Lab 6: Capability Modelling for the growth of Tea Cultivation in the U.S.

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Q1. Tea, derived from *Camellia sinensis*, is one of the most widely consumed beverages worldwide. Coming from a country that is among the leading cultivators and exporters of tea, I have observed that tea cultivation is a challenging process that requires precise environmental conditions. Factors such as temperature, elevation, and specialized agricultural techniques like terrace farming play a crucial role in its successful growth.
In India, tea is primarily grown in hilly regions of the Northeast and the southern highlands, where the climate is significantly cooler compared to the mainland. These higher elevations, particularly in regions such as Assam, Darjeeling, and Nilgiris, provide ideal conditions for cultivating high-quality tea. Given these specific requirements, this study aims to analyze potential areas in the United States that could support tea cultivation.

A traditional tea farm in Darjeeling, India which has an average temperature of 13°C (55°F) and lies at an elevation of 2,045 meters (6,709 ft).

Q2. The objective of this study is to analyze and identify regions in the United States that have the environmental conditions necessary to support tea cultivation. This analysis considers key factors such as temperature, annual precipitation, elevation, and soil pH to determine areas that could be suitable for expanding tea farming. The demand for tea in the U.S. has been steadily growing, and while domestic production remains limited, the largest tea farm in the country is currently located in South Carolina. This suggests that commercial tea cultivation is viable in certain parts of the U.S., and this study aims to identify additional regions with similar potential.

Previous studies, such as "Effects of soil temperature and moisture on tea growth and functional quality parameters" (Ahmed et al., 2014) and "Exploring the potential for tea production in the United States" (Wheeler & Tai, 2019), have highlighted the crucial role of environmental factors in tea cultivation. These studies provide insights into the impact of temperature, precipitation, and soil composition on tea plant health and yield, reinforcing the importance of conducting a suitability analysis for tea farming in the U.S.

Through research on the ideal climate and environmental factors for tea cultivation, it became evident that certain southern states and parts of the western U.S. share similarities with established tea-growing regions in Asia. This model is designed to evaluate whether those areas possess the necessary conditions to sustain successful tea farming. While the analysis covers all 50 states, particular attention is given to southern states such as Alabama, Georgia, and South Carolina, as well as coastal regions in Oregon and Washington. By examining these locations, this study aims to determine whether they have the potential to support a domestic tea industry, offering opportunities for sustainable agriculture and economic expansion in the U.S.

Q3.

Variable	Layer Description	Data Source	Raster/Vector	Raster Cell Size	Date
US States Shapefile	U.S. States Shapefile for the 50 states	https://www.census.gov/geographies/mapping-files/time-series/geo/carto-boundary-file.html	Vector	N/A	2018
Temperature	Annual mean temperature for the 50 states in Celsius	https://databasin.org/datasets/35bed46ed5674db58d3a56fd3423a3f6/	Raster	1000	Jul-16
Precipitation	Annual mean precipitation for the 50 states in mm (measured from 1950-2000)	https://www.cec.org/north-american-environmental-atlas/precipitation-1950-2000-annual/	Raster	1000	2011
Soil pH	Mean pH reading for the topsoil from 0 to 14	https://www.arcgis.com/home/item.html?id=0961138215b8460e9f4e436d38c3b3b4	Raster	250	10/25/2023
Elevation	Digital elevation model for the 50 states in meters	https://www.earthenv.org/topography	Raster	1000	2018

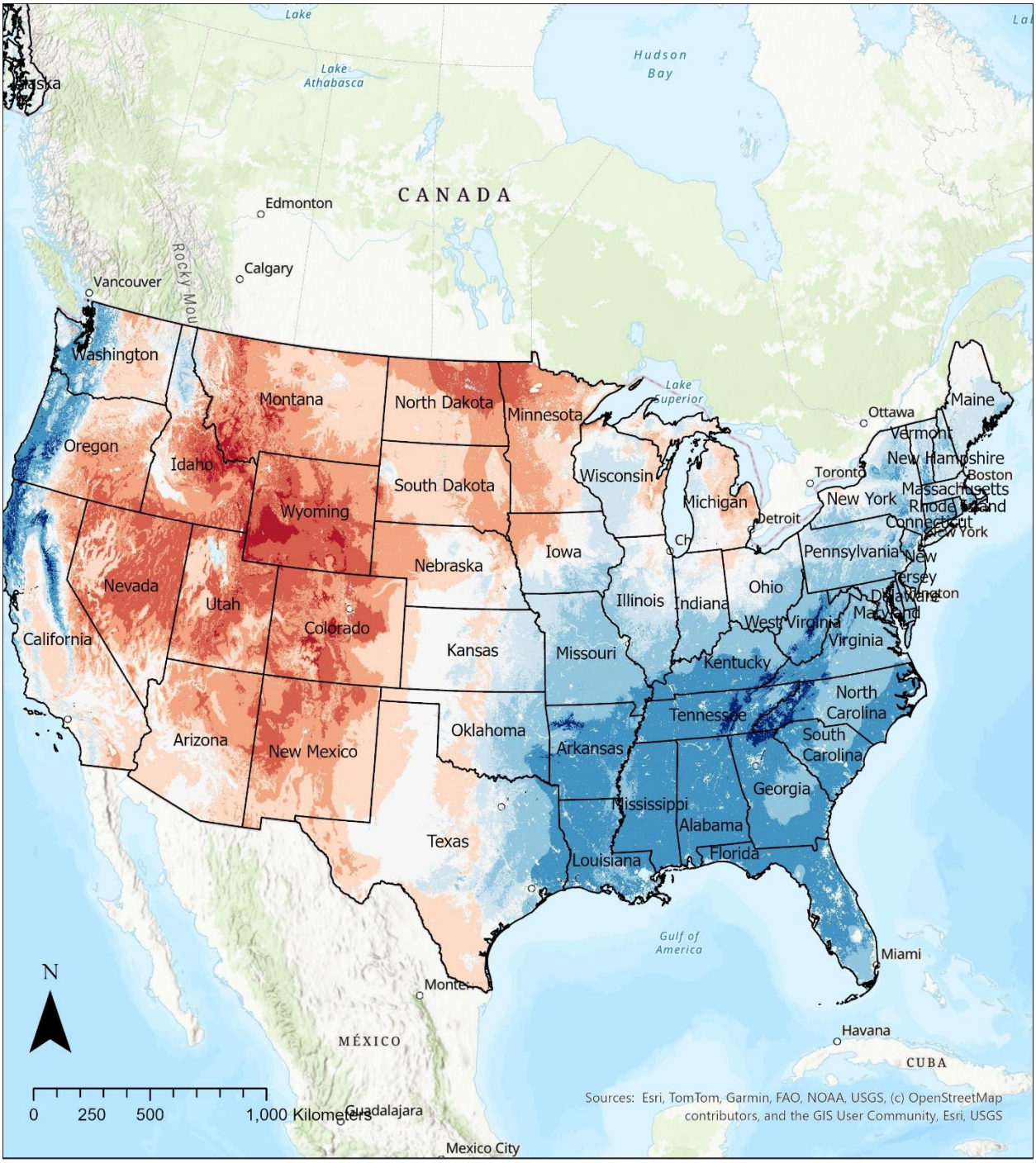
During model all the raster files were resampled to a cell size of 1000 x 1000, which was the extent of the smallest raster file i.e. 1 km.

Q4. For this analysis, I will be using an Ordinal Combination Addition of Factor model to evaluate the potential for tea cultivation in the United States. Each environmental factor—temperature, precipitation, soil pH, and elevation—will be classified into three categories: 1) Not Suitable, 2) Moderately Suitable, and 3) Highly Suitable, with numeric values of 1, 2, and 3 assigned, respectively.
After reclassification, the Raster Calculator will be used to sum the layers together, producing a final suitability score. The combined values will range from 4 (least suitable) to 12 (most suitable), indicating areas that offer the most favorable conditions for tea cultivation.

Q5. The parameters/factors chosen for modelling and their suitability ranges are as follows:

Variables/Suitability Parameters	Not Suitable : 1	Moderately Suitable : 2	Highly Suitable : 3
Temperature (Celsius)	<4°C	5°C-10°C	10°C-25.6°C
Annual Precipitation (mm)	<800mm & >2500mm	800mm-1200mm	1200mm-2500mm
Soil pH	<4 & >7.5	4.0-4.5 & 6.5-7.5	4.5-6.5
Elevation (m)	<0m & >1500m	0m-500m & 1000m-1500m	500m-1000m

Q6. The suitability model map that we obtained at the end of our analysis is:



Suitability Model

Value

4
5
6
7
8
9
10
11
12

Tea Cultivation Suitability Map of the U.S.:
This map represents the suitability model values for tea cultivation across the United States. The color gradient indicates different suitability levels, with values ranging from 4 to 12.

As the suitability model we chose was an Ordinal Combination Addition of Factors with 4 factors and each factor coded between 1 to 3 in terms of suitability, therefore with the following

combination we get a range between 4 and 12 with 4 being the least suitable condition for cultivation and 12 being the areas that are the most suitable for cultivation. Therefore, following this result, we can that all of the South-East states such as Tennessee, South Carolina, Georgia and Alabama are coded between 10-12, this indicates that these states are possess high suitability for cultivation with areas in Tennessee and North Carolina having areas coded as 12. This validates assumptions that areas in these regions are the most suitable for cultivation. In addition to these areas, the coastal parts of states such as Oregon and California also have a high component of suitability for cultivation.

While these scores are a combination of 4 environmental factors it can be expected that there will be very few areas coded as 12 i.e. regions having the perfect conditions for all parameters but there are a lot of regions, especially in the South-East of the country which are coded between 10-12 which would indicate areas having near to desired conditions for cultivation. In addition, areas in the coastal states of Oregon, Washington and California also emerge as areas of high suitability. While the Midwest of the country, which has the most agricultural land, has most of it's areas coded between 7-9 which would indicate moderate suitability. The output obtained has much more area than I predicted, as I believe zones of high suitability would appear as patches between states instead of being a wide distribution.

As visible from the map states such belonging to the Central Regions such as Wyoming, Utah and Colorado emerge as zones of low suitability along with states bordering with Canada such as North Dakota and Montana. This leads me to believe that the limiting variable would be Precipitation and Elevation for the suitability with Elevation being the more limiting variable. As these states are mountainous and are at a higher elevation than most of the South-East states while factors such as temperature and precipitation are not differing greatly between them.

To enhance the accuracy of visualization and analysis, factors in the suitability model could have been weighted to reflect their varying degrees of influence on environmental conditions. Since not all factors contribute equally to growth, assigning different weights would allow for a more realistic assessment of suitability. Certain environmental variables, such as temperature and precipitation, play a more critical role in tea cultivation than others, such as elevation. By applying a weighted overlay approach, the model could better represent the individual impact of each factor, leading to a more precise and interpretable suitability map.

References

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2. Wheeler, J. L., & Tai, Y. (2019). **Exploring the potential for tea production in the United States**. *Horticultural Reviews, 46*, 83-112. DOI: 10.1002/9781119625406.ch3

3. Soil Survey Staff, USDA NRCS. (2023). **Soil pH and Suitability for Crop Growth in the United States**. *National Cooperative Soil Survey*, Retrieved from https://websoilsurvey.sc.egov.usda.gov/.