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Where, Wheat, When?

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Historical and Modern Climate Envelopes for Cereal Grain Growth in Washington with a Discussion of Reintroduction of Wheat Agriculture in Western Washington

Abstract

Cereal grains have been grown in Washington since the early 20th century (National Association of Wheat Growers [NAWG], n.d.). However, cereal grains like wheat are primarily grown in Eastern Washington (Washington Grain Commission [WGC], n.d.). Climate change analysis allows us to project where suitable growth areas for cereal grains are historically and in modern times, as well as provide framework for new areas to grow wheat in. Interest in growing wheat in the Western side of the state has formed, mirroring the agricultural systems on the San Juan Islands in the early 1900s; wheat growth still exists in Western Washington, but at a miniscule scale compared to Eastern Washington (Historic Barns of the San Juan Islands [HBSJI], n.d.a). More analysis should be completed to determine if it is beneficial to grow cereal grains in a larger system in Western Washington.

Introduction

Wheat is a cereal grain/grass crop that holds enormous value in the agricultural field. Rooted in the beginning of sedentary agriculture fields, wheat allows for the creation of multiple baked goods including bread, desserts, pasta, and more (NAWG, n.d.). In the modern United States, wheat dominates as an agricultural commodity and allows for large consumptions of wheat-related products (NAWG, n.d.). Top-producing states include North Dakota and Kansas, but the majority of states grow some species of wheat (NAWG, n.d.).

Washington (WA) is one of these states that grow wheat, with winter wheat being the preferred wheat species to grow in WA, which is sown in the fall (WGC, n.d.). While wheat thrives within a specific range of precipitation, it seems to have found a happy home in Eastern Washington, where precipitation is on the dry side (WGC, n.d.). There are multiple methods used to reduce the impacts of large-scale, industrial, wheat cropping on this dry environment (WGC, n.d.).

To the West, mountains split Eastern and Western WA both physically and culturally (Selfa & Qazi, 2005). In modern times, it is rare for wheat to be grown in Western WA (Selfa & Qazi, 2005). Therefore, Eastern WA supplies food for the whole state and a few other states; Eastern WA subscribes to the traditional, industrial model of growing the crop, selling, processing, and finally reselling to consumers (Selfa & Qazi, 2005). Western WA prefers a more intimate setting, with farmers hosting markets to sell un-processed or minimally processed crops to consumers (Selfa & Qazi, 2005).

These two methodologies contradict each other, with expectations of food systems varying dramatically on both sides of the state (Selfa & Qazi, 2005). However, there has been a recent interest in bringing the wheat crop back to Western WA (Selfa & Qazi, 2005). While this will likely be small-scale and modeled after current farms in the area, it does have the potential to create a hybrid of both existing agriculture markets in the states (Selfa & Qazi, 2005).

History of Wheat in Washington: Changing Agricultural Practices Modeled by San Juan Islands

While Washington boasts a large, industrial farming system in the 21st century, this was not the method of farming practiced by the residents of the state originally (HBSJI, n.d.a). Before European colonizers came to WA, the indigenous peoples of the area practiced sustainable agriculture of native plants in order to feed themselves and sustain Washington's various ecosystems (HBSJI, n.d.a). The best example of the switch from indigenous practices to European practices occurred on the San Juan Islands (White, 1991).

On these islands, the Homestead Act of 1862 encouraged colonizers to come and settle in the area (HBSJI, n.d.a). This means that the head of the household, a European man, could earn 160 acres of land for him and his family in Washington to create the beginnings of industrial-style agriculture (HBSJI, n.d.a). Unfortunately for the indigenous peoples of WA, many fell ill from introduced diseases and the ecosystem they maintained carefully was being dismantled and changed radically (White, 1991).

However, this change of agriculture was not successful on these islands (HBSJI, n.d.a). Due to the changing political climate of the world in the 1940s and 1950s, many shifted their priorities (HBSJI, n.d.a). In addition, the islands would not sustain their agricultural fields as well as they had hoped, as the methods they used were not always conducive to the climate of Western Washington (White, 1991). Despite this, some did find success by adapting their methods properly to the wetter, milder climate of the San Juan Islands; moisture could be retained in this soil for long periods of time, reducing the need for irrigation and other watering (HBSJI, n.d.b.). This led to the dramatic deconstruction of the Homestead Act, with farm numbers and acreage reducing drastically (HBSJI, n.d.b.). Even other methods of farming, like dairy cows, cattle, and chickens, declined as people moved elsewhere or found another career to pursue (HBSJI, n.d.b.). Agriculture in Western Washington is entirely possible, but it requires a shift of priorities and methods in order to adapt to the wetter climate (compared to Eastern WA).

Eastern Washington: Climate and Agriculture

Because the region of Eastern WA sits in a pseudo-valley between the Rocky and Cascade Mountain Ranges, there is higher elevation and less moderate weather than in Western WA (Western Regional Climate Center [WRCC], n.d.). Areas in this region that are more elevated experience the least amount of precipitation, but Eastern WA, as a whole, does not receive large amounts of precipitation in a typical year (WRCC, n.d.). In addition, wind and weather is often blown from Western WA through the Cascades and into Eastern WA, though this is not a limitation to where wind comes from (WRCC, n.d.).

In the Central Basin region of Eastern WA, elevations are the lowest (WRCC, n.d.). This area does not receive large amounts of rainfall and oftentimes goes without during the summer seasons (WRCC, n.d.). The Central Basin begins in Ellensburg and extends South to the Oregon border, encompassing the majority of the South-Eastern part of the state (WRCC, n.d.). This is where most of the agricultural systems take place in the state and in Eastern Washington (WRCC, n.d.). Near Big Bend and Okanogan, we find higher rates of precipitation and elevation (WRCC, n.d.). This is an area of high wheat agricultural output (WRCC, n.d.).

There are numerous rivers that run through the state, but the largest is the Columbia (WRCC, n.d.). This river provides a large amount of water for both the agriculture and energy industries, as well as other industries (WRCC, n.d.). Dry-land agriculture occurs in areas like the Central Basin, due to the lack of precipitation and large need for irrigation in the area (WRCC, n.d.).

Agricultural Systems

Local markets are not as common in Eastern WA as they are in Western WA (Selfa & Qazi, 2005, p. 456). This is especially true for crops that are not as popular or organic-based (Selfa & Qazi, 2005, p. 456). However, there is also less demand for farmer’s markets in rural areas compared to urban areas; we can see this change in demand in Western WA as well as Eastern WA (Selfa & Qazi, 2005, p. 456). This is likely due to the large, industrialized agriculture system in Eastern WA that can be difficult to break out of (Selfa & Qazi, 2005, p. 455). Another factor that affects the upkeep of this industrial system are the high rates of poverty in Eastern and Central WA (Selfa & Qazi, 2005, p. 455). This makes it difficult for lare changes to occur when citizens are having trouble maintain consistency in their lives and current systems (Selfa & Qazi, 2005, p. 455).

This shows that while there is a local system in place, it may not necessarily support the people in that vicinity (Selfa & Qazi, 2005, p. 458). People who live in Eastern WA are therefore more inclined to believe that their local systems are county or state-wide, rather than within a certain mileage of their city or home (Selfa & Qazi, 2005, p. 458). This changes the definition of what a local system entails for citizens of Eastern WA, which is much different than what a local food system means for those who live in Western WA (Selfa & Qazi, 2005, p. 458).

Western Washington: Climate and Agriculture

West of the Cascade Range, we find mild summers and winters across the Puget Sound and Peninsula region (WRCC, n.d.). This is an area of both high and low elevation, with mountainous terrain near the ranges and low valleys near the Puget Sound (WRCC, n.d.). In addition, the whole area receives large amounts of precipitation compared to Eastern WA (WRCC, n.d.).

The main agricultural output from Western WA are flowers, berries, potatoes, and other similar crops (WRCC, n.d.). These crops must be able to grow in a wet area with mild temperatures, as it generally does not get extremely cold or extremely hot, but still experiences frost and cooler temperatures in the winter (WRCC, n.d.).

Agricultural Systems

For Western counties, many consumers and agriculture producers shared that, to them, the label of local is acceptable as long as the food comes from an adjacent area in the Puget Sound (Selfa & Qazi, 2005, p. 460). However, many people in this area also desire produce that “tastes good” and is fresh (Selfa & Qazi, 2005, p. 460). This means that food must be shifted quickly to various areas if it does not come from the immediate proximity, showcasing the potential for strong infrastructure (Selfa & Qazi, 2005).

While a “local” system is subjective, there is a pattern of increased diversity and therefore more desire for different kinds of crops in Western Washington compared to the East (Selfa & Qazi, 2005In addition, there are multiple local markets, including farmer's markets, that consumers can choose from, increasing the trust between producers and consumers (Selfa & Qazi, 2005).

Compared to the Eastern side of the state, consumers in the West have a stronger relationship with where their food comes from and who grew it (Selfa & Qazi, 2005). This could be part of their local system infrastructure that Eastern Washington has struggled to create. It is also important to note that despite this increased relationship, there is still a strong disconnect between those who never interact with producers of crops (Selfa & Qazi, 2005).

Data on agriculture in Western Washington can be limited, showcasing a need for more studies in this area (Hills et al., 2013). However, feedback from bakers in the Puget Sound region shows that some would prefer to buy flour and other baking materials from local areas in close proximity rather than importing from out-of-state or waiting for shipments from Eastern WA (Hills et al., 2013). This could provide a reason to create more cereal grain or wheat farms in Western WA (Hills et al., 2013).

GIS in Agriculture and Climate

Geographic Information Science or Systems (GIS) is a tool that helps people analyze, organize, and store spatial data electronically (ESRI, n.d.). GIS is one tool in a larger, geographical system, but proves especially useful when trying to understand patterns and spatial relationships across various landscapes (ESRI, n.d.). These patterns and relationships can then be displayed for a visual component, allowing anyone to understand and dissect these analyses (Hammonds, 2017).

For agriculture, GIS is especially useful when determining climate baselines and changes, landcover change, soil health, and more (Hammonds, 2017). It is also an excellent way to keep track of crop yields over time (Hammonds, 2017). This makes it valuable for not just private companies, but farmers hoping to keep track of their land and crops (Hammonds, 2017).

In terms of climate, GIS helps provide a system to understand climate systems and natural resources, as well as create future projections for climate, resources, and more (ESRI, 2010). These projections are especially useful when understanding how climate change may affect an area (ESRI, 2010). GIS also allows analysts to look at other climate conditions, like temperature and precipitation (ESRI, 2010). Overall, GIS is a powerful tool in order to understand multiple physical systems and provide an explanation for them (ESRI, n.d.).

Introduction to GIS Analysis

Climate Envelope for Cereal Grains Growth in Washington

My analysis using ArcGIS Pro aimed to determine both a modern and historical climate envelope for cereal grains in WA. This envelope could then be used to understand where cereal grains could have been grown in the past based on selected climate variables, as well as where they currently grow. This baseline could help when deciding if cereal grains could be grown in Western WA once more in specific locations, rather than almost exclusively in Eastern Washington.

Data for GIS Analysis

The climate variables for this analysis were provided by the University of Alberta, which span over multiple years. My historical climate years were 1901-1930 and the modern climate years were 1991-2020. This is the data used to make the envelope of suitability. The variables I used are:

- MAT
- MCMT
- MWMT
- MSP
- AHM
- DD.0

Without the abbreviations, these are:

- Mean Annual Temperature (Celsius)
- Mean Temperature of the Coldest Month (Celsius)
- Mean Temperature of the Warmest Month (Celsius)
- Mean Summer (May – Sep) Precipitation (mm)
- Annual Heat Moisture Index
- Degree Days Below 0 Celsius (chilling degree days)

It is important to note that I did not use projections, but recorded data.

The area of cereal grain growth is from the Washington State Department of Agriculture. The specific layer used is titled “Agricultural Land Use,” which was then trimmed down to only look at the cereal grains within ArcGIS Pro. To get the cell size, which is about 32 x 32 meters, and extent area, a DEM (Digital Elevation Model) layer was downloaded from the University of Alberta. The resolution of each cell was about 1 kilometer.

Methods for GIS Analysis

To begin, I had to convert the DEM raster into a point shapefile. This output can be used to provide XY coordinates of each point, which has a specific elevation value. This is what I input into the climate variable program. After receiving the CSV file of climate variables from the program, I converted this file to points of each variable I used. Then, I converted these points to the ESRI GRID format. This creates a usable raster for analysis. Then, I did any necessary pre-processing, which includes projecting the rasters into NAD 1983 StatePlane HARN Washington South FIPS 4602 (meters). To finish pre-processing, I converted indexes that had been multiplied by 10 into their actual Celsius temperature by dividing the raster values by 10.

By using the Zonal Statistics as Table tool, I determined the 90^{th} and 10^{th} percentile of each climate variable in order to create a minimum and maximum value for variables. Then, I looked for areas that fit where each of these variables overlap (between their 90^{th} and 10^{th} percentile values). This is where the envelope is actually occurring, as this would be an area that satisfies all necessary, recorded conditions of the historical climate envelope.

I repeated this process with the modern climate data, creating another raster output that has a modern climate envelope for cereal grains in WA. Then, I used the Raster Calculator tool to look for areas that satisfied each of these conditions within the 90^{th} and 10^{th} percentile using the historical parameters. This provides me with an envelope for historical data and an envelope for modern data. By subtracting the historical envelope from the modern one, I can determine where suitability has changed (lost, gain, or remained the same).

Both the modern and historical envelope are excellent in helping to determine areas that are eligible and preferable for cereal grain growth. The change raster, which is the final output, allows me to determine areas that are now suitable, used to be suitable, and have not changed over time.

Results from GIS Analysis

Based on the climate variables I chose, most of the suitable growth areas identified were in Eastern Washington. The historical envelope, from years 1901 – 1930, was more widespread than the modern historical envelope, which is from years 1991 – 2020. However, there are varying amounts of overlap between the two envelopes, indicating that the climate has not changed dramatically in certain areas of Eastern Washington. Much of the state remains unsuitable for cereal grain agriculture based on this analysis.

However, this analysis is limited and should not be used as the main indicator of suitable growth areas for cereal grains because it does not include every factor that may contribute to agricultural areas. Other factors could include things like soil quality and depth, irrigation, which season the crop is being sown in, and more.

As a disclaimer, the rasters are distorted because of the source data. This means that they have a somewhat mottled appearance, but this does not change the values of the rasters.

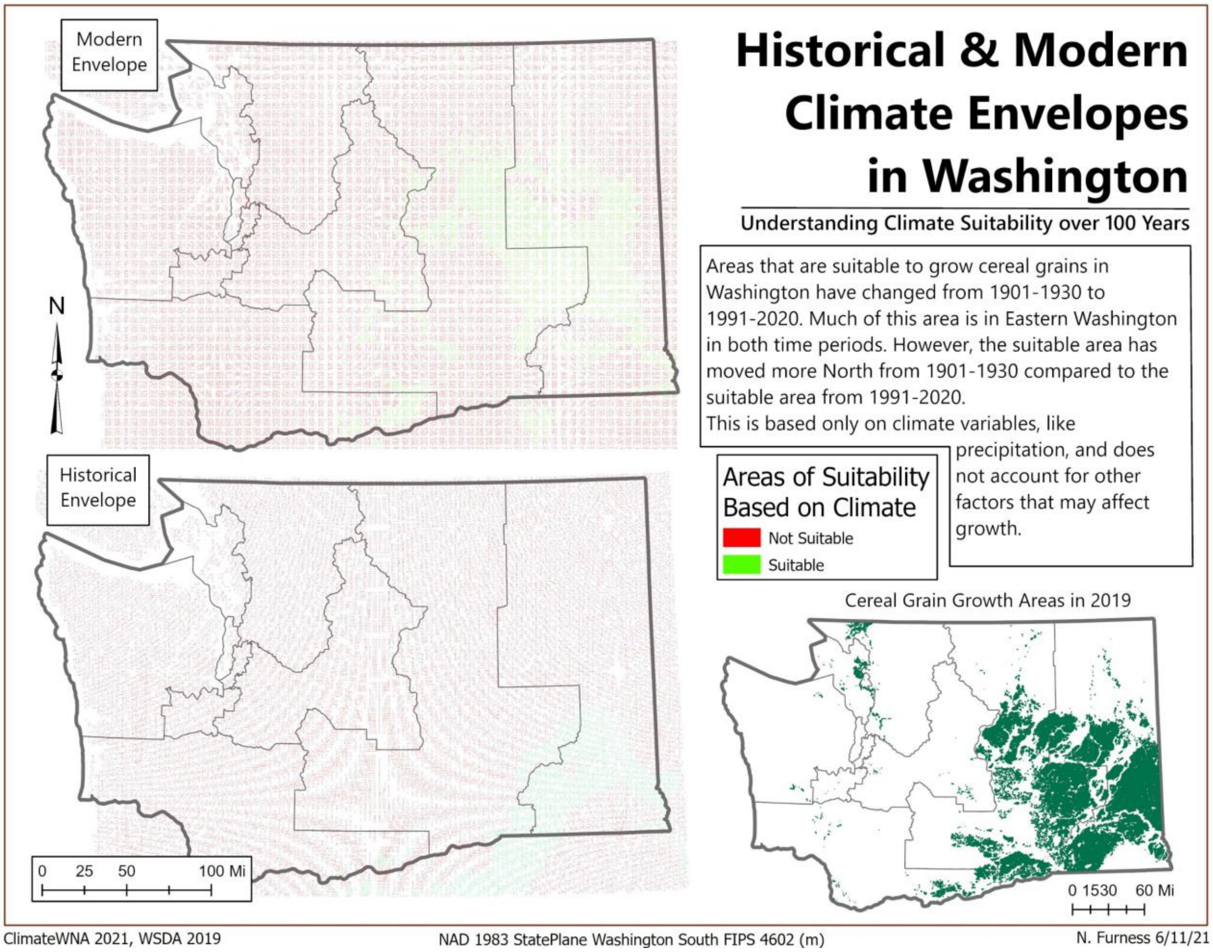

Figure 1: Map of Historical and Modern Climate Envelopes in Washington, with a mini-map of where cereal grains are currently grown (in 2019).

Combining these envelopes allowed me to discover where suitability was gained, lost, or had not changed over the last 100 years. Based on the climate variables, suitability has not changed dramatically during these time periods. Despite that, there was still change in suitability; suitability was gained in the Northeastern and North-central part of the state, centered around Eastern Washington. Washington remained suitable in the Southwest corner.

To create a more accurate assessment of suitable areas for cereal grains, other variables or factors would need to be included. Urban areas, as well as wildlife areas, would need to be assessed in order to determine areas that would make sense for agriculture based on human activity. Then, there are multiple other climate variables that could be used in a larger analysis, as well as factors mentioned before.

In addition, many of the climate variables did not change greatly over time. This means that there was not a large, drastic change of the envelope. This leads to our modern envelope, that has shifted and gained suitability but did not dramatically change over the last 100 years.

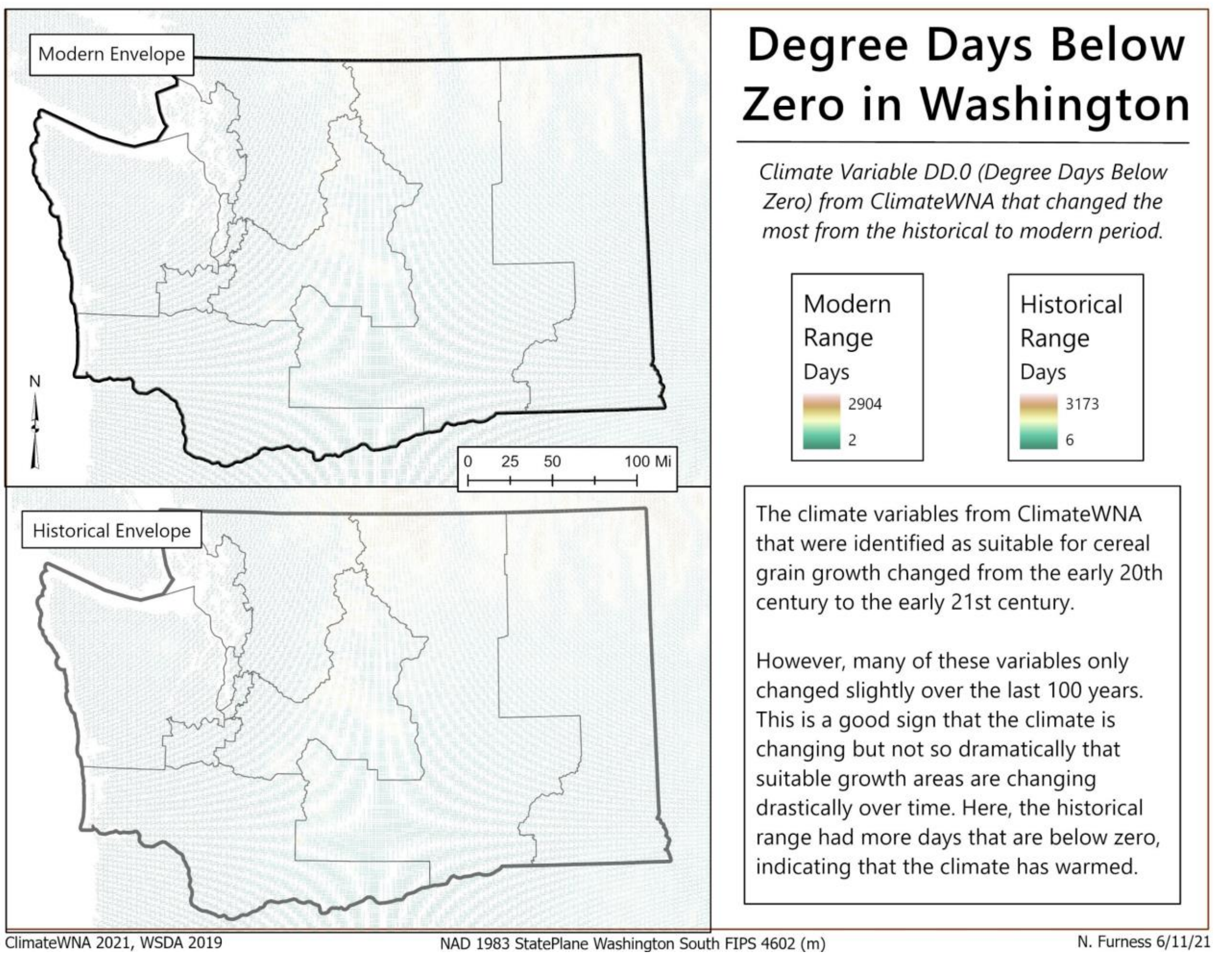

Figure 2: Map showing DD.0 climate variable.

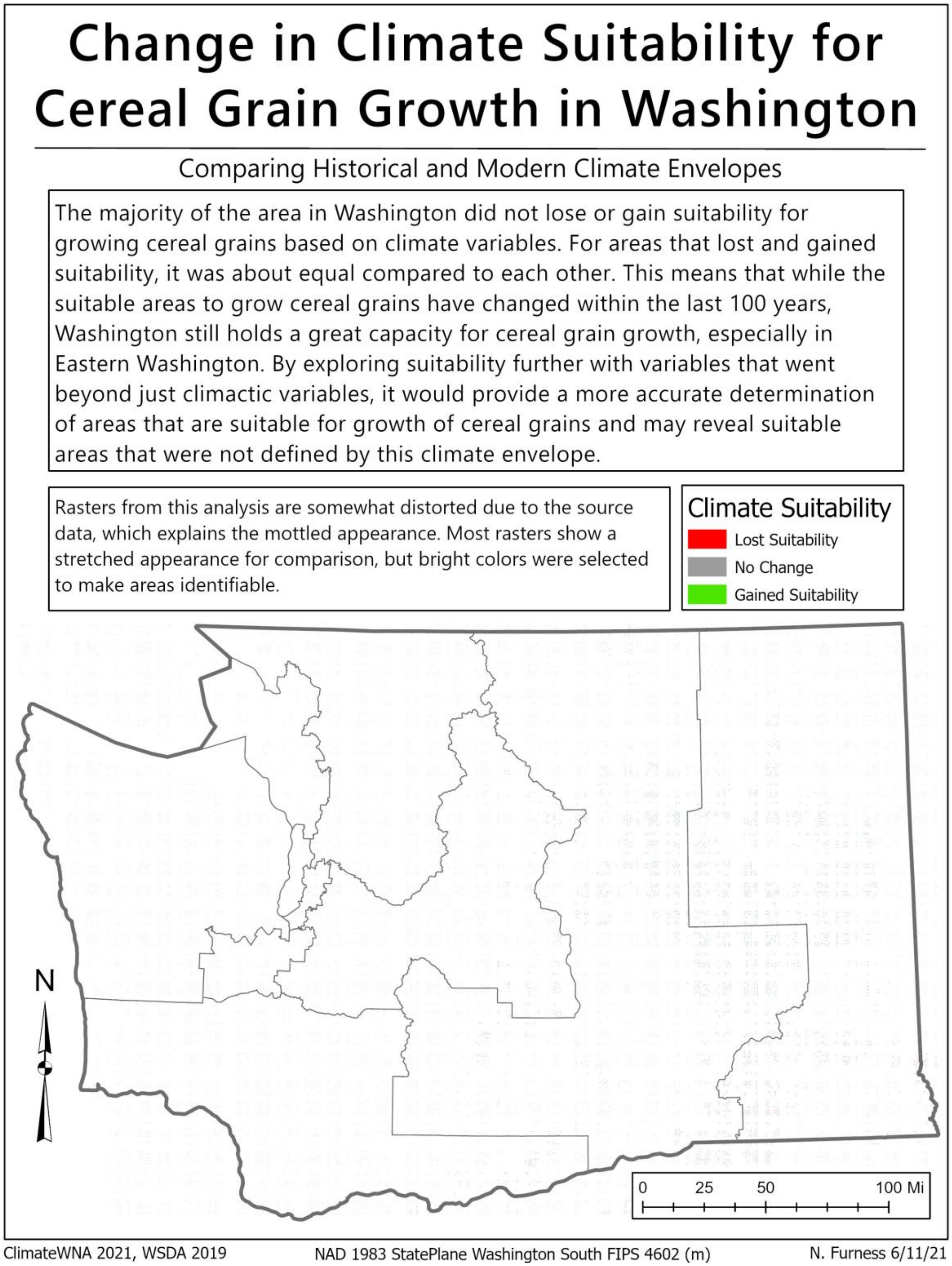

Figure 3: Final suitability change envelope from historical and modern time periods.

Because of this raster distortion, here is a snippet of an image that is showing the values more clearly:

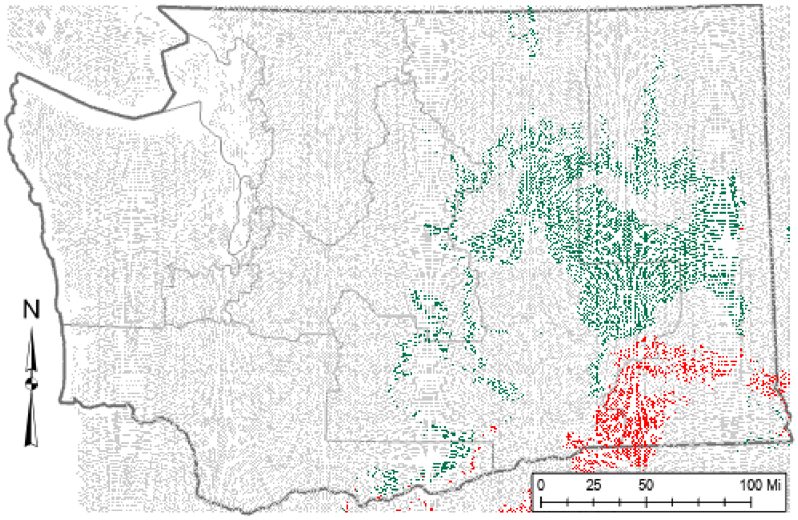

Figure 4: Snippet showing climate suitability more clearly.

Wheat Growth in Western Washington: Pipe Dream or Future Reality?

While it would be optimal to grow wheat wherever consumers desired it, that is not a plausible reality based on multiple factors like climate and social systems. Because Western WA is frequently focused on local systems, as well as processes and crops that are organic, reintroducing cereal grains to the Puget Sound area would have to be modeled differently than in Eastern Washington (Østergård, H., & Fontaine, L., 2006). One option for healthy cereal grain growth would be to practice non-industrial and sustainable agriculture (Østergård, H., & Fontaine, L., 2006).

A favorable option for a sustainable system would be to grow cereal grains that are perennials rather than annual crops that are sown and harvested yearly (Østergård, H., & Fontaine, L., 2006). By using perennials, or crops that last for multiple years, there will be less need for fertilizers or other nutrient-rich chemicals because there will be less disturbance within the soil (Østergård, H., & Fontaine, L., 2006). In addition, there are multiple ways to reduce weeds and other pests in a more natural manner that would be geared towards an organic, sustainable-minded market (Østergård, H., & Fontaine, L., 2006).

The ultimate goal of growing wheat in Western WA would be to increase access to nutritious food (Østergård, H., & Fontaine, L., 2006). Using a preferable system would be a bonus, although may be necessary for cereal grains to be grown in the West of the state and create a profit once more. In addition, creating this agricultural system in Western WA may be viewed as superfluous and costly compared to Eastern WA, especially because they have the capability to grow wheat for the state as they are currently doing (Østergård, H., & Fontaine, L., 2006). However, this is a valuable topic to explore in order to increase access to nutritional food and, if invested in properly, could create new jobs and a more active economy in the West (Østergård, H., & Fontaine, L., 2006).

Conclusion

Suitable areas for cereal grown growth based on climate has shifted over the last 100 years, but there are still large swaths of suitable area within Washington. Growing cereal grains like wheat are excellent for the economy of Washington, and could prove to be beneficial if it was more widespread rather than concentrated in Eastern WA (Selfa & Qazi, 2005). However, there are potential barriers to reintroducing these crops back in the West, like climate variables (Selfa & Qazi, 2005).

While it would be tricky to create a new agriculture system in Washington, it is a worthwhile endeavor in order to increase accessibility to healthy foods (Østergård, H., & Fontaine, L., 2006). It would also be beneficial for social aspects of the state, as it may create more unity between the Western and Eastern sides that are currently socially polarized (Selfa & Qazi, 2005). Even if this topic is explored with further analysis and deemed too expensive or not possible with the current climate and other physical and/or social barriers, food is a great unifier and may lead to more understanding between the various social groups of Washington.

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