tbase	Source
Corn	10	(Darby & Lauer, 2002)
Soyabean	10	(Edey., 1977)
Potatoes	7	(Sands et al., 1979)
Sugarbeet	10	(Baskerville & Emin, 1969)
Wheat	5.5	Idso, 1978
Alfafa	5	(Sharratt et al., 1989)
Peas	5	(Edey., 1977)

Results

Spatial interpolation of Corn Annual Accumulated GDD in North Dakota:

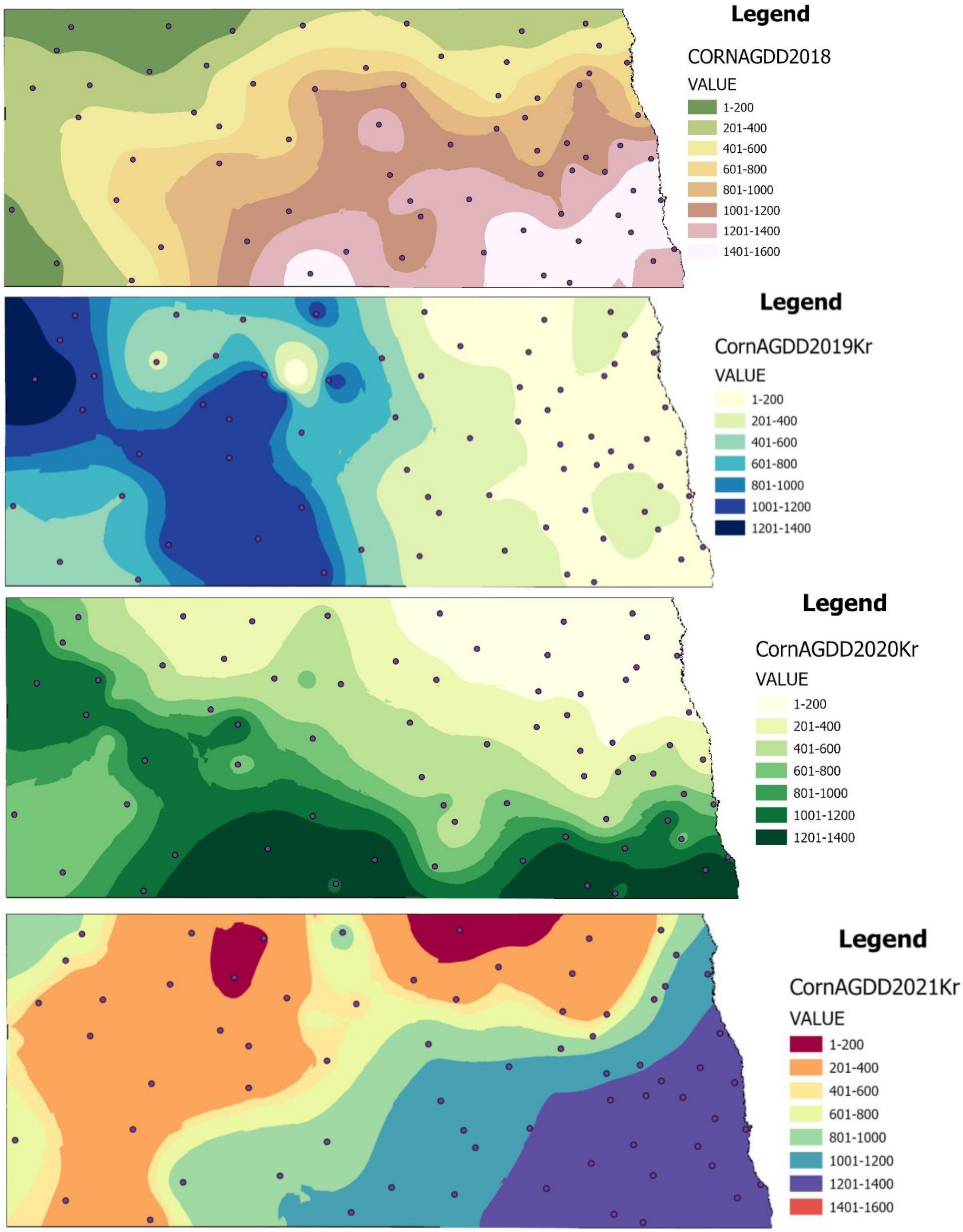

Figure 4: Maps showing spatial interpolation of corn in ND annual Accumulated Growing Degree Days in 2018, 2019, 2020 and 2021 from top to bottom respectively.

Spatial interpolation of Wheat Annual Accumulated GDD in North Dakota:

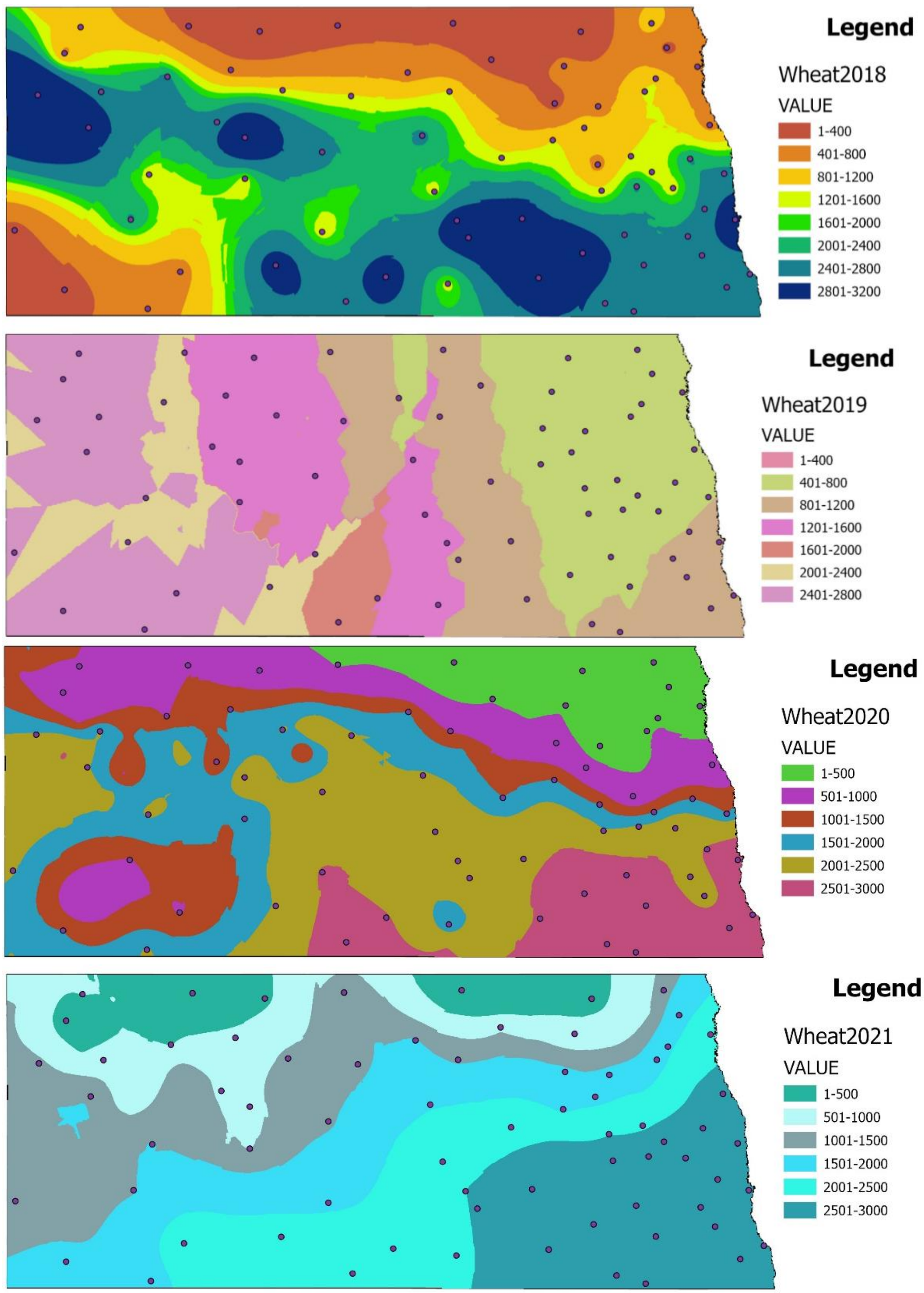

Figure 4: Maps showing spatial interpolation of wheat in ND annual Accumulated Growing Degree Days in 2018, 2019, 2020 and 2021 from top to bottom respectively

The differences in different locations of North Dakota in annual AGDD trends can be clearly seen in both Wheat and Corn from 2018 to 2021. The difference between the maps are mainly due to the difference in temperature every years. The input predicted planting date for both crops in all years is May 1 to September 30. Despite the fact that I kept same starting planting date and ending date in each year for each crop. Corn AGDD was higher in 2018 (max: 1400-1600) than in 2019, 2020 and 2021 (1200-1400). There is spatial difference in interpolated AGDD every year while visually comparing in between years for both crops.

Results Verification

The choice of interpolation method can also be influenced by the quality of the sample point set. If the sample points are few or poorly distributed, which may be the case above, the surface may not adequately represent the topography. Given the close proximity of the sample sites, Krigging probably is the good fit for the interpolation of annual Accumulated Growing Degree Days.

I visually checked the results better than other interpolation technique AGDD maps in between different years. I ran the tools with the same parameters. For the annual AGDD, I found krigging is the best spatial interpolation technique based spatially correlated distance or directional bias in the data. It is also often used in soil science and geology. I verified my results by comparing the maps in between years and getting different interpolated AGDD. It clearly shows that there was temperature difference in between years at the same time. So, that interpolated AGDD was different in different years.

Discussion and Conclusion

This project and class is very important to me because I will apply all methods and technique I learned in my own research work and I am planning to do further analysis on Minnesota Accumulated Growing Degree Day for my research work in future and take out average AGDD of different years.

This project gave me insight learning of spatial interpolation technique.

I learned different interpolation techniques and learnt to choose best fit interpolation method. The most effective interpolation technique depends on a number of factors. There is no single method that solves all problems; it depends on the type of variable and the time scale on which it is represented. Instead of thinking one interpolation approach is better than another, all interpolation strategies should be researched and their results should be compared in order to determine the best interpolation method for a specific project.

References

Kukal, M. S., Irmak, S., Walia, H., & Odhiambo, L. (2020). Spatio-temporal calibration of Hargreaves-Samani model to estimate reference evapotranspiration across U.S. High Plains. *Agronomy Journal*, *112*(5), 4232–4248. https://doi.org/10.1002/agj2.20325

Chai, H., Cheng, W., Zhou, C., Chen, X., Ma, X., & Zhao, S. (2011). Analysis and comparison of spatial interpolation methods for temperature data in Xinjiang Uygur Autonomous Region, China. Natural Science, 3(12), 999

Kurtzman, D., & Kadmon, R. (1999). Mapping of temperature variables in Israel: sa comparison of different interpolation methods. Climate Research, 13(1), 33–43.

How krigging works: ArcGIS for Desktop.
https://desktop.arcgis.com/en/arcmap/10.3/tools/spatial-analyst-toolbox/how-kriging-works.htm

Self-score

Category	Description	Points Possible	Score
Structural Elements	All elements of a lab report are included **(2 points each)**: Title, Notice: Dr. Bryan Runck, Author, Project Repository, Date, Abstract, Problem Statement, Input Data w/ tables, Methods w/ Data, Flow Diagrams, Results, Results Verification, Discussion and Conclusion, References in common format, Self-score	28	**28**
Clarity of Content	Each element above is executed at a professional level so that someone can understand the goal, data, methods, results, and their validity and implications in a 5 minute reading at a cursory-level, and in a 30 minute meeting at a deep level **(12 points)**. There is a clear connection from data to results to discussion and conclusion **(12 points)**.	24	**22**
Reproducibility	Results are completely reproducible by someone with basic GIS training. There is no ambiguity in data flow or rationale for data operations. Every step is documented and justified.	28	**25**
Verification	Results are correct in that they have been verified in comparison to some standard. The standard is clearly stated **(10 points)**, the method of comparison is clearly stated **(5 points)**, and the result of verification is clearly stated **(5 points)**.	20	**18**
		100	**93**