Summer 2023

Against the Grain: A Mixed-Methods Analysis of the Effects of Climatic and Cultural Changes on Grain Agriculture in Northwest Washington

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By

Natalie Furness

Accepted in Partial Completion

of the Requirements for the Degree

Master of Arts

ADVISORY COMMITTEE

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Master's Thesis

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July 14, 2023

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A Thesis

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ABSTRACT

Local food movements are growing in popularity across the United States. Communities are interested in gaining more control over their food choices and food sources. Northwest Washington is one area where multiple communities are concerned with their food choices. Over the last 10 years, communities have invested increasing amounts of resources and energy in growing grains in San Juan, Skagit, and Whatcom counties rather than importing all their grain from Eastern Washington. This study examines how grain agriculture has changed both climatically and culturally in Northwest Washington since the late 19th century. To address this knowledge gap, climatic factors, like temperature, are analyzed to understand how the climate has changed and will change in the future. Further, this research explores the impact that local communities have on grain agriculture and local food systems in Northwest Washington. My findings suggest that community interest in local grains is increasing, leading to larger investment in local, small farms and businesses using local grains. However, many farmers and bakers are concerned with the longevity of this movement in the face of climate change, unsure of how production will be affected by changing temperatures and precipitation. This aligns with climatic models that suggest decreasing climatic suitability for optimal growth thresholds for winter wheat in Northwest Washington.

ACKNOWLEDGEMENTS

To begin, I would like to thank my committee members, Dr. Rossiter and Dr. Whitley, for their encouragement, patience, knowledge, and support over the last two years. Their interdisciplinary knowledge complemented my research and pushed me to consider multiple viewpoints. I would like to thank my family for their continued support. Without them, I would not have been able to even start this research, and I am eternally grateful for how loved I am. I would also like to thank all my friends for listening to me stress, enthuse, and cry along the way. You are all too kind and deserve many awards for your support.

To my wonderful friends, colleagues, and partners, Kailey and Lamai, I thank you a million times over for the bond we have formed during this program. It was more than I could ask for at that first all-advisee meeting to forge such valuable friendships with both of you. You are both an inspiration and have pushed me to be the best person and researcher I could be. I'd also like to thank Kenna, Colter, and Gary for their support, critiques, and encouragement as I wrapped up my final year.

Finally, I would like to express my deep gratitude and love for my advisor and chair, Dr. Aquila Flower, for everything she has done for me. When we met while I was an undergraduate, I was already blown away by your knowledge and support. The opportunity to work with you during my graduate studies has been the honor of my life. You have guided and supported me not only academically and professionally, but as a human being, and you have helped to shape me into who I am today. You are one of the most inspiring, dedicated, and fantastic people I have ever had the pleasure of meeting. All your students hit the jackpot when they get to work with you.

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1. INTRODUCTION

Across the United States, many communities are becoming increasingly interested in local food movements, which give individuals more control over what they eat and where their food comes from (Brinkley, 2017; Béné et al., 2019;). These movements emphasize better social connections between food producers and consumers within local communities, more resilient and sustainable agricultural systems, reduced greenhouse gas emissions related to food transportation, and increased economic activity that directly benefits people from the area rather than export-focused industrial operations (Selfa & Qazi, 2005; Brinkley, 2017; Béné et al., 2019). Local food movements have primarily focused on fruits, vegetables, and animal products, but some communities are starting to focus on cereal grains, especially wheat, as it is a staple crop that makes up a large part of many people's diets in the United States (Hills et al., 2013). One area that has shown interest in expanding local grain production systems in Northwest Washington (Hills et al., 2013).

Today, Eastern Washington is known as a prime grain growing region, but both Eastern and Western Washington were historically considered to be excellent for grain agriculture (Rowe, 2018). In the past few years, more farmers have started growing grains for food rather than feed on the western side of Washington state (Hills et al., 2013; Winkler et al., 2016). This represents a resurgence of traditional agricultural practices, as grains were a common part of the mix of crops grown on many farms in western Washington during the early 20th century (Winkler et al., 2016). As technology and American ideologies changed through both World Wars, it became less common for farmers to grow a mix of crops. Many chose to stop growing grains, as the Eastern side of the state began to focus on field crops. Since then, Northwest Washington, or San Juan, Skagit, and Whatcom counties, has not commonly produced grains on a large scale (Figure 1). Instead, many farmers have chosen to focus on fruits and vegetables (Dimitri et al., 2005).

Figure 1: Northwest Washington study area map.

Farmers' decisions about which crops to grow are based on a complex and interactive set of cultural and physical factors, including economic incentives, climatic and edaphic limitations of crops, and social norms. Both the mid-twentieth century decrease in grain agriculture and the recent resurgence of interest in grain crops in western Washington have likely occurred in response to some mix of changing cultural and/or climatic conditions. What physical, cultural, and historical factors that have contributed to both the past decrease and recent increase interest in grains in San Juan, Skagit, and Whatcom counties? To date, there has been no comprehensive analysis of these factors for this region. In addition, while the general trends in grain agriculture are known, there is no readily available source of detailed geospatial data that can be used to visualize and spatially analyze the changing extent and locations of grain agriculture over the 20th and early 21st centuries. This knowledge gap hampers our understanding of historical and current patterns of shifting agricultural grain production in the region.

The purpose of this study is to explore both the motivations of grain farmers and local bakers, as well as the biophysical suitability of local lands for grain agriculture. I used a mix of interviews, historical records, and spatial analyses of climate, soil, and land use zoning records to explore the socio-ecological factors influencing farmers' decisions regarding grain agriculture in San Juan, Skagit, and Whatcom counties. I focus specifically on wheat agriculture because wheat is a staple crop across the world, yet many Americans lack an understanding of both the importance and growth processes of wheat crops (Hills et al., 2012). Wheat research is popular, with researchers seeking to find ways to increase yields as climate change continues to alter the availability of food resources world-wide (Curtis & Halford, 2014).

The combination of both qualitative and quantitative analyses helps increase awareness and understanding of how and why the prevalence of grain farming has changed over the 20th and early 21st centuries. In a time of changing availability of staple crops, local food movements can be an integral part to countering food insecurity (Curtis & Halford, 2014). To understand both the physical extent and modern interest in grain growing, I pose the following questions:

1. How and why has the extent of grain agriculture changed in Northwest Washington since the early 20th century?
    a. Which areas of Northwest Washington have suitable climate and soil conditions for growing grains in Northwest Washington currently and in the future?
    b. Where and why are farmers bringing grain agriculture back to Northwest Washington?

1.1 History and Culture

Settlement in Northwest Washington was highly encouraged by the United States government in the late 1800s and early 1900s. As homesteading gained traction in the Western states, numerous handbooks and guides were published regarding settlement, farming, and culture, indicating a positive outlook on living west of the Cascades (Brockett, 1882). Becoming a farmer in Northwest Washington was considered an excellent career path because of the fertile lands, increasing yields, and potential profits (Brockett, 1882). Grains and fruits grew particularly well, generating a healthy profit for families (Brockett, 1882). These grain crops include barley, oats, wheat, and more.

Because of the push to settle in the West, the number of farms and families living in Northwest Washington grew quickly in the late 19th and early 20th centuries (Ellis, 1978). This activity stimulated the job market and economy, allowing for trade and sales (Ellis, 1978; Chiang & Reese, 2002; Daniels, 2005). This was especially successful when coupled with other profitable industries in the area, like logging (Ellis, 1978; Chiang & Reese, 2002; Daniels, 2005). For example, both the number and acreage of farms increased in the Skagit Valley through the 1950s (ECONorthwest, 2010). San Juan County followed suit, increasing nearly 50% over 40 years, from 338 farms in 1900 to 497 in 1940 (Dwyer, et al., 1956). In 1959, Whatcom County had around 3,000 farms with almost 12,000 acres of these farms being devoted to small grains (Dimitri et al., 2005). These farms were mostly small and under 1,000 acres, especially in San Juan County (Dwyer, et al., 1956).

However, due to the large amount of acreage being given away, lands became increasingly scarce (Ellis, 1978). These lands were also seen as less desirable because they were far away from existing infrastructure, like railroad lines (Allen, 1991; Sneddon, 2008; Edwards, 2009). Many families felt isolated from larger infrastructure and struggled with the difficulties of the new environment, lack of communal support, and farm life in general (Chiang & Reese, 2002; Dimitri et al., 2005). Adding to this difficulty, fraudulent claims were extremely common, so much of the land did not actually go to new farmers (Allen, 1991; Edwards, 2009). As a result, many families chose to either leave the area or stop farming altogether, with many men choosing to pursue work in other popular industries, like logging, to survive during the Great Depression (Dimitri et al., 2005).

Adding to the difficulties of homesteading in this region, technological advances during World War I and World War II introduced tools like motorized vehicles and chemical fertilizers (Winkler et al., 2016). These new technologies increased productivity and efficiency, especially on farms, but there were also repercussions from the United States investing in these technologies (Hendrickson & James, 2005). If farmers were interested in remaining small, using minimal technology, and not specializing on only a few, specific crops, they would often struggle to compete against the farms choosing to utilize new methods for farming (Dimitri et al., 2005; Hendrickson & James, 2005). Many farms were consolidated or simply disappeared as the focus of agriculture began to shift to trade and large amounts of sustenance (Dimitri et al., 2005; Hendrickson & James, 2005). This was supported by the United States government; Secretary of Agriculture Ezra Taft Benson, who assisted President Eisenhower, adamantly supported non-restricted agriculture, with a focus on separation from governmental-supported agricultural systems (Benson, 1962).

To meet the changing expectations of the United States agriculture industry, many farmers began to specialize in certain crops or livestock, rather than growing a little bit of everything (Winkler et al., 2016). This is especially evident when looking at livestock feed purchases: farmers in the beginning of the 20th century purchased considerably smaller amounts of grains to feed livestock than they did in the mid-20th century (Winkler et al., 2016). In addition, due to consolidation of grain agriculture to the Midwest, Washington farms tended to change their focus crops to vegetables or fruit, so grain growth decreased significantly (Meinken, 1953). For farmers that were extremely discouraged by this changing landscape, many chose to find careers in other industries, like logging, as the technological advances that hurt the farming industry in Northwest Washington boosted the logging industry (Chiang & Reese, 2002). One example of this is the railroads, as they allowed for easy transportation of the logged trees (Chiang & Reese, 2002). Many communities formed around logging mills, with most of the families in the community relying on the logging industry to support themselves (Daniels, 2005). This industry was not immune to the fluctuations in economy, but it was a viable alternative to growing crops in this region (Daniels, 2005). Interest in the logging industry combined with decreasing support from the U.S. government and technological advances, resulting in declining rates of homesteading and farming in Northwest Washington.

1.2 Climatic Needs of Wheat

Wheat (*Triticum aestivum L.*) grows best in specific climatic conditions. Wheat is sown either in the Fall or in the Spring, depending on the variety (Miles, 2009). Winter wheat is typically planted in the Fall, lying dormant in the winter after initial growth in Fall (Sacks et al., 2010). In Washington, a mid-latitude area, temperatures tend to be moderate, with wheat crops experiencing both cold and warm temperatures (Sloat et al., 2020). This works well with the necessary temperature requirements of wheat, as both cold and warm temperatures are required for growth (Wiersma et al., 2006).

Suitable ranges for precipitation and temperature have been quantified and published for both optimal growth and absolute thresholds (Sys et al., 1993; Porter & Gawith, 1999). Because wheat has a long history of cultivation, farmers and researchers alike have been able to explore how the crop responds to extreme temperatures, as well as how wheat yields are affected by specific temperatures and precipitation levels (Pomeroy & Fowler, 1973; Drozdov et al., 1984; Porter & Gawith, 1999). In addition, these researchers have analyzed how these outside factors affect the different growth stages of the crop, including photosynthesis rates (Hunt et al., 1991; Blum & Sinmena, 1994; Porter & Gawith, 1999). By combining this research, Porter & Gawith (1999) have provided a foundation for multiple researchers exploring the thresholds for both absolute and optimal wheat growth.

Temperature is a main limiting factor for growing cereal grains in Northwest Washington (Zabel & Mauser, 2014). Because of the mild seasons, it may not get warm enough to facilitate optimal growth in the spring and summer (Miles, 2009; Meints et al., 2021). In the winter, there is a risk of the temperature not getting cold enough for vernalization to occur in winter wheat (Miles, 2009; Meints et al., 2021). However, even if temperatures are not in optimal thresholds, wheat can still grow within the absolute thresholds (Sys et al., 1993; Sloat et al., 2020). The crop may not have as high of a yield if it was grown in perfect conditions, but it will grow (Sloat et al., 2020). Due to climate change, surface air temperature has increased, which may lead to higher rates of growth during the summer, but decreased chances of successful vernalization in the winter in Northwest Washington and nearby areas (Zhu et al., 2019).

The level of acceptable precipitation for growing wheat is variable, as many crops can receive necessary water through irrigation (Tavakkoli & Oweis, 2004). This means that while there are recommended amounts of water that wheat should receive, wheat agriculture is not entirely dependent on precipitation (Tavakkoli & Oweis, 2004). More water is needed while the crop is still growing, as warm, dry conditions are more suitable for the final stages of growth for wheat to reduce moisture-related disease (Sys et al., 1993). Because of the availability of irrigation, as well as precipitation levels that fall within an acceptable range for wheat, precipitation is not the main limiting factor to grow wheat in Northwest Washington.

1.3 Best Soils for Wheat

While wheat can be grown in most soils, loamy soils with good water drainage are considered excellent for growing wheat (Lemus, 2017). These are medium-grain soils that can hold their structure while also allowing for water absorption and drainage, as well as root development below-ground (Herbert, 1982; Griffee, 2017). Wheat can also grow well in moist soils, like clay-rich soils, but still needs some water drainage (Havilah, 2011). Therefore, soils that meet the criteria should be able to facilitate wheat growth.

2. METHODS

2.1 Study Area

San Juan, Skagit, and Whatcom Counties are in the northwestern part of Washington. Washington State's climate and ecology vary greatly across space (Washington Native Plant Society [WNPS], 2019). The Cascade Mountain Range creates a natural climatic divide between the western and eastern sides of the state through its influence on precipitation and wind direction. The Western side of the state has wet, mild winters and cooler summers with varying levels of precipitation (Western Regional Climate Center [WRCC], 1985). Within Washington State, precipitation is spatially variable due to the diverse local topography (Figure 2).

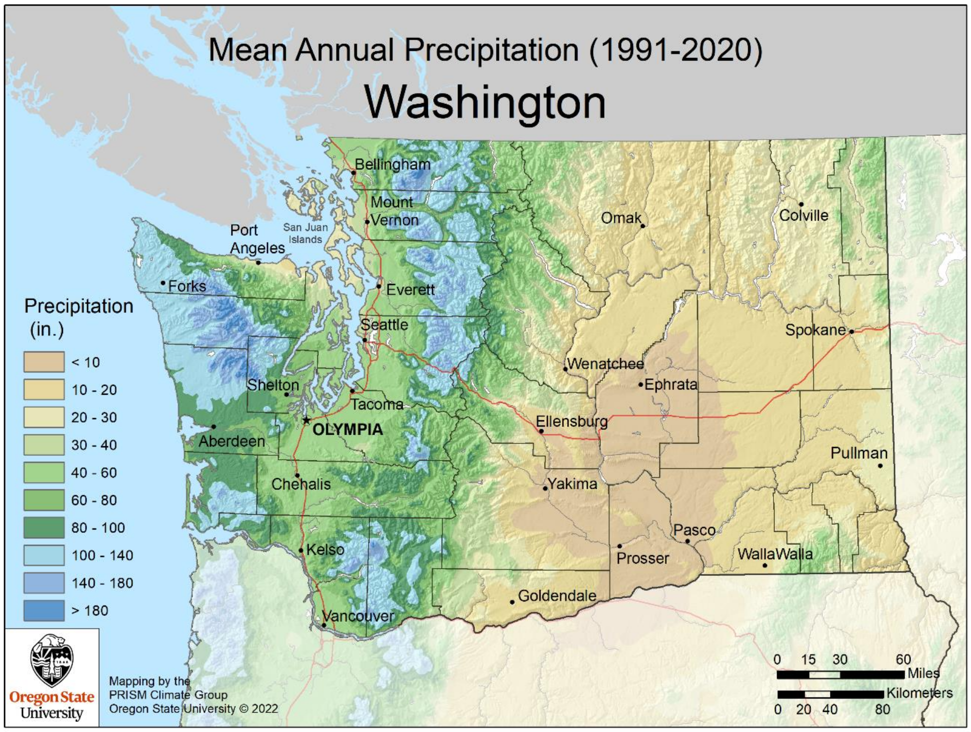

Figure 2: Map of the Mean Annual Precipitation from 1991 - 2020 in Washington State. Map from the PRISM Climate Group at Oregon State University (2022).

Much of Western Washington is within the Köppen climate types Csb and Cfb, which are both temperate coastal Mediterranean climate types (Chen & Chen, 2013; Peel et al., 2007; Pierson, 1947). This climate type causes Skagit, Whatcom, and San Juan counties to have milder winters with less precipitation and dry, warm summers (Figure 3) (LandScope Washington, n.d.c.; Peel et al., 2007). Temperatures are generally mild year-round, which is due to the proximity of the Pacific Ocean (Pierson, 1947). Precipitation is generally highest on the Olympic Peninsula, which boasts a temperate rainforest biome type. Areas like the San Juan Islands fall inside of the rain shadow cast by the Olympic Mountains, causing the islands to be drier than other neighboring counties despite also being in the Puget Trough ecoregion (WRCC, 1985).

Eastern Washington is semi-arid, with warm summers, cold winters, and less precipitation overall compared to Western Washington (WRCC, 1985; WNPS, 2019).

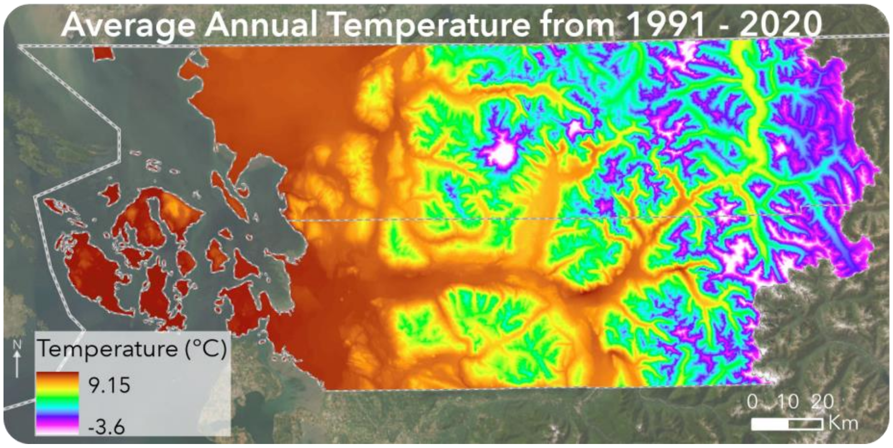

Figure 3: Map of average annual temperature from 1991 - 2020 in Northwest Washington.

Formed from glacial activity, rocks, and volcanic eruptions, soils in Washington State vary greatly in conjunction with topography (Sievers & Holtz, 1924; Hipple, 2011). Some of this variation includes soil content, parent material, and age of soil (Hipple, 2011). Due to the large variety of soil types, farmers cultivate numerous crops across the state (Hipple 2011, Awale et al., 2017). Unfortunately, soil health is declining from heavy agricultural usage, leading to efforts to increase soil health and alter agricultural practices and management (Awale et al., 2017).

2.2 Agricultural Census Data Collection

The United States Department of Agriculture National Agricultural Statistics Service (NASS) collects data from farmers across the country, documenting “land use and ownership, operator characteristics, production practices, income and expenditures” (NASS, n.d.). While originally the census of agriculture was taken with the decennial census, it was taken in years ending in the numbers 4 and 9 from 1954 - 1979 (United States Census Bureau [USCB], 2022). Now, the agricultural census is taken in years ending with the numbers 2 and 7 (USCB, 2022).

Unfortunately, the agricultural census is not always easily accessible for certain time periods and locations. Prior to 1925, only agricultural census bulletins are available for specific Washington counties, which were often preliminary results of the official census (USCB, 2021). These bulletins are also not always readily available, as they were often subject to change, correction, and incorporation into the main census at any time (USCB, 2021). For my research, I focused on 4 bulletin years with clear data that could be compared to the later census years (Table 1).

Census Years		**Bulletin Years**
• 1925	• 1974	• 1889
• 1930	• 1978	• 1900
• 1935	• 1982	• 1910
• 1940	• 1987	• 1920
• 1945	• 1992	
• 1950	• 1997	
• 1954	• 2002	
• 1959	• 2007	
• 1964	• 2012	
• 1969	• 2017	

Table 1: Census and bulletin years for the Census of Agriculture.

Historical agricultural censuses and bulletins, including the most recent agricultural census in 2017, are an excellent way to compare agriculture output across multiple years (NASS, n.d.). However, while these reports are designed to be comparable, there are a few data quality issues with census data (Steckel, 1991). These issues can include incorrect counting, accidental omission of farms or farmers, changing collection methods, and numerical errors from data input to analysis (Steckel, 1991). Thankfully, NASS is aware of these sources of errors, and releases a "coefficient of variance" to transparently share how reliable the census data is for that year (NASS, n.d.) This means that the data is accurate enough to use and compare across years.

I collected data from each census and bulletin year for Washington with the help of a research assistant and compiled the data in an Excel spreadsheet. To ensure consistency in analysis and data collection, specific cereal grain crops were included from each year (Table 2). As many cereal grain crops as possible were included to get a clearer picture of how many cereal grains are being grown in the study area.

Crops Included	Years
Barley, Buckwheat, Indian Corn, Oats, Rye, and Wheat	1889 to 1945
Barley, Buckwheat, Corn for grain, Oats, Rye, Triticale, and Wheat	1950 to 2017

Table 2: Crops included from the Census of Agriculture in my analysis.

2.4 Climatic Data Collection

To understand the climatic conditions that wheat has been grown in both historically and in modern times, high-resolution climate data were needed. I used the program ClimateNA (Climate North America) to download historical climatic data. ClimateNA statistically downscales PRISM data grids to a scale-free version that covers the entirety of North America (PRISM Climate Group, 2014; Wang et al., 2016). To capture changes across the 20th century, I downloaded 30-year climate Normals from 1901 – 1930, 1931 – 1960, 1961 – 1990, and 1991 – 2020. For future analysis, I downloaded a 20-year CMIP6 SSP126 projection from 2021 – 2040.

To get climate data, I input 30x30m resolution Digital Elevation Models (DEM) from the United States Geological Survey ([USGS], 2022) in ASCII format in the ClimateNA program.

The program used these elevation values to statistically downscale interpolated climate variable surfaces and output ASCII files including 60 monthly variables (Table 3). For my analysis, I focused on minimum and maximum temperature variables for each month.

Variables	**Meaning**
TMIN01 – TMIN12	Minimum temperature per given month
TMAX01 – TMAX01	Maximum temperature per given month
TAVE01 – TAVE12	Average temperature per given month

Table 3: ClimateNA Variables used for my climate analysis.

In addition, The National Oceanic and Atmospheric Administration (NOAA) climate stations collect climate data for public use. These stations vary in location, as well as length of collection history, but many collect precipitation and temperature information that is archived and can be accessed online (Matthew et al., 2012; Menne et al., 2012). The data is available in a U.S. Historical Climatology Network Monthly (USHCN) dataset, which was last updated in 2014 (Menne et al., 2009). The data within this dataset are minimum, maximum, and average temperature, as well as precipitation. The temperature data has been adjusted by NOAA for any non-climatic factors, like changing methods or instruments for data collection, that would affect the data collection or records from these stations, but the precipitation data has not. I collected data from three climate stations, which are Olga 2 SE, Blaine, and Sedro-Woolley. Data comes in a compressed TAR file, which I extracted and created excel spreadsheets of. From there, I could look at how many months fell into the optimum threshold for growing wheat, as well as understand precipitation and temperature changes over time.

2.5 Land Zoning and Soil Data Collection

Agriculture land zoning data is necessary to understand where wheat can be grown, as agriculture fields will not occur in areas that are not properly zoned. I used an agriculture zoning shapefile created by Dr. Aquila Flower in the Salish Sea Atlas (2021) to understand which areas have been zoned properly for wheat growth. The zoning data for Northwest Washington is collected from the Washington State Department of Commerce's Puget Sound Mapping Project (2018). Dr. Flower (2021) selected the "Primary Agricultural" and "Other Active Agricultural" zoning classes.

I also collected soil data to continue refining the climatic suitability envelopes for wheat. Using a soil shapefile from The Soil Survey Geographic Database (SSURGO), I could identify soils that were loam or clay-based, as well as classified as possible agricultural land. This database is maintained by the Natural Resources Conservation Service (2022).

2.6 Census analysis

I created graph visualizations of the collected census records using Microsoft Excel with the goal of exploring the changing landscape of grain farms and output over time. I wanted to understand how cereal grain output (bushels) had changed, as well as how both the number of farms growing grains and acres of grain sowed were different across time. I chose to normalize the data in multiple ways so different variables could be compared across time and counties (Borkin et al., 2019).

For comparison across time and the three counties, I looked at multiple normalizations that include acres of cereals as a percent of total county-specific farm acres and total acres of cereals in the state, bushels of grain harvested per number of farms in a county, and percentage of grain farms within total farms. I also looked at wheat, barley, and oat bushels per acre of farmland for each county.

2.7 National Oceanic and Atmospheric Administration Climate Station Analysis

I created chart visualizations to understand how often specific areas in the study area had been within the optimal temperature threshold for growing wheat. Before I began analysis, I converted the data into Celsius by dividing the precipitation values by 10 and temperature values by 100, as values were listed in tenths of millimeters and hundredths of a degree Celsius respectively.

To begin analysis, I counted the number of months that satisfied the optimal growth temperatures within the warm growing season. The warm growing season I selected for winter wheat is between February and August. The vernalization process during winter months is not included in this analysis because winter temperatures generally do not limit growth of winter wheat in Northwest Washington due to the mild climate; it will not be too hot or too cold for vernalization to occur. Therefore, it is assumed that vernalization will take place and allow wheat growth during the warm season.

Once I had the number of months that satisfied the optimal growth threshold, I created a percentage of how many months satisfied those conditions (Equation 1). From this dataset, I created a simple linear regression model for the monthly maximum and minimum temperatures for each year, as well as the percentage of days satisfying optimal conditions for each year to quantify any trends over time in the data. I excluded any years with data that is missing from more than half of the year. I did this analysis by utilizing the linear model function in the RStudio version 2023.03.01.

$$\frac{Number\ of\ days\ within\ optimal\ growth\ temperature\ threshold}{Total\ number\ of\ days\ in\ warm\ growing\ season} * 100$$

Equation 1: Percentage of days satisfying optimal conditions for each year.

2.8 Climate analysis

To begin, all ASCII files were copied into ArcGIS Pro. I converted these ASCII files to Esri GRID rasters at 30x30 meter resolution. Afterwards, I projected the rasters to NAD 1983 UTM Zone 10N from WGS 1984. Then, as the rasters were in Celsius * 10, I divided the values of each raster by 10 to get the temperatures back into Celsius. To complete pre-processing, I clipped the rasters to the study area (Figure 4).

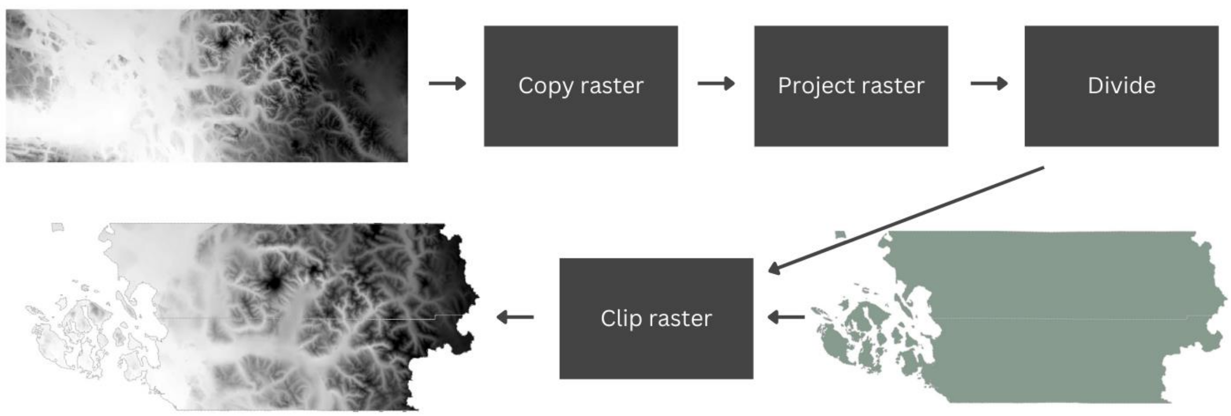

Figure 1: Pre-processing diagram.

After pre-processing, I used Raster Calculator to identify areas that met either suitable conditions, optimal conditions, or both. I identified these thresholds through literature review of previously published experimental and correlative analyses of the relationship between wheat growth rate of the entire plant measured by °C d^{-1} and weather or climatic conditions. From this literature, I determined suitable conditions for wheat to be between 0°C and 37°C (Sys et al., 1993; Porter & Gawith, 1999; Zabel et al., 2014; Griffee, 2017). Optimum conditions for growth are between 17°C and 23°C (Porter & Gawith, 1999). I used climate data to determine temperature suitability for wheat growth (Sacks et al., 2010; Sloat et al., 2020). By identifying thresholds of both suitable and optimal temperature for wheat growth, I was able to look for areas that satisfied one or both of those conditions, which is also known as multi-criteria evaluation (MCE) (Carver, 1991; Mustafa et al., 2011). When a condition was met, the value of

1 was assigned. If it was not met, then a value of 0 was assigned. These created envelopes of areas that have optimum conditions and areas that have suitable conditions (Figure 5).

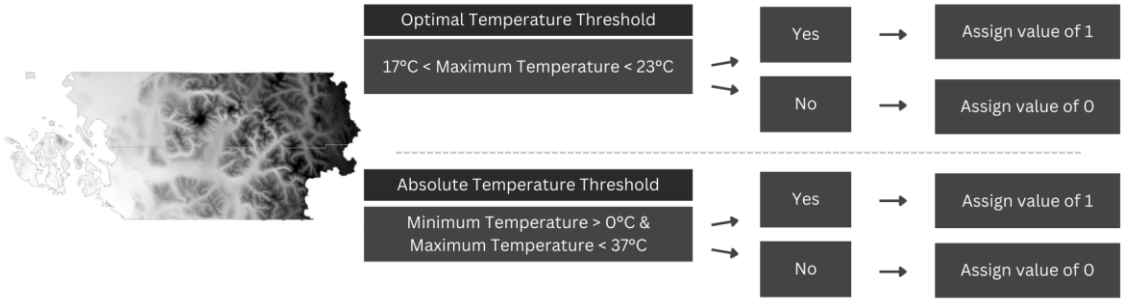

Figure 2: Temperature thresholds for absolute and optimal climatic growing envelopes.

To create a final optimum score, I assigned a value of 1 to places where both the suitable and optimum envelopes are 1 (or meeting the conditions). Altogether, these rasters were combined to create a final envelope model that returns a count of the number of months that hold optimum temperature conditions for wheat growth in each 30x30 meter cell of the study region (Figure 6). To count the number of months that are suitable for growth, I summed the climatic suitability envelopes for each month to create a count. I repeated this process for each climate normal and year.

Figure 3: Example of binary temperature classification.

Finally, to understand how areas of climatic suitability have changed compared to the present, I subtracted the results for each normal from the 1991 – 2020 normal. These rasters show the change from one normal period to the most modern period, which could be loss or gain of climatic suitability. The goal of this change analysis is to understand how growing season length has changed over time.

2.8.1 Refining Climatic Suitability

In addition to the temperature suitability to grow wheat, ideal soil types and areas zoned for agriculture should be considered. This allows for a holistic approach to understanding the most suitable areas for crop growth, as these factors all affect wheat crops. To do this, I overlaid agriculture-zoned areas in the study area with areas that satisfy the optimal conditions for temperature. Following that, I intersected the output with soil types that are loam or clay-based to identify areas of highest suitability (Figure 7).

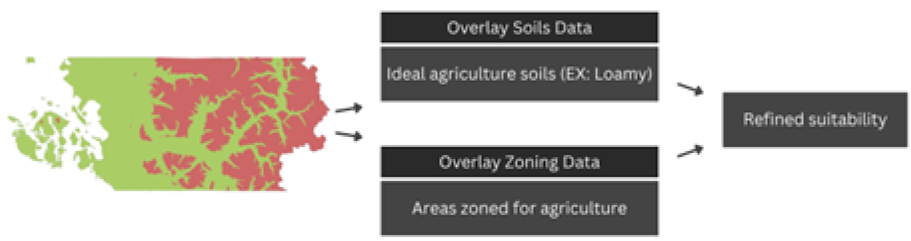

Figure 4: Model of refining climatic suitability of optimal growth thresholds.

2.9 Interviews

Using a mixture of intentional and snowball sampling, I interviewed farmers who grow grains and bakers or millers who use local grains in Northwest Washington. Face-to-face or online interviews occurred after selection of interviewees that met a certain criterion. This criterion includes grain farmers in San Juan, Skagit, or Whatcom counties, as well as bakers or millers who utilize grains from the study area. Interviewees were identified either from internet research, which is intentional sampling, or from snowball sampling, where an interviewee is recommended to me by a contact (Parker et al., 2019).

I spoke to seven farmers, bakers, and millers, with one interviewee being both a farmer and a baker. These interviews were semi-structured to allow interviewees to answer my questions in a conversational way (Couzy & Dockes, 2008; Horseman et al., 2014). This interview style also allows the interviewee to engage with me on topics that are important to them but may not be a direct answer to one of my interview questions (Couzy & Dockes, 2008; Horseman et al., 2014). This loose structure may also make the interviewee feel more comfortable speaking with me.

These interviews were meant to understand the interviewees' motivations and processes. There will be no identifiable information about them shared to increase the likelihood that interviewees will speak candidly (Horseman et al., 2014). In addition, interview questions started broad to help build a relationship with interviewees before they became more focused and specific (Horseman et al., 2014). Interviews were transcribed using Rev. From these transcriptions, I selected quotes that represent common themes from the interviewees (Weston et al., 2001; Couzy & Dockes, 2008; Basurto & Speer, 2012; Horseman et al., 2014; Morse et al., 2014; Ramney et al., 2015).

The interview questions are available in the Appendix.

3. RESULTS

3.1 Changes in cereal grain acreage

The acres of cereal per farm in each county has been variable since 1900 but shows an overall decline (Figure 8). Almost 25% of crop acreage was cereal grains on average in Skagit County in 1900, with only about 10% in 2017. Whatcom County had over 5% of all crop acreage prior to 1960, declining and remaining around 2.5% of all crop acreage until 1997, when it dipped to almost 0%. San Juan County had over 5% of crop acreage being cereal grains in 1920, declining to around 2.5% through a large portion of the 20th century. In 1978, growth rose to 5% before a major decline to minimal amounts of grain being grown. There has been a recent uptick in cereal grains on farms in San Juan County since 2012.

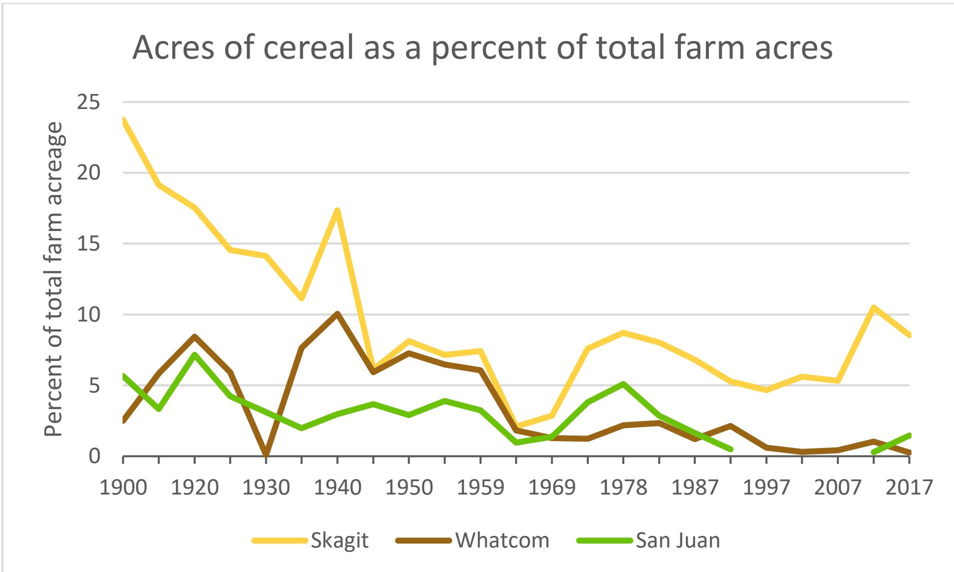

Figure 5: Chart showing acres of cereal grains as a percent of all farm acres in a county.

Cereal grains grown in Northwest Washington have always been a small percentage of all cereal grains grown in Washington state. In 1900, Skagit County cereal grains made up almost 1.5% of all cereal grains in the state. Whatcom County and San Juan County both represented less than 1% of the cereal grains within the state. This percentage fluctuated since then, but overall has declined since 1900, with a sharp decline occurring around 1960. There was a small uptick in growth in 2007, but all counties represent less than 1% of state cereal grains in 2012 (Figure 9).

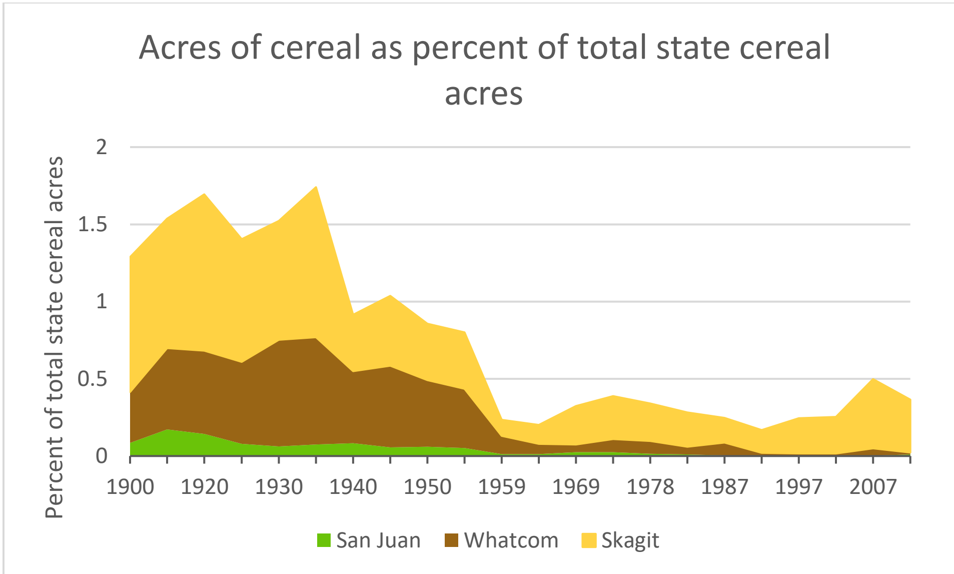

Figure 6: Chart showing acres of cereal grains as a percent of all cereal grain acres in Washington state.

3.2 Changes in cereal grain farms

In addition to changing cereal grain acreage, the number of farms that grow grains and output of bushels per farm have changed since the early 20th century (Figure 10). The percentage of grain farms within all farms has declined. For example, Whatcom County went from around 7% grain farms in 1925 to less than 1% in 2012.

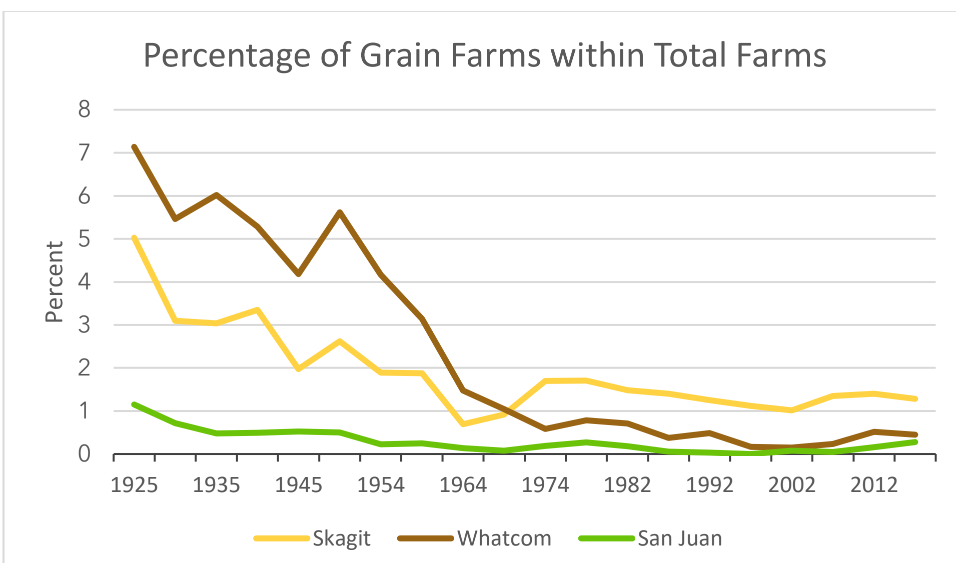

Figure 7: Chart showing the percentage of farms that grow grains out of all farms per county.

When averaging cereal grain output over all farms in a county, the bushels per farm have declined as well (Figure 11). Skagit County has declined since 1900, with sharp decreases around 1910 and again around 1960. Since then, grain output has fluctuated in the county, with the county producing a little over 500 bushels per farm in 2017. Whatcom and San Juan County output also decreased around 1960. San Juan County also fluctuated, increasing to around 250 bushels per farm after 1969, but decreased to 0 until the 2012 census. Whatcom County output generally varied between 50 – 200 bushels per farm since the 1960 decrease.

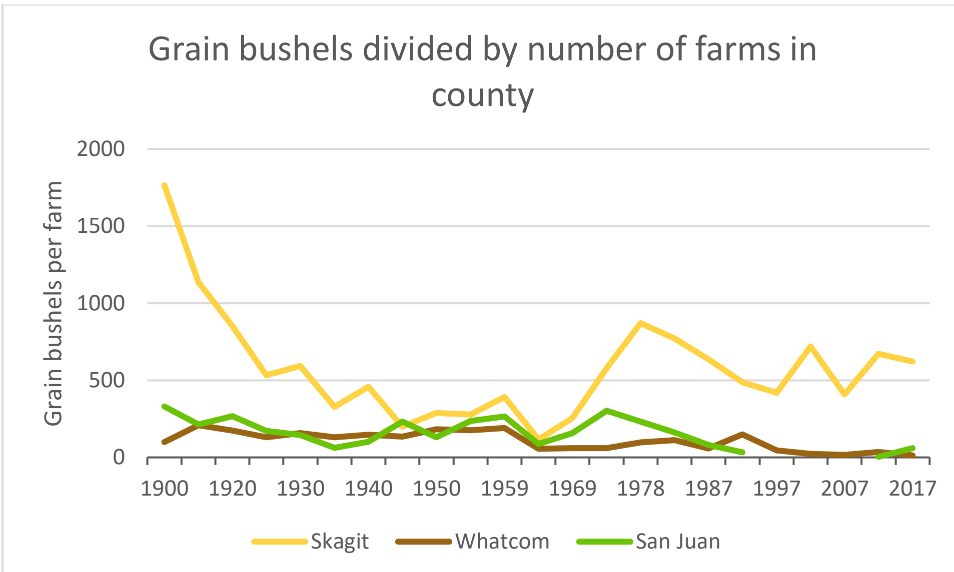

Figure 8: Chart showing the number of bushels grown at each farm on average per county.

3.3 Climate Station Temperature Changes

Increasing temperatures are a symptom of climate change, as temperature has increased globally and is projected to continue this increase in multiple future climate scenarios (Huppert et al., 2009; Intergovernmental Panel on Climate Change [IPCC], 2023). While the effects of rising temperatures are different across ecosystems and species, it does have an impact on suitable habitat distribution and the potential range for many species, including agricultural crops such as cereal grains (Harsch et al., 2017; IPCC, 2023). Since 1900, temperatures have changed in Northwest Washington. Using climate stations in Olga, Blaine, and Sedro-Woolley, both maximum and minimum temperature records were analyzed to quantify local trends in temperature over the last 120 – 123 years.

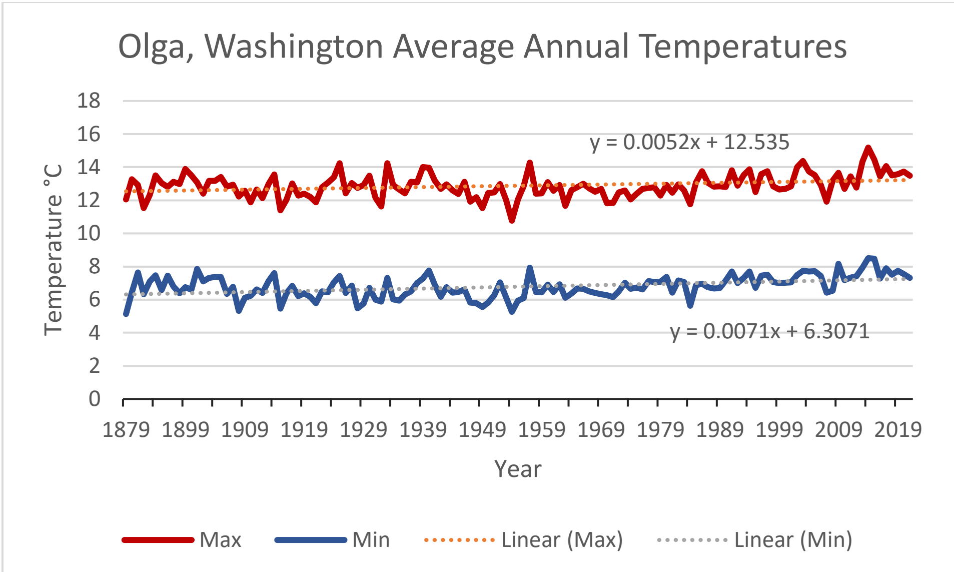

Figure 9: Average annual minimum and maximum temperatures at the Olga 2 station in San Juan County.

At the Olga 2 climate station in Olga, Washington, both maximum and minimum temperature have increased from 1879 - 2022 (Figure 12). This is a positive yearly trend of 0.0052 °C for maximum temperature and a positive yearly trend of 0.0071 °C for minimum temperature, both with a coefficient significance level of $p < 0.05$.

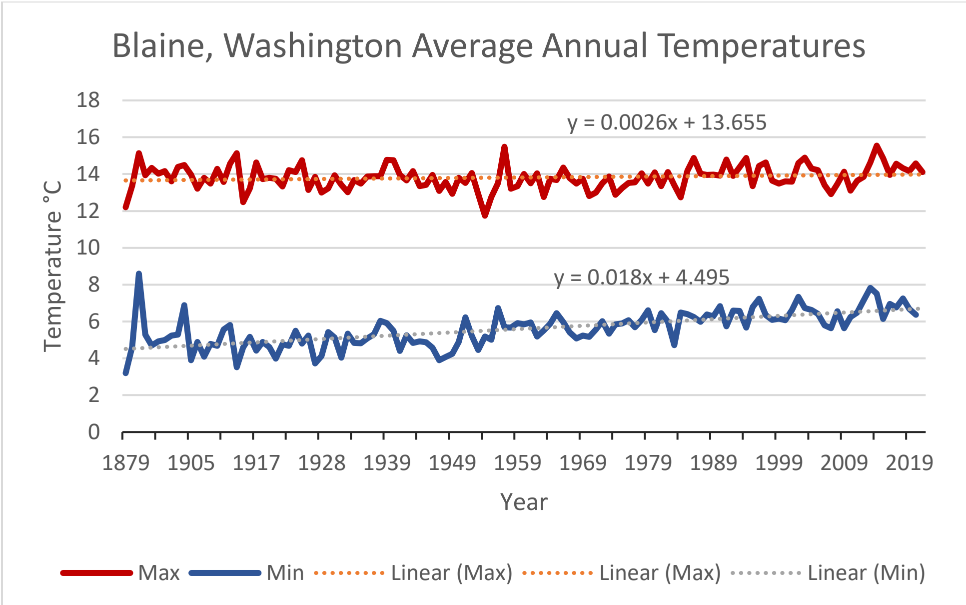

Figure 10: Minimum and maximum temperatures at the Blaine station in Whatcom County.

At the Blaine climate station in Blaine, Washington, maximum and minimum temperature have increased from 1879 - 2022 (Figure 13). This is a positive yearly trend of 0.0026 °C for maximum temperature and a positive yearly trend of 0.018 °C for minimum temperature. The maximum temperature is not statistically significant. The minimum temperature has a coefficient significance level of $p < 0.05$.

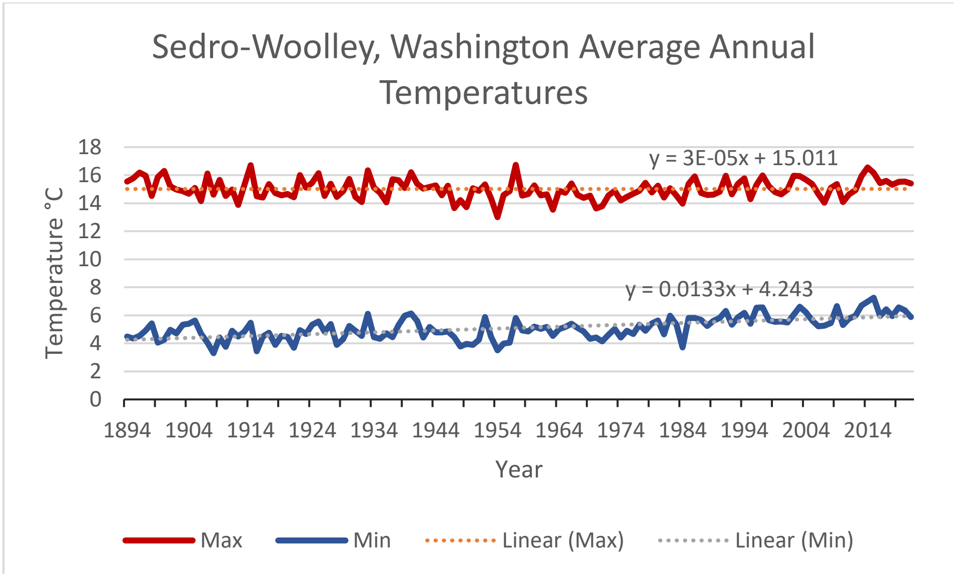

Figure 11: Minimum and maximum temperatures at the Sedro-Woolley station in Skagit County.

At the Sedro-Woolley climate station in Sedro-Woolley, Washington, maximum temperature has decreased, and minimum temperature has increased from 1894 - 2022 (Figure 14). Maximum temperature decreased at a slow, gradual pace, so change has been minimal. This is a negative yearly trend of 0.00003 °C for maximum temperature and a positive yearly trend of 0.0133 °C for minimum temperature. The maximum temperature is not statistically significant. The minimum temperature has a coefficient significance level of $p < 0.05$.

3.3.1 Precipitation

Precipitation has fluctuated since 1890, with Skagit County receiving the most precipitation and San Juan County receiving the least (Figure 15). Olga receives about 61.4 millimeters of precipitation each year on average, Blaine receives about 86.9 millimeters of precipitation, and Sedro-Woolley receives about 98.5 millimeters on average. Blaine has a positive yearly trend of 0.0043 mm for average total annual precipitation. Sedro-Woolley has a positive yearly trend of 0.0344 mm for average total annual precipitation. Olga is the only climate station with a negative yearly trend of 0.0208 mm for average total annual precipitation. None of the precipitation levels for each station are statistically significant.

This shows a range of acceptable precipitation levels for growing cereal grains. However, this data has not been adjusted to account for anything that would affect these records like the temperature data has been, so a cautious approach to identifying patterns should be used. It is also important to note that irrigation can fill in gaps if there is not enough precipitation in a year for proper crop growth although this is only possible in areas with suitable irrigation infrastructure.

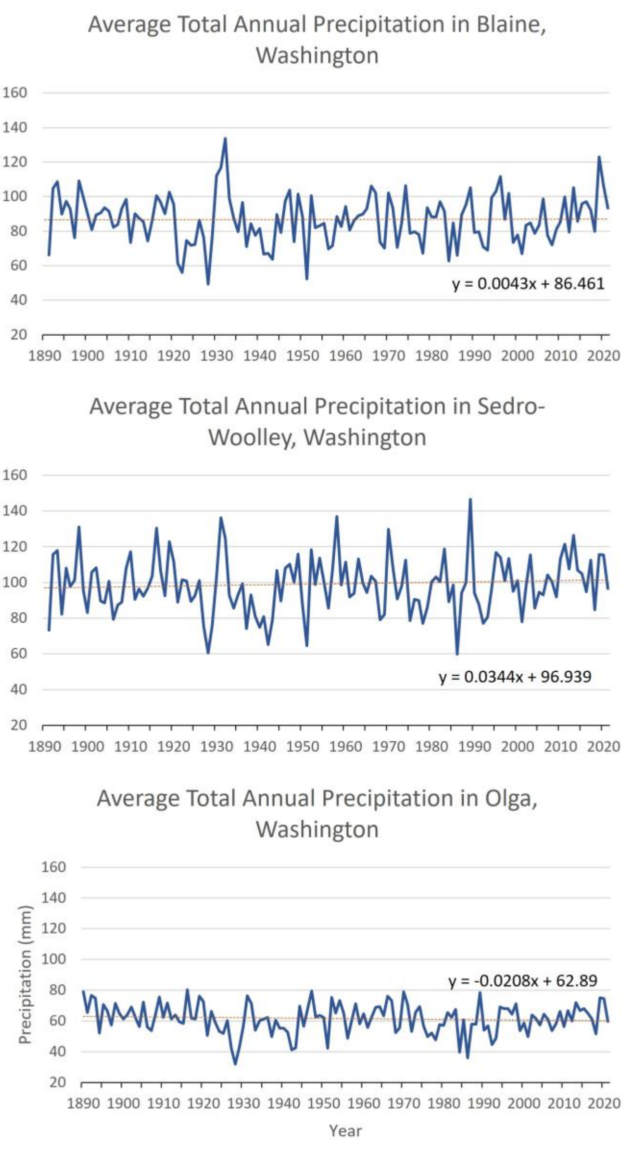

Figure 12: Average annual precipitation of climate stations in Olga, Blaine, and Sedro-Woolley, Washington.

3.4 Shifting temperature suitability for Wheat

Specific areas within optimal thresholds for growing wheat shifted in Northwest Washington since 1900. Despite this shift, each 30-year climate normal period had at least some areas with five months of optimal temperatures for wheat, though the location of the longest suitable growing season conditions shifted over time (Figure 16). The 1931 – 1960 period is the most different from current conditions, with the most suitable areas being directly by the coast. It also had less areas that met optimal conditions on the mainland than the other time periods, with 5 months of optimal climatic suitability occurring on almost all parts of the San Juan Islands.

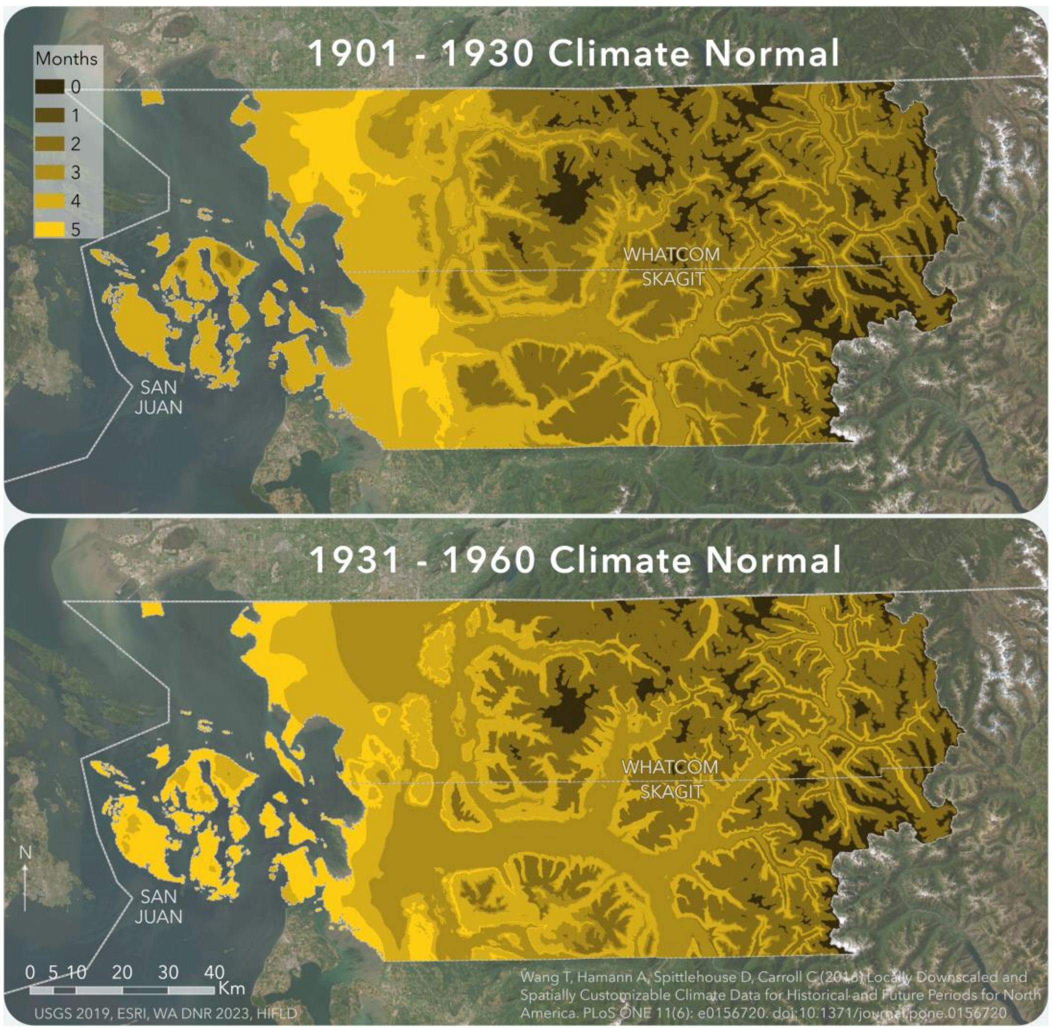

Figure 13: Maps showing number of months with optimal conditions in Northwest Washington from 1901 - 1930 and 1931 - 1960.

The 1961 – 1990 and 1991 – 2020 periods are somewhat similar, with the longest period of optimal temperatures occurring inland of the Salish Sea (Figure 17). However, there is a shift in areas with mid-range climatic suitability around 2-3 months. Within the 5-month optimal climatic suitability period, there are less areas with 0 months of optimal climatic suitability. Instead, many areas have at least 1 month of optimal climatic suitability. This change is not dramatic but shows that it may become easier to grow grains in this area based on temperature alone.

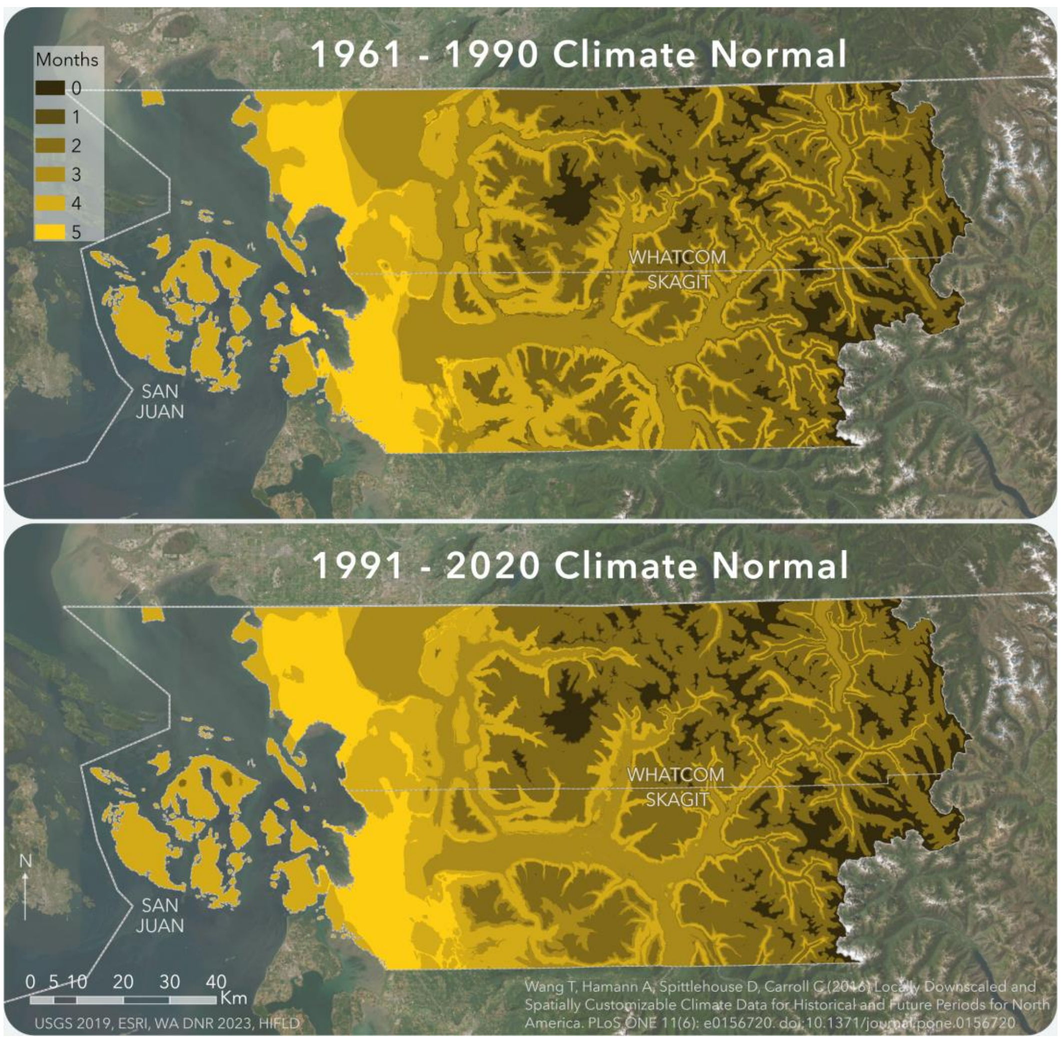

Figure 14: Maps showing number of months with optimal conditions in Northwest Washington from 1961 - 1990 and 1991 - 2020.

Overall, these results show that there has been an increase in the length of the growing season. Areas that are becoming more suitable for wheat growth are inland areas near the coast of the Salish Sea. Interestingly, there is also a pattern of decreasing climatic suitability in central areas of Orcas Island. High-elevation areas on peaks of the Cascade Range have been constant across the 100-year period, with no months in the optimal climatic suitability range. Near the Nooksack River, there is increased climatic suitability, but still only reaching a few months within the optimal temperature threshold range.

3.4.1 Future Temperature Suitability for Wheat

Climatic suitability will continue to change in the future. There are multiple climate projection scenarios available. The CMIP6 SSP126 scenario shows a continued temperature increase until 2065, when temperature begins to decline gradually (Chou, 2021). Absolute growth thresholds for wheat in Northwest Washington using this projection scenario show that some mountainous regions still do not fit into the temperature threshold to grow wheat (Figure 18).

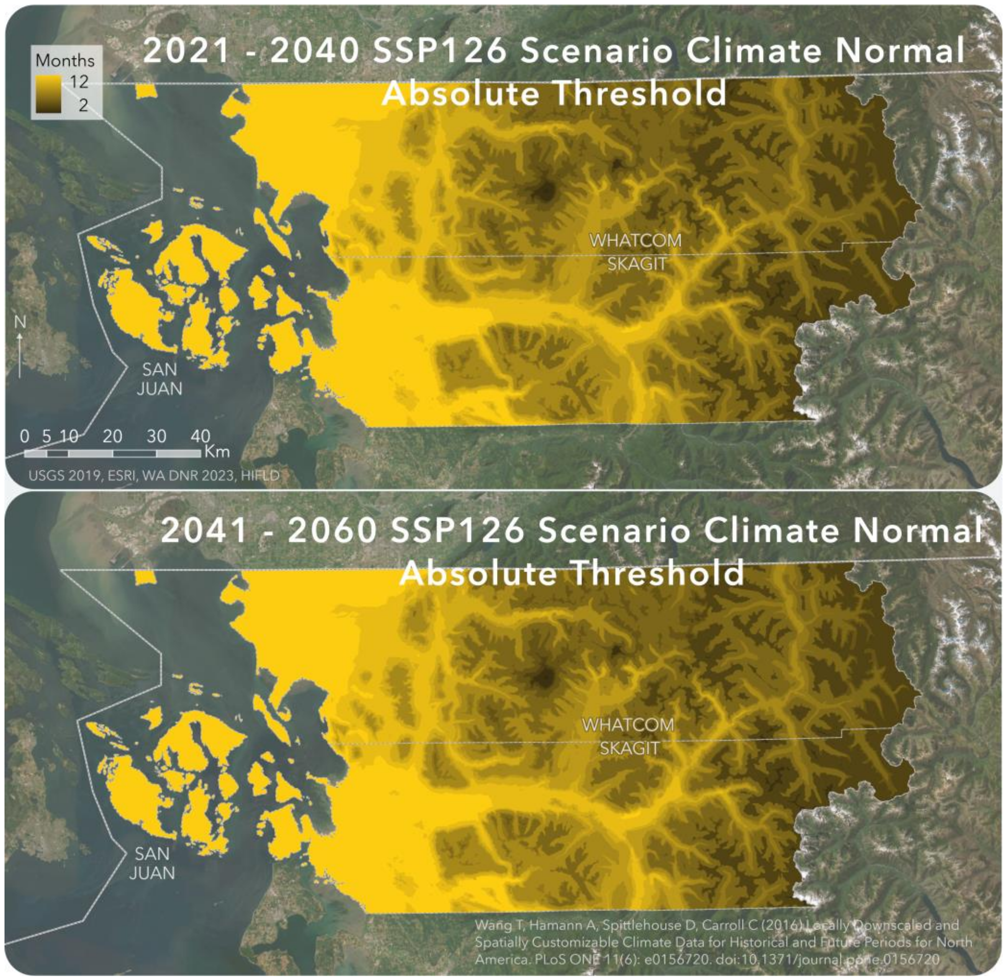

Figure 15: Map of the absolute threshold of climatic suitability for wheat in the future.

Climatic suitability for wheat growth will decrease based on the SSP126 Climate Scenario from 2021 – 2040 and 2041 - 2060. The absolute threshold patterns for both time periods are similar. There will be a two-month loss of months that fit within the optimal temperature thresholds by the coast to the Cascade Mountain Range (Figure 19). The most notable change is a large increase in climatic suitability in mountain range areas. Temperatures are growing increasingly warmer, leading to more climatic suitability in the Western side of the Cascade Mountains. However, a large portion of the mountainous areas still only have 2 months of optimal climatic suitability despite the warming in this scenario.

Climate suitability from the 2041 – 2060 SSP126 Climate Scenario shows a wider range of suitability than in 2021 – 2040. Some areas have up to 5 months of climatic suitability, like inland Orcas Island. Near the coast, climatic suitability ranges from 1 – 4 months. Mountain tops remain at 0 months of climatic suitability. More mountain areas show climatic suitability than the 2021 – 2040 scenario.

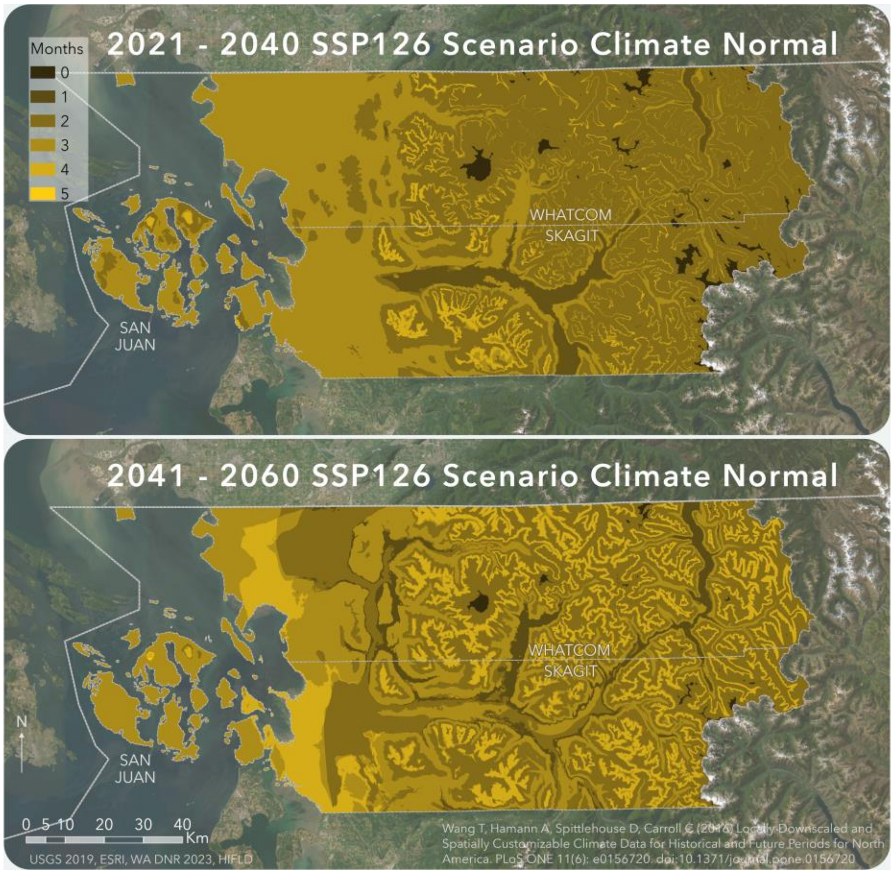

Figure 16: Map of months of optimal climatic suitability for wheat growth in Northwest Washington.

3.5 Changing length of growing season.

Because of the changing temperature in Northwest Washington, the growing season length has been affected over time. The largest change is from the historical 1901 – 1930 normal to the modern 1991 – 2020 normal (Figure 20). Areas closer to the coast have gained up to 2 months of climatic suitability for wheat growth, with more inland areas losing up to 2 months of climatic suitability. This is the largest loss of climatic suitability seen from any of the climate normals to the modern climate normal. From 1931 – 1960 to 1991 – 2020, there has been some loss of climatic suitability in San Juan County, as well as directly on the coast. This stays stable through 2020. The least change has occurred from the 1961 – 1990 period to 1991 – 2020 period, likely due to the proximity in time. Despite that, there has been some gain of climatic suitability in the inland areas. Overall, areas west of the Cascade Mountains and some areas near the coast on the mainland have undergone the most change in the last 120 – 123 years.

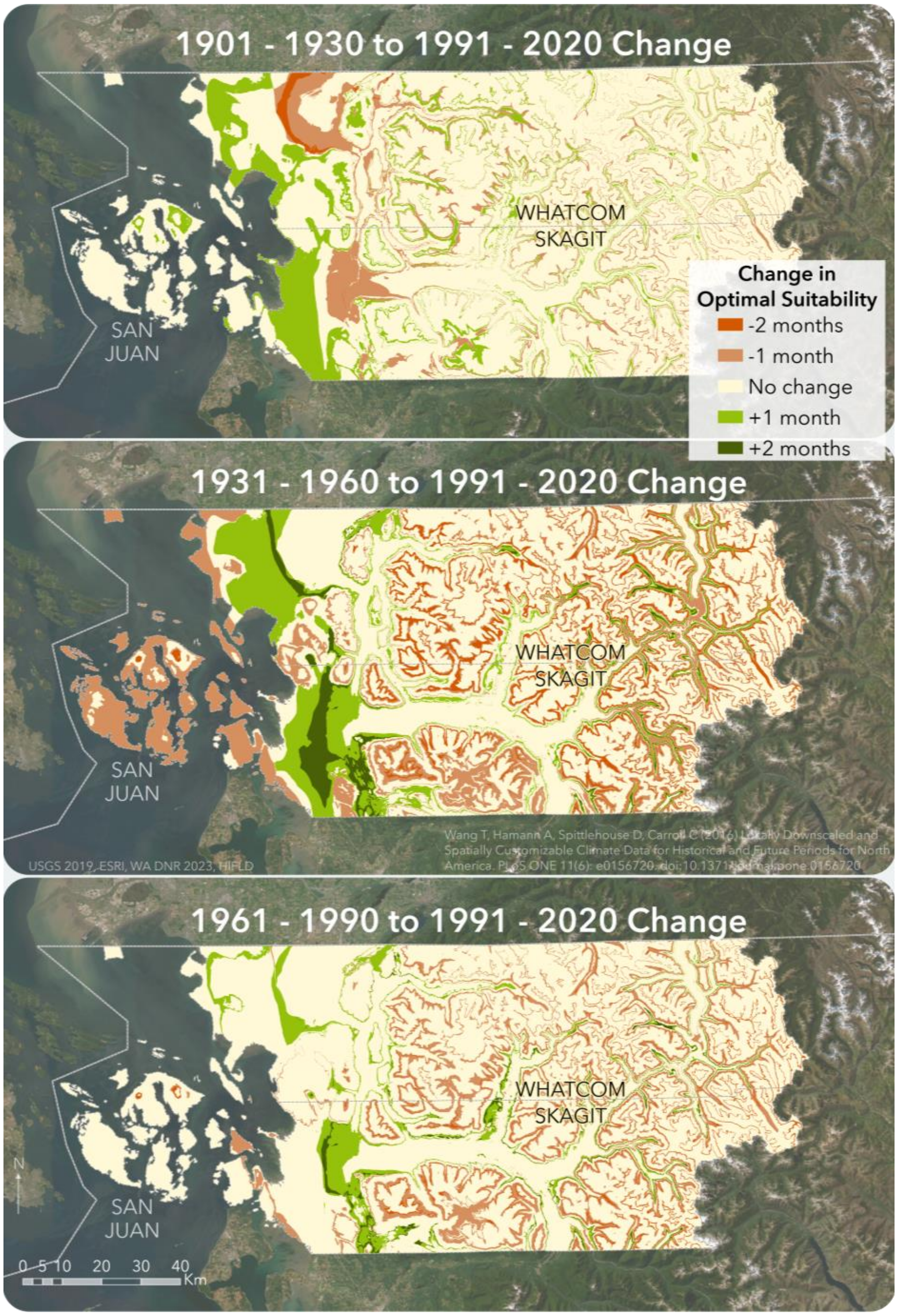

Figure 17: Maps showing the change in optimal climatic suitability from the 1991-2020 climate normal to the 1901 – 1930, 1931 – 1960, and 1961 – 1990 climate normals.

In the future 20 years, there will be up to 2 months of loss for optimal climatic suitability near the coast (Figure 21). There is also a loss of climatic suitability along rivers. Areas that gain climatic suitability are higher elevation mountainous areas and inland areas on Orcas Island.

From 2041, 2060, there will be up to 4 months of climatic suitability loss in areas near the coast. Mountain areas continue to gain climatic suitability based on temperature alone, up to 3 months. The change from the 1991 – 2020 time period to the 2041 – 2060 time period is the largest for climatic suitability loss, with smaller amounts of climatic suitability gain.

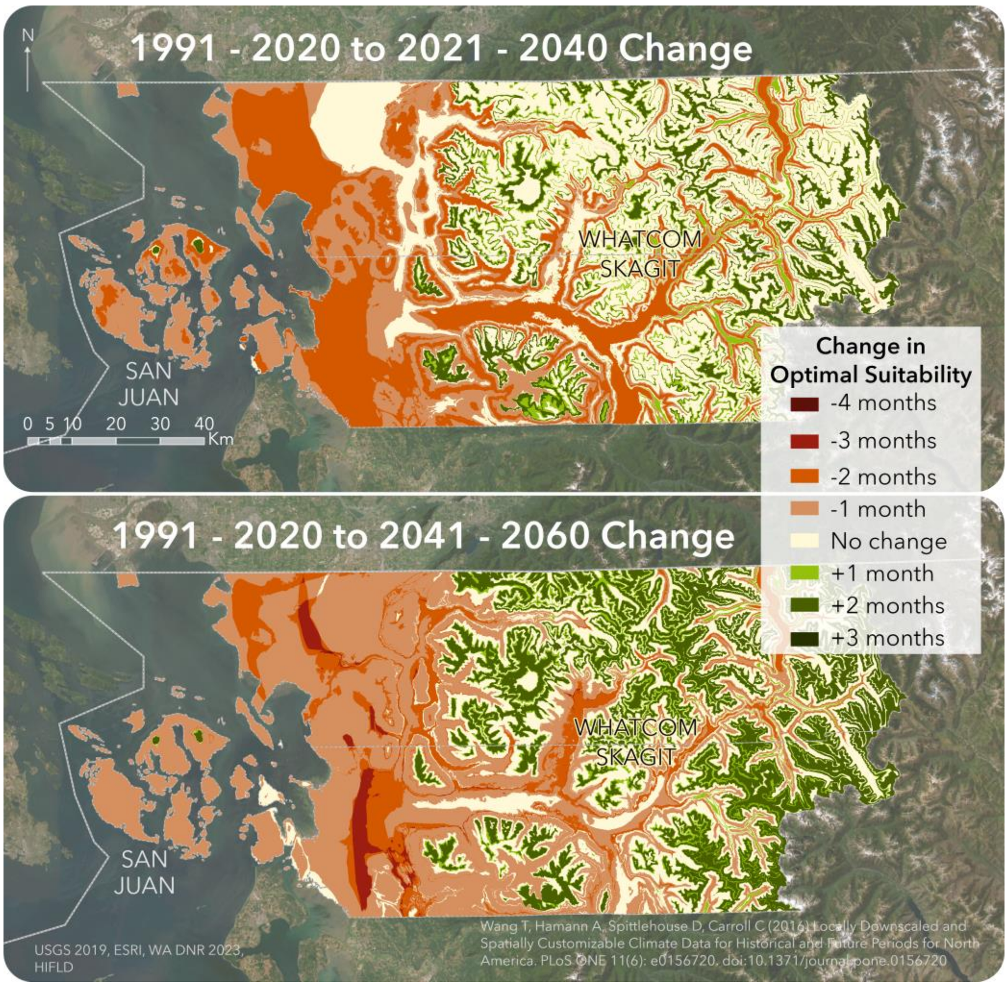

Figure 18: Change in optimal climatic suitability from 1991 - 2020 to 2021 - 2040.and 1991 – 2020 to 2041 – 2060.

3.6 Available Areas to Grow Wheat

A suitable temperature is not the only requirement to grow wheat. Assuming the crop would receive adequate water through rainfall or irrigation, soil types and land use zoning should be considered to determine areas that are most suitable for wheat growing in Northwest Washington. By combining both ideal soil types for growing wheat and agricultural land zoning, I was able to determine areas of highest climatic suitability for the 1991 – 2020 climate normal suitability.

While there is variable climatic suitability across the study area, only areas that have been zoned for agriculture would be able to grow wheat in large quantities. Areas primarily zoned for agriculture range from the coast to inland, as well as some zoning along rivers (Figure 22). Areas that meet optimal temperature thresholds and are zoned for agriculture are largely near the coast or just inland of the coast. These areas have the highest suitability, but less optimal suitability is found along waterways or further from the coast. Optimal suitability in this area ranges from 5 months within optimal temperatures to 2 months within optimal temperatures.

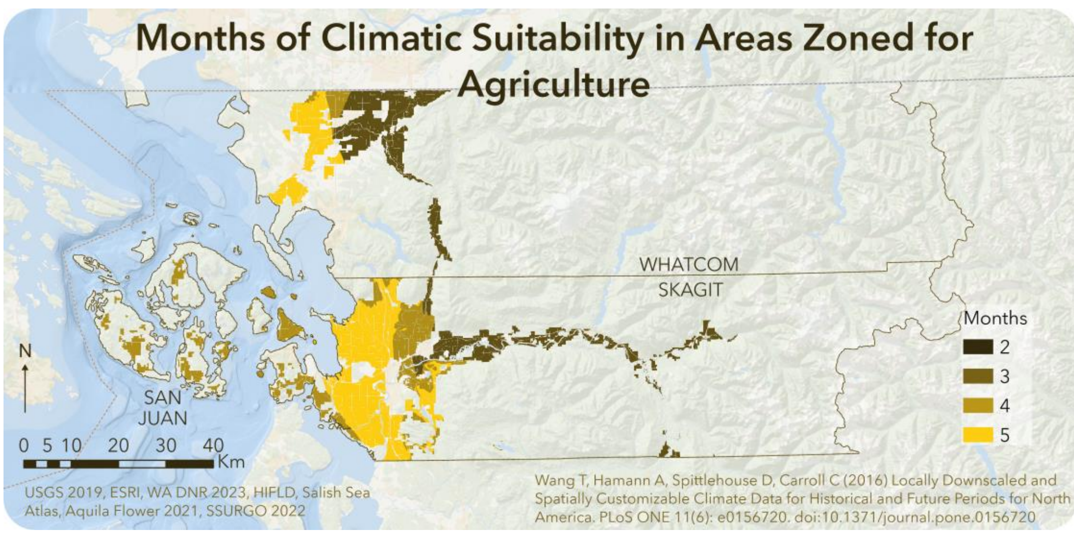

Figure 19: Areas of optimal suitability that are also zoned for agriculture.

If zoning is ignored, there are more areas available for growing wheat. There are multiple soil types in Northwest Washington. Not every soil is suited for either agriculture or growing wheat in general, so it is important to select soils that have the best characteristics for growing crops. The Soil Survey Geographic Database (SSURGO) is a dataset of soil types collected by the Natural Resources Conservation Service (2022) and includes both soil types and a farmland suitability scale, ranging from not suitable to suitable for agriculture. I selected soil types that are either clay or loam, as well as types that are a suitable agriculture class as defined within the SSURGO database (Figure 23).

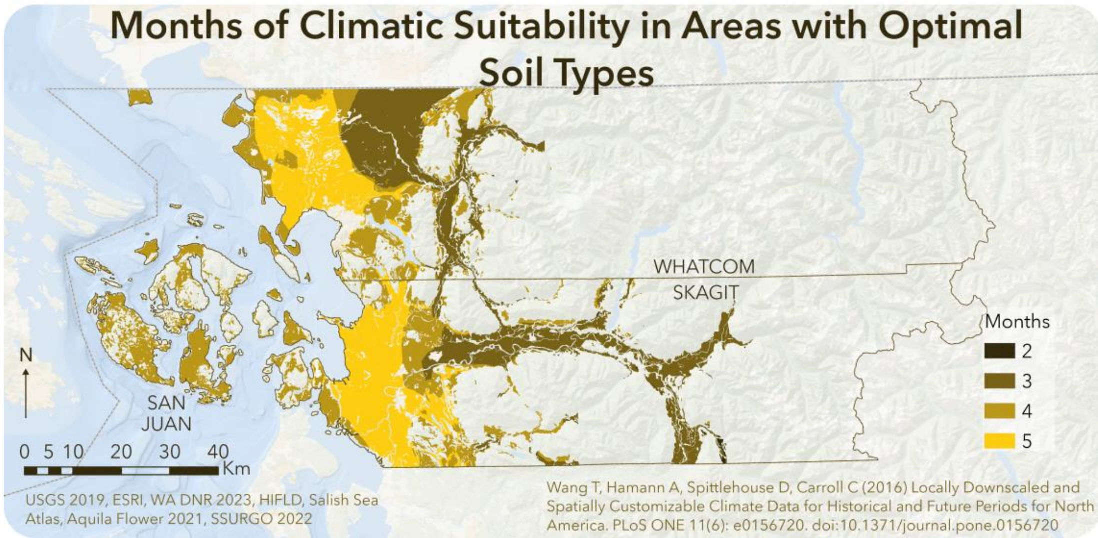

Figure 20: Areas where there are months of climatic optimal suitability intersecting with preferable soil types.

Combining both soil types and zoning provides the most refined results for areas that not only can grow wheat but have multiple months of optimal climatic suitability. After overlaying ideal soils for wheat, the most suitable areas for wheat growth have only changed slightly (Figure 24). This shows that many agriculturally zoned areas are on top of soils that are suitable for wheat growth and agriculture in general. In addition, agriculture zoning is more limiting than soil types are. This soil and zoning combination with optimal temperatures for wheat growth provides specific areas that could be targeted for ideal wheat growth in Northwest Washington.

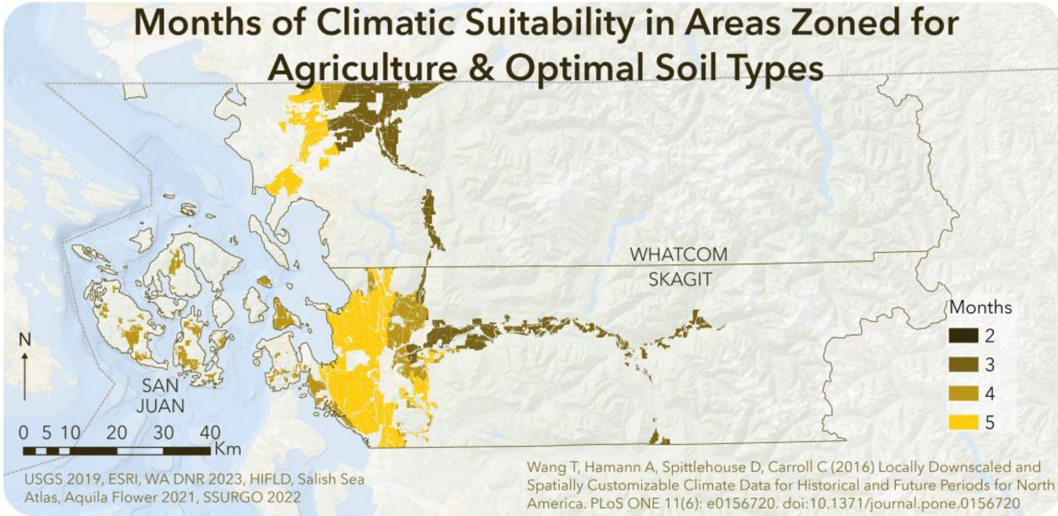

Figure 21: Areas of optimal suitability that are zoned for agriculture and have optimal soil types.

Optimal soil types have the largest area of optimal months, with a total of 2,506.91 square kilometers for 2 to 5 months of optimal climatic suitability (Table 4). Areas that are only zoned for agriculture have a total of 1,097.3 square kilometers. Looking at areas that have both optimal agriculture soils and agricultural zoning, there are 978.53 total square kilometers of areas that have 2 to 5 months of optimal climatic suitability.

Months of Climatic Suitability	Area of Suitable Soils (km^2)	Area of Agriculture Zoning (km^2)	Area of Both Soils and Zoning (km^2)
2	5.9	0.04	0.02
3	805.23	349.52	325.51
4	877.44	277.94	221.51
5	818.34	469.8	431.49

Table 4: Areas of suitable soils, agriculture zoning, and both combined overlaid with optimal climatic suitability months.

Looking at the future suitability time periods from 2021 – 2040 and 2041 – 2060, there is less optimal climatic suitability in areas that have prime agricultural soil and are zoned for agriculture (Figure 22). The months of optimal climatic suitability range from one to four months. The highest suitability remains inland of the coast, with less suitability closer to the mountains. Some suitability is gained from 2041 – 2060 compared to 2021 – 2040 but is still less than the historical time periods.

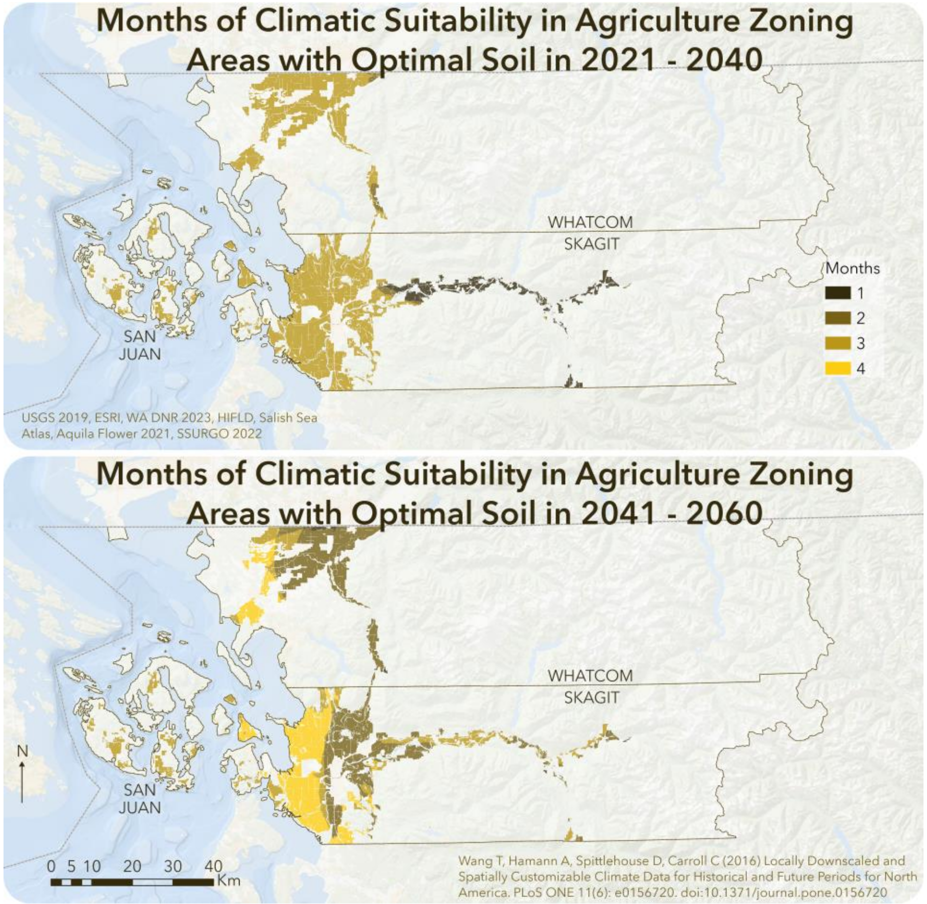

Figure 22: Refined climatic suitability for 2021 - 2040 and 2041 - 2060.

3.7 Interview Results

Results from these transcribed interviews show that there are a few overall themes regarding grain farming in Northwest Washington that interviewees agree on. The main points that interviewees spoke about were an increasing interest in grain growing, climate change affecting farming in the area, and the importance of community within these agricultural systems. I discuss these themes that were highlighted in the interview in the follow sections.

Figure 23: Word cloud of most-used words from interviews.

3.7.1 Increasing Interest in Grain Growing

When asked about the future of grain farms in Northwest Washington, interviewees agreed that there will be continued interest in growing grains here. In addition, this interest will likely grow as grain becomes more important for niche, artisan food rather than animal feed or commercial bread in this area. Interviewees pointed out that with a growing customer base for local foods, wheat and other grains have the possibility to be sold for more money than before. Many also mentioned that the presence of Cairnspring Mills to facilitate coordination between farmers, bakers, and consumers has been an integral part of this system, with all people involved feeling more supported. In addition, the future potential of both growing and using grains in Northwest Washington was commonly discussed. Many interviewees commented that the system could continue to grow and improve alongside the interest in having local grains.

‘I think [grain] is just going to get more varieties, more diverse, better for the consumer. There’s still room for us to switch from growing feed or commodity grain to growing more of this other stuff.’ – Farmer 1

‘Wheat is one of the most adaptable crops and there are hundreds of other varieties that we can cultivate to be viable as we see the impacts of climate change. We’re seeing a tremendous amount of market demand for regeneratively grown grains.’ – Miller 1

‘It seems like it’s only expanding, and people are embracing locally grown grain. These people are growing stuff anyways, but then they’re not growing half the year or have something, like a cover crop, that doesn’t make money. They can grow wheat instead.’ – Baker 3

‘I think that depending on the investors that they maybe have through places like Cairnspring [Mills] or maybe wanting to do another mill, we could see more grain being grown here.’ – Baker 1

‘More ground is broken this year by different farms who have never really grown grain before. It’s cool, just the concept of growing grain at a small scale seems more available to farmers now than it did when we first moved here.’ – Farmer 2 and Baker 2

3.7.2 Competition and Costs

Despite this rising interest, farming grains in Northwest Washington can be difficult. It may be difficult to find footing in this area, as well as having enough funds for both the crops and equipment needed for those crops. Adding to this difficulty are corporations or other parties who are interested in acquiring large amounts of land for big farming operations, leaving less land for independent farmers.

‘[Grain farmers] are competing with each other as well as competing with the national brands and mills just trying to find a little shelf space. So, they need a competitive variety.’ – Farmer 1

‘If I was really getting serious about grain and wanted to do it, the equipment alone, like a good combine, you can drop 50 grand, a hundred grand depending on what scale you want.’ – Farmer 3

‘What will largely happen is that the people who have the money to step in and pick up those holdings that are that large are going to be corporate.’ – Farmer 3

‘The biggest challenge now is cost increases – fuel, freight, land rent.’ – Miller 1

3.7.3 Climate Change

Many interviewees mentioned uncertainty about the future because of climate change. Their language suggests that they have concerns about the future of grain farming as the climate continues to be unpredictable. In addition to concerns about changing climate, a few interviewees have faced struggles growing grain here, with one farmer saying that “the climate is tricky.”

‘But I do worry that just in general, like the research being done for climate change stuff is not going to happen fast enough for what we’re going through.’ – Baker 1

‘The state of our climate is obviously a huge factor. It’s going to be really rough for all of us. So, [we should] just have hope but also caution and action.’ – Baker 4

‘When you look at climate change and other things that affect food production, places like this are more and more being recognized as being of extreme value.’ – Farmer 3

‘We have some hurdles to cross before we can produce all [Cairnspring Mills’] grain with the climate we have. It’s really tough.’ – Farmer 1

3.7.4 Importance of Community

Community relationships have been identified as an important factor in this agricultural community. Local grain systems seem to be reliant on the connections between bakers, farmers, and millers in Northwest Washington.

‘I think I feel like I’ve gotten pretty lucky, but I also feel like it’s because there’s a good community of people who are really interested in local food.’ – Baker 3

‘It’s just clear that people here care about local food or, you know, agriculture. It’s a strong connection to agricultural livelihoods here.’ – Farmer 2 and Baker 2

‘There is a collaborative spirit in the valley on big issues. There’s also a lot of independence from each farm; each farm has its own independence.’ – Farmer 1

‘It’s all relationship based. We continue to not only seek out new growers so that we can seek out and strengthen the supply chain, but farmers are hearing from other farmers that we’re working to lift them out of the commodity system.’ – Miller 1

3.7.5 Changes in Community

Because community has been identified as an important component to local grains, any changes to the community has the potential to change the grain system in Northwest Washington.

‘Any change in the grain growing system, especially in Western Washington, has to be accompanied by change the end users: bakeries, millers, whatever. Then also, a change in consumer expectations in terms of what does bread look like and taste like.’ – Farmer 2 and Baker 2.

‘[People] do want to move up here and have a piece of this lifestyle and it’s just a lot of people, a lot of human beings competing for finite and ever-decreasing resources.” – Farmer 3

‘There’s new producers on the scene all the time and there’s folks coming that have never farmed in their life and they want to grow grain.’ – Farmer 1

4. DISCUSSION

4.1 Census records

The history of grain agriculture in Northwest Washington is complex, with a rich history of both growth and sales of various cereal grains since European settlement. Agriculture census records show that there was a period of decreasing grain acreage, bushel output, and number of farms in the mid-20th century. However, when comparing these trends to the climatic suitability, it shows that there was a slight decrease in climatic suitability in 1931 – 1960 but became more suitable in 1961 – 1990. This suggests that farmers may have stopped growing grains primarily due to social factors rather than climatic factors if there was still suitability for wheat.

In the 21st century, cereal grain growth has fluctuated, with some years showing an increase in growth and output of cereal grains. This small rise is not enough to compare to the late 19th and early 20th centuries, as census records do not show a large increase in grain production based on numbers alone. However, farmers, bakers, and millers suggest that there is a rising interest in local grains, so production does not seem to match community interest and increasing demands yet.

Even if cereal grain acreage continues to rise in Northwest Washington, it is likely that the farms will still not look the same as they did in the early 20th century. This is because efficiency and specialization are still ideals held within the United States agricultural industry, leading farmers to still focus on a few crops rather than growing a mix. Cereal grains could become part of this mix, but small farms still need to rely on more lucrative crops like vegetables and fruits to make a profit. Understanding the historical context of these systems can help farmers and bakers decide what choices to make regarding cereal grains, especially if they should grow and use them at all.

4.2 Changing temperature

Minimum temperature has increased in both Whatcom and Skagit counties, but surprisingly, the maximum temperature had no statistically significant change. Meanwhile, both minimum and maximum temperature in San Juan County have increased significantly since 1900. This is evidence of climate change having different spatial effects while simultaneously causing change (Walthe et al., 2002). Overall, the changing temperature of these regions could have major impacts on multiple ecological processes like sea level and acidity, precipitation levels and snowpack, as well as water access for agriculture (Elsner et al., 2010; Huppert et al., 2009).

I was able to identify areas of best suitability for wheat growth based on temperature, soil type, and land zoning. Climatic suitability fluctuated across the last 120 – 123 years, but there has been an overall loss of optimal climatic suitability in some areas inland of the coast since the 1901 – 1930 climate normal. Looking at the temperatures of each month in the 1991 – 2020 climate normal, August showed a higher average temperature in those areas than the optimal envelope of 17 – 23 °C. While this temperature is still in the acceptable temperature growth range, it does not register as optimal, bringing climatic suitability down in areas that were previously within the optimal threshold. Despite some loss of climatic suitability, there are areas that have increased in climatic suitability over time. These areas are mostly inland from the coastline. The largest change is from the 1991 – 2020 climate normal to the 2041 – 2060 climate normal, with climatic suitability increasing up to three months or decreasing up to 4 months.

Future climatic suitability from 2021 – 2040 shows a large decrease inland of the coast, as well as on the coast. July and August have increasing temperatures that fall outside of the upper limits of the optimal suitability threshold. If temperatures continue to increase as projected through 2065, more climatic suitability could be lost through areas near the coastline. This could also continue to increase temperature suitability in mountainous areas. This is problematic because of the difficulties growing crops like wheat in uneven, mountainous areas. In addition, there is a lack of agricultural zoning that would make it impossible for wheat to be grown by farms in these areas without a zoning change.

Because of this disconnect between increasing temperatures being above what is considered optimal, this would decrease overall suitability for much of Northwest Washington. It is worth reconsidering what the optimal threshold is, as increasing temperature with climate change may mean that no temperature is within the ‘optimal’ threshold. Therefore, it is worth discussing what the optimal threshold is as temperature increases in the future. While there are still identifiable areas of optimal growth in the current 17°C to 23°C range, this may not be true in the future.

Even though optimal climatic suitability is shifting, wheat and other cereal grains can still be grown in the area. There are still many months within the current growing season that have temperatures that support crop growth, even if they are not the ideal temperature. For example, the growing season in Skagit County could lengthen as there are more warm months, but optimal conditions are not as common in future projections. In addition, farmers may have to reconsider their growing season if they would prefer to grow during optimal temperatures.

4.3 Farmer and Baker Decision-making

Three main themes shared between farmers and bakers can be identified. Within these main themes, 2 subthemes can be identified. First, there is increasing interest in growing grains and participating in local food systems in Northwest Washington. Second, many interviewees are worried about the impacts of climate change both on wheat crops and the local food system. The subtheme supporting this main theme is competition and costs, with finances or brand competition being a large part of the businesses operating in Northwest Washington. Third, farmers and bakers agreed on the importance of community within the local grain system. In addition to this community importance, there were common sentiments of changing community demographics altering the local food systems.

While many of the interviewees share common sentiments regarding these themes, my results are limited by a small sample size. Due to the busy nature of these professions, it was difficult to have steady contact with some interviewees, resulting in less interviews. Despite this limitation, interviewees provided insight to the growing local grain system in Northwest Washington. Overall, farmers and bakers engaged in local grain systems in Northwest Washington are hopeful for the future of grains, especially as their value continues to increase. It would be interesting to compare this to a larger sample size of farmers and bakers in the study area to see if these themes continue to appear. In addition, these results provide a basic understanding of why farmers and bakers choose to become involved in local grain systems. A study looking more closely at the financial reasons farmers and bakers make decisions could build on these results, as well as a study looking at changing community demographics affecting the makeup of bakers and farmers in Northwest Washington.

5. CONCLUSION

Recently, local food movements have been increasing in popularity in the United States. Communities in Northwest Washington have shown interest in this movement as well, especially with their local grain systems. Artisan, nutrient-packed breads have become a popular choice for local bread despite Northwest Washington not being viewed as a typical grain-growing region. Many farmers and bakers value community-focused crop systems, understanding the history of cereal grains in Northwest Washington. It is difficult to predict the future of local grains in Northwest Washington based on the results of this study, but the community shows a focus on resilience and sustainability that indicates growing cereal grains in the area has a chance of continuing to be successful.

The results of my study show that multiple factors affect a community's decision to invest in local grain agriculture. There is a connection between social, historical, and physical factors. Farmers and bakers have shown concern over climate change and the capability of a community to be competitive with larger industries, but also seem optimistic about the local grain movement in Northwest Washington succeeding. More research regarding climate change, temperature, and habitat suitability for cereal grains is needed as temperatures continue to rise in the 21st century.

As climate change continues to affect temperature and precipitation, climatic suitability for growing wheat will continue to change. Based on current projections, temperature will continue to warm and impact climatic suitability of wheat, leading to loss of suitability in coastal areas of Northwest Washington. It is possible that current definitions of optimal temperature suitability will eventually become obsolete as temperatures continue to change. The study results suggest that there is community interest in continuing to invest in grain agriculture. More research should be conducted to understand other factors that could affect grain agriculture in Northwest Washington and how they interact with climate and community dynamics.

REFERENCES

Allen, D. W. (1991). Homesteading and Property Rights; Or" How the West Was Really Won". *The Journal of Law and Economics, 34*(1), 1-23.

Basurto, X., & Speer, J. (2012). Structuring the calibration of qualitative data as sets for qualitative comparative analysis (QCA). *Field Methods, 24*(2), 155-174.

Béné, C., Oosterveer, P., Lamotte, L., Brouwer, I. D., de Haan, S., Prager, S. D., ... & Khoury, C. K. (2019). When food systems meet sustainability–Current narratives and implications for actions. *World Development, 113,* 116-130.

Borkin, D., Némethová, A., Michaľčonok, G., & Maiorov, K. (2019). Impact of data normalization on classification model accuracy. *Research Papers Faculty of Materials Science and Technology Slovak University of Technology, 27*(45), 79-84.

Brinkley, C. (2017). Visualizing the social and geographical embeddedness of local food systems. *Journal of Rural Studies, 54,* 314-325.

Brockett, L. P. (1882). *Our Western Empire: Or the new west beyond the Mississippi: The latest and most comprehensive work on the states and territories west of the Mississippi.* Bradley, Garretson & Company.

Carver, S. J. (1991). Integrating multi-criteria evaluation with geographical information systems. *International Journal of Geographical Information System*, *5*(3), 321-339.

Chiang, C. Y., & Reese, M. (2002). Evergreen state: exploring the history of Washington’s forests. *Center for the Study of the Pacific Northwest, University of Washington, Wash*.

Chou, J., Zhao, W., Li, J., Xu, Y., Yang, F., Sun, M., & Li, Y. (2021). Changes in extreme climate events in rice-growing regions under different warming scenarios in China. *Frontiers in earth science, 9*, 200.

Collow, A. B. M., Mersiovsky, H., & Bosilovich, M. G. (2020). Large-scale influences on atmospheric river–induced extreme precipitation events along the coast of Washington State. *Journal of Hydrometeorology*, *21*(9), 2139-2156.

Couzy, C., & Dockes, A. C. (2008). Are farmers businesspeople? Highlighting transformations in the profession of farmers in France. *International Journal of Entrepreneurship and Small Business*, *6*(3), 407-420.

Curtis, T., & Halford, N. G. (2014). Food security: the challenge of increasing wheat yield and the importance of not compromising food safety. *Annals of applied biology*, *164*(3), 354-372.

Daniels, J. M. (2005). *The rise and fall of the Pacific Northwest log export market* (Vol. 624). US Department of Agriculture, Forest Service, Pacific Northwest Research Station.

Deitch, M. J., Sapundjieff, M. J., & Feirer, S. T. (2017). Characterizing precipitation variability and trends in the world's Mediterranean-climate areas. *Water*, *9*(4), 259.

Dimitri, C., Effland, A., & Conklin, N. C. (2005). *The 20th century transformation of US agriculture and farm policy* (No. 1476-2016-120949).

Donaldson, E., Schillinger, W. F., & Dofing, S. M. (2001). Straw production and grain yield relationships in winter wheat. *Crop Science, 41*(1), 100-106.

Drozdov, S. N., Titov, A. F., Balagurova, N. I., & Kritenko, S. P. (1984). The effect of temperature on cold and heat resistance of growing plants: II. Cold resistant species. *Journal of experimental botany*, *35*(11), 1603-1608.

Dwyer J., Newell S., and Washington Crop and Livestock Reporting Service. (1956). San Juan County Agriculture: County agricultural data series. Washington Crop and Livestock Reporting Service. https://s3.wp.wsu.edu/uploads/sites/2054/2019/11/1956-San-Juan-County-Agriculture.pdf.

ECONorthwest. (2010). *Economic Indicators of Agriculture's Future in Skagit County.* https://www.skagitcounty.net/envisionskagit/documents/econw_finalreport.pdf.

Edwards, R. (2009). Changing perceptions of homesteading as a policy of public domain disposal. *Great Plains Quarterly*, *29*(3), 179-202.

Ellis, E. (1978). *The History of San Juan County agriculture with an appendix of excerpts from the annual narrative reports filed by the county agents.* Washington State University. https://s3.wp.wsu.edu/uploads/sites/2054/2019/11/The-History-of-San-Juan-County-Agriculture-with-an-appendix-of-excerpts-from-the-Annual-Narrative-Reports-filed-by-the-County-Agents-1978.pdf.

Elsner, M. M., Cuo, L., Voisin, N., Deems, J. S., Hamlet, A. F., Vano, J. A., ... & Lettenmaier, D. P. (2010). Implications of 21st century climate change for the hydrology of Washington State. *Climatic Change*, *102*, 225-260.

Flower, A. (2021). *Salish Sea Bioregion Agricultural Areas* [Data Set]. Salish Sea Atlas, Western Washington University. https://wwu.maps.arcgis.com/home/item.html?id=cee4dc9d354c4df7bb4254aab2421ae1.

National Oceanic and Atmospheric Administration. (2014). *U.S. Historical Climatology Network Monthly (USHCN)* (Version 2.5.0.20230702) [Data set]. https://www.ncei.noaa.gov/pub/data/ushcn/v2.5/readme.txt.

Griffee, P. (2017). *Triticum aestivum L*. EcoPort. http://ecoport.org/perl/ecoport15.pl?searchType=entityDisplay&entityId=2114.

Harsch, M. A., Phillips, A., Zhou, Y., Leung, M. R., Rinnan, D. S., & Kot, M. (2017). Moving forward: insights and applications of moving‐habitat models for climate change ecology. *Journal of ecology*, *105*(5), 1169-1181.

Havilah, E. J. (2011). FORAGES AND PASTURES: Annual forage and pasture crops – species and varieties. In J. W. Fuquay (Ed.). Encyclopedia of Dairy Sciences (2nd ed., pp. 552-562). Academic Press. https://doi.org/10.1016/B978-0-12-374407-4.00193-X.

Hendrickson, M. K., & James, H. S. (2005). The ethics of constrained choice: How the industrialization of agriculture impacts farming and farmer behavior. *Journal of Agricultural and Environmental Ethics*, *18*(3), 269-291.

Herbert, S. (1982). *Spring Cereal Grains.* University of Massachusetts. https://ag.umass.edu/sites/ag.umass.edu/files/research-reports/1982-08-spring-cereal-grains.pdf.

Hills, K. M., Goldberger, J. R., & Jones, S. S. (2013). Commercial bakers' view on the meaning of" local" wheat and flour in western Washington State. *Journal of Agriculture, Food Systems, and Community Development*, *3*(4), 13-32.

Hipple, K. W. (2011). Washington soil atlas. *Natural Resources Conservation Service, Washington*. https://www.nrcs.usda.gov/sites/default/files/2022-09/Washington%20Soil%20Atlas.pdf.

Horseman, S. V., Roe, E. J., Huxley, J. N., Bell, N. J., Mason, C. S., & Whay, H. R. (2014). The use of in-depth interviews to understand the process of treating lame dairy cows from the farmers' perspective. *Anim. Welf*, *23*, 157-165.

Hunt, L. A., Poorten, G. V. D., & Pararajasingham, S. (1991). Postanthesis temperature effects on duration and rate of grain filling in some winter and spring wheats. *Canadian Journal of Plant Science*, *71*(3), 609-617.

Huppert, D. D., Moore, A., & Dyson, K. (2009). Chapter 8: Coasts. In *The Washington Climate Change Impacts Assessment: Evaluating Washington's future in a changing climate (pp. 285 – 309).* Climate Impacts Group, University of Washington, Seattle, Washington. https://doi.org/10.7915/CIG0MS3K2.

Intergovernmental Panel on Climate Change. (2023). Summary for Policymakers. In: Climate Change 2023: Synthesis Report. A Report of the Intergovernmental Panel on Climate Change. Contribution of Working Groups I, II and III to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change [Core Writing Team, H. Lee and J. Romero (eds.)]. IPCC, Geneva, Switzerland, 36 pages. (In press).

LandScope Washington. (n.d.a). North Cascades Climate. http://www.landscope.org/washington/natural_geography/ecoregions/north_cascades/climate

LandScope Washington. (n.d.b). North Cascades ecoregion. http://www.landscope.org/washington/natural_geography/ecoregions/north_cascades/.

LandScope Washington. (n.d.c). Puget Trough Climate.

http://www.landscope.org/washington/natural_geography/ecoregions/puget_trough/climate/

LandScope Washington. (n.d.d). Puget Trough Ecoregion. http://www.landscope.org/washington/natural_geography/ecoregions/puget_trough/.

Lemus, R. (2017). *Small Grain Cereals for Forage Production.* Cooperative Extension Service at Mississippi State University. https://extension.msstate.edu/sites/default/files/newsletter/forage-news/2017/2017_September.pdf.

Menne, M. J., Durre, I., Vose, R. S., Gleason, B. E., & Houston, T. G. (2012). An overview of the global historical climatology network-daily database. *Journal of atmospheric and oceanic technology*, *29*(7), 897-910.

Meinken, K. W. (1953). *The demand and price structure for oats, barley, and sorghum grains* (No. 1080). US Department of Agriculture.

Meints, B. M., Endelman, J., Hayes, P., Lyon, S. R., & Jones, S. (2021). Growing barley in western Washington.

Menne, M.J., C.N. Williams, & R.S. Vose. (2009) The United States Historical Climatology Network monthly temperature data (Version 2). *Bulletin of the American Meteorological Society, 90*, 993-1007.

Menne, M. J., Durre, I. Korzeniewski, B., McNeill, S., Thomas, K., Yin, X., Anthony, S., Ray, R., Vose, R., Gleason, B. E., & Houstin, T. G. (2012). *Global Historical Climatology*

Network – Daily (GHCN-Daily) (Version 3) [Data set]. NOAA National Climatic Data Center. doi:10.7289/V5D21VHZ. Accessed May 25, 2023.

Miles, C. A. (2009). *Growing wheat in western Washington*. Washington State University Extension.

Morse, W. C., Lowery, D. R., & Steury, T. (2014). Exploring saturation of themes and spatial locations in qualitative public participation geographic information systems research. *Society & Natural Resources*, *27*(5), 557-571.

Mustafa, A. A., Singh, M., Sahoo, R. N., Ahmed, N., Khanna, M., Sarangi, A., & Mishra, A. K. (2011). Land suitability analysis for different crops: a multi criteria decision making approach using remote sensing and GIS. Researcher, 3(12), 61-84.

National Agricultural Statistics Service. (n.d.) Census of Agriculture. United States Department of Agriculture. https://www.nass.usda.gov/AgCensus/.

Natural Resources Conservation Service. (2022). *Soil Survey Geographic Database* [Data set]. Natural Resources Conservation Service. https://www.arcgis.com/home/item.html?id=06e5fd61bdb6453fb16534c676e1c9b9.

Parker, C., Scott, S., & Geddes, A. (2019). Snowball sampling. *SAGE research methods foundations*.

Perryman, C. E., Peterson, A. W., Hintze, R. C., Holland, J. C., Waud, K. E., & Hagood, M. A. (1966). Deep well irrigation of grain on summer fallow farms of eastern Washington.Pomeroy, M. K., & Fowler, D. B. (1973). Use of lethal dose temperature estimates as indices of frost tolerance for wheat cold acclimated under natural and controlled environments. *Canadian Journal of Plant Science*, *53*(3), 489-494.

Porter, J. R., & Gawith, M. (1999). Temperatures and the growth and development of wheat: a review. *European journal of agronomy*, *10*(1), 23-36.

PRISM Climate Group. (2014). *PRISM Gridded Climate Data* [Data Set]. *Oregon State University*. https://prism.oregonstate.edu. Data accessed 2023.

PRISM Climate Group. (2022). *Mean Annual Precipitation (1991 – 2020): Washington* [Map]. Oregon State University. https://prism.oregonstate.edu/projects/gallery_view.php?state=WA.

Ranney, M. L., Meisel, Z. F., Choo, E. K., Garro, A. C., Sasson, C., & Morrow Guthrie, K. (2015). Interview‐based qualitative research in emergency care part II: Data collection, analysis and results reporting. *Academic Emergency Medicine*, *22*(9), 1103-1112.

Rowe, K. (2018). *Agriculture in Washington 1792 to 1900.* The Free Encyclopedia of Washington State History. https://www.historylink.org/.

Ruckelshaus, M.H., McClure, M., & Mantua, N.J. (2007). *Sound Science: Synthesizing Ecological and Socioeconomic Information about the Puget Sound Ecosystem.* Report prepared in cooperation with the Sound Science collaborate team. U.S. Dept. of Commerce, National Oceanic and Atmospheric Administration (NMFS), Northwest Fisheries Science Center. Seattle, Washington.

Overland, J. E., & Walter, B. A. (1983). Marine weather of the inland waters of western Washington. *National Oceanic and Atmospheric Administration.* https://www.pmel.noaa.gov/pubs/PDF/over595/over595.pdf.

Sacks, W. J., Deryng, D., Foley, J. A., & Ramankutty, N. (2010). Crop planting dates: an analysis of global patterns. *Global ecology and biogeography, 19*(5), 607-620.

Sievers, F. J., & Holtz, H. F. (1924). The fertility of Washington soils. https://s3.amazonaws.com/na-st01.ext.exlibrisgroup.com/01ALLIANCE_WSU/storage/alma/78/F6/09/2F/55/2B/66/0E/E9/66/85/E8/6C/4C/FC/80/eb_1924_12_n189.pdf?response-content-type=application%2Fpdf&X-Amz-Algorithm=AWS4-HMAC-SHA256&X-Amz-Date=20230702T191757Z&X-Amz-SignedHeaders=host&X-Amz-Expires=119&X-Amz-Credential=AKIAJN6NPMNGJALPPWAQ%2F20230702%2Fus-east-1%2Fs3%2Faws4_request&X-Amz-Signature=8ceb153c46111a71ffaa19ab71b7dc5cf68d7a10b415a6b787be92f6b928df0b.

Sloat, L. L., Davis, S. J., Gerber, J. S., Moore, F. C., Ray, D. K., West, P. C., & Mueller, N. D. (2020). Climate adaptation by crop migration. *Nature communications*, *11*(1), 1243.

Sneddon, M. (2008). Northwest homesteader: A curriculum project for Washington schools [Project]. Center for the Study of the Pacific Northwest. http://www.washington.edu/uwired/outreach/cspn/Website/Classroom%20Materials/Curriculum%20Packets/Homesteading/Northwest%20Homesteader.pdf. *Retrieved April 24, 2023*.

Steckel, R. H. (1991). The quality of census data for historical inquiry: A research agenda. *Social Science History*, *15*(4), 579-599.

Tavakkoli, A. R., & Oweis, T. Y. (2004). The role of supplemental irrigation and nitrogen in producing bread wheat in the highlands of Iran. *Agricultural Water Management*, *65*(3), 225-236.

Sys, C., Van Ranst, E., Debaveye, J., & Beernaert, F. (1993). *Land Evaluation. Part III: crop requirements. Agricultural Publications n° 7, GADC, Brussels, Belgium, 1993, 191 p*.

Walther, G. R., Post, E., Convey, P., Menzel, A., Parmesan, C., Beebee, T. J., ... & Bairlein, F. (2002). Ecological responses to recent climate change. *Nature*, *416*(6879), 389-395.

Washington Native Plant Society (2019). *Ecosystems*. https://www.wnps.org/ecosystems#lowland-forest.

Wang T, Hamann A, Spittlehouse D, Carroll C (2016) Locally Downscaled and Spatially Customizable Climate Data for Historical and Future Periods for North America. PLoS ONE 11(6): e0156720. doi: 10.1371/journal.pone.0156720

Western Regional Climate Center. (1985). *Climate of Washington.* https://wrcc.dri.edu/Climate/narrative_wa.php.

Weston, C., Gandell, T., Beauchamp, J., McAlpine, L., Wiseman, C., & Beauchamp, C. (2001). Analyzing interview data: The development and evolution of a coding system. *Qualitative sociology*, *24*(3), 381-400.

United States Census Bureau. (2021) *1890 Census Bulletins.* https://www.census.gov/library/publications/1890/dec/bulletins.html.

United States Census Bureau. (2022). *Census of Agriculture.* https://www.census.gov/history/www/programs/agriculture/census_of_agriculture.html#:~:text=The%20census%20of%20agriculture%20originated,collect%20data%20related%20to%20agriculture.

U.S. Geological Survey. (2022a). *USGS 1/3 Arc Second n49w121* (20220919) [Data set]. U.S. Geological Survey. https://www.sciencebase.gov/catalog/item/632a9a8ed34e71c6d67b9598.

U.S. Geological Survey. (2022b). *USGS 1/3 Arc Second n49w122* (20220919) [Data set]. U.S. Geological Survey. https://www.sciencebase.gov/catalog/item/640824fcd34e76f5f75e4051.

U.S. Geological Survey. (2022c). *USGS 1/3 arc-second n49w123* (1 x 1 degree) [Data set]. U.S. Geological Survey. https://www.sciencebase.gov/catalog/item/5f7784c682ce1d74e7d6ca60.

U.S. Geological Survey. (2022d). *USGS 1/3 arc-second n49w124* (1 x 1 degree) [Data set]. U.S. Geological Survey. https://www.sciencebase.gov/catalog/item/5f7783c282ce1d74e7d6c19a.

Winkler, L. R., Murphy, K. M., & Jones, S. S. (2016). The history of oats in western Washington and the evolution of regionality in agriculture. *Journal of rural studies*, *47*, 231-241.

Wiersma, J. J., Durgan, B. R., Hollingsworth, C., MacRae, I. V., & Rehm, G. (2006). Winter wheat in Minnesota. University of Minnesota, St. Paul, Minnesota. https://conservancy.umn.edu/bitstream/handle/11299/191680/Winter%20Wheat.pdf?sequence=1.

Zabel, F., Putzenlechner, B., & Mauser, W. (2014). Global agricultural land resources–a high resolution suitability evaluation and its perspectives until 2100 under climate change conditions. *PloS one*, *9*(9), e107522.

Zhu, X., Troy, T. J., & Devineni, N. (2019). Stochastically modeling the projected impacts of climate change on rainfed and irrigated US crop yields. *Environmental Research Letters*, *14*(7), 074021.

Appendix A: IRB

WESTERN
WASHINGTON UNIVERSITY

Office of Research & Sponsored Programs
Old Main 530 - MS #9038
516 High Street, Bellingham, Washington 98225
(360) 650-3220 - Fax (360) 650-6811
www.wwu.edu/compliance

To: Natalie Furness and Aquila Flower
From: Stephanie Richey
Subject: Human Subjects Application
Date: 6/17/2022
Action Taken: Exemption Granted
Principal Investigator: Natalie Furness
Faculty Advisor: Aquila Flower
Project Title: Against the Grain: Examining the effect of social and physical factors on small, grain-growing regions and farms in Northwest Washington
Protocol Number: 4709EX22
Funding: WWU College of the Environment Small Grant, June 2022 - December 2023

The Western Washington University (WWU) Institutional Review Board (IRB) designee determined that your project meets the requirements outlined in §45 CFR 46 and WWU institutional procedures to receive the following exemption determination:

Exempt Category 2

This determination means that your research is valid indefinitely, as long as the nature of the research activity remains the same. You may begin recruitment and data collection. After 6 years, according to the University's retention schedule, this exemption file will be deleted. After this point, you will no longer be able to make modifications to this protocol.

This exemption is given under the following conditions:

1. The research will be conducted only according to the protocol.
2. The research will be conducted in accordance with the ethical principles of Justice, Beneficence, and Respect for Persons, as described in the Belmont Report, as well as with federal regulations and University policy and procedure.
3. PIs, Faculty Advisors, PI Proxies, and any individual interacting or intervening with human subjects or their identifiable data must be appropriately trained in human research subject protections (CITI Basic Social/Behavioral Research – Basic/Refresher course), research methods, and responsible conduct of research **prior to** initiating research activity.
4. The Principal Investigator will retain documentation of all past and present personnel, including documentation of their training(s).
5. The Principal Investigator will ensure that all personnel training(s) remain(s) up to date.

Active Minds Changing Lives

6. IRB approval will be obtained **prior to making any modifications** that affect the research study's eligibility for this exemption category or fundamentally change the research. This includes changes to the Principal Investigator (PI), PI Proxy, or Faculty Advisor (if applicable), subject population, recruitment methods, compensation amounts or methods, consent procedures or documents, or changes in study materials that deviate from the approved scope.

   The following types of changes can be made without submitting a modification: Adding or removing research personnel other than the PI, PI Proxy, or Faculty Advisor (if applicable), edits in spelling, punctuation, and grammar on study materials (not including consent forms), minor wording changes to study materials (not including consent forms) that do not change the overall content and resulting comprehension, and adding or editing questions in questionnaires that are within the scope of the questions currently approved.

7. All research records (the application determination packet, correspondence with the IRB, any other IRB-related determinations, signed consent forms, and documentation of research personnel trainings in human research subject protections) will be maintained in accordance with WWU's guidelines for document retention.

8. The IRB will be promptly informed of any issues that arise during the conduct of the research, such as adverse events, unanticipated problems, protocol deviations, or any issue that may increase the risk to research participants.

Thank you for your attention to these details. If you have questions at any point, please review our website (www.wwu.edu/compliance) or contact a Research Compliance Officer.

Research Compliance Officer: Stephanie Richey
Exemption timestamp: 6/17/2022

Modification: Human Subjects Research

IRB Use Only:

Mod Number: 01

Review Status:
- ☐ Exempt – LR
- ☑ Exempt
- ☐ Expedited
- ☐ Full

RECEIVED STAMP: Received 10/4/2022

APPROVAL STAMP: Approved 11/21/2022

Reviewed Date: 10/28/2022

Reviewer: Stephanie Richey

<u>Interview Questions</u>

Against the Grain: Exploring Changing Relationships between Grains, Climate, and Community in Northwest Washington

Natalie Furness

<u>Starting statement:</u> Thank you for taking the time to meet with me. I am excited to chat with you about your work!

1. To start, I was wondering if you could tell me a little about your farm.
2. Can you tell me specifically what you grow on the farm and how you made the selection to grow these particular crops?
3. You mentioned some of this briefly, but could you tell me more about how you became a farmer in this region?
    a. Why did you pick this region?
4. You mentioned growing grains. This isn't typically considered a grain region; can you tell me more about your decision to grow grains?
5. I find it really interesting that you grow grains. What have been the biggest challenges in deciding to grow this crop?
6. Do you still face these same challenges now?
    a. If so, why do you think that is?
7. Compared to when you started farming, what are some new challenges that you are facing today?
8. Since you have been farming for X years, how have you seen farming change in this region?

a. How has this impacted grain farming?

9. You clearly have a large amount of experience and information in this industry. If you were to predict the future of grain farming in this region, what do you think it will look like and why?

10. Farming can be a collaborative process, with information exchanged among the farmers in your region. Since starting to farm grains, have you connected with any other grain farmers in the area? Have you relied on these relationships to build business?

  a. If so, who specifically or what farms specifically have you connected with that have been particularly helpful?
  b. In addition, what farms do you feel you have helped?

11. Now, let’s talk about something a little bit different. How has COVID-19 impacted your farm?

  a. Did it impact what crops you grow?

Recruitment Text

Against the Grain: Exploring Changing Relationships between Grains, Climate, and Community in Northwest Washington

Natalie Furness

For use by email or phone:

Dear [Name],

I am conducting a research study to understand the motivations and drivers behind farmers choosing to grow grains in San Juan, Skagit, and Whatcom counties starting in the early 20th century. This study also seeks to understand the relationship between grain farmers and their communities. This will supplement my research on climatic factors that have affected grain growth in Northwest Washington. The overall goal of this study is to understand the story of grain growth in this area.

If you are interested in participating in this study, you would consent to an interview with me in-person. If in-person is not available for any reason, we can meet over Zoom. This interview would take up to 30 minutes, depending on the depth of your answers to my questions. This interview is meant to be somewhat conversational. I am not offering any financial compensation for your participation. There are no known risks involved in this research. If you have any questions, please let me know. I am eager to hear back from you. I am best reached by email.

Natalie Furness

College of the Environment, Western Washington University

furnesn@wwu.edu

<u>Study Participant Consent Form</u>

Overview:

I am asking you to participate in a research study titled "Against the Grain: Exploring Changing Relationships between Grains, Climate, and Community in Northwest Washington." I will describe this study to you and answer any of your questions. This study is being led by myself, Natalie Furness, an MA student at Western Washington University located in Bellingham, Washington. The Faculty Advisory Committee for this study is comprised of: Dr. Aquila Flower, College of the Environment, Western Washington University, Dr. Cameron Whitley, College of Humanities and Social Sciences, Western Washington University, and Dr. David Rossiter, College of the Environment. You may ask questions about anything that is not clear. When we have answered all of your questions, you can decide if you want to be in the study or not. This process is called "informed consent."

What this study is about:

The purpose of this research is to understand why an increasing number of farmers are choosing to grow grains in San Juan, Skagit, and Whatcom counties, which are typically not identified as grain regions. The research goal also includes documenting grain regions in these counties in the early 20th century for comparison to current grain growth in these areas.

The outcomes of this research will be used as part of an analysis provided to the scholarly community at large, as well as the public. Interviewees will receive a copy of my thesis once completed.

What you will be asked to do:

You are asked to participate in an interview led by me, which will run for up to 30 minutes. You will be asked a series of questions regarding your crop and farm location decisions if you are a farmer, as well as your background. If you work at a mill or bakery, you will be asked a series of questions regarding your interactions with farmers.

Risks:

There are no foreseen risks to your participation in this research. However, you may feel uncomfortable sharing certain details. You may decline to answer any questions that you do not feel comfortable answering.

Benefits:

A possible benefit of participation in this research is the opportunity to be a part of your agricultural community's input. This research is meant to be representative of communities like yours, with the goal of creating stronger infrastructure systems between local communities.

Compensation for participation:

You will not receive any monetary compensation for participation.

Audio recording:

An audio recording device will be used during the study session. The recordings will be transcribed by a professional third-party service and then archived. The recordings will be destroyed after transcription.

The recording and transcriptions are needed for qualitative research analysis. It is important to the research to capture the nuances and entirety of the conversation. It also allows us to have a more natural conversation as an interviewer and interviewee.

The identity of the individual will not be disclosed in the publication of this study unless written and signed permission is granted from the individual. Regardless of whether or not you give permission to be identified, there is a chance that someone could identify your responses indirectly.

Privacy/Confidentiality/Data security:

Protection of the participant's privacy and/or confidentiality:

- De-identification of data – when transcribing the data, identifying information about you will be removed from the transcript. The research team will have access to the identifiable data.
- Recording security - Security of the recordings will be kept digitally in a password-protected program.
- Encrypted data – Any correspondence with the recordings or data will be encrypted, if associated with an individual participant.

Third-party company services:

Third-party transcription services may not be HIPAA-compliant. Audio recordings will be supplied to the third-party transcription service and audio recordings will be destroyed once written transcriptions are created.

Please note that email communication is neither private nor secure. Though I am taking precautions to protect your privacy during the participant recruitment process, you should be aware that information sent by e-mail could be read by a third party.

Your confidentiality will be kept to the degree permitted by the technology being used (NVivo software for coding qualitative research). I cannot guarantee safety from interception of data sent via the internet by third parties.

Sharing De-identified data collected in this research:

De-identified data from this study may be shared with the research community at large to advance social sciences without your additional informed consent. Despite these measures, I cannot guarantee the anonymity of your personal data. This means you could be indirectly linked to your answers within the research based on contextual clues, but every effort will be made to keep your identity private.

Taking part is voluntary:

Your participation is voluntary. You may refuse to participate before the study begins, discontinue at any time, or skip any questions/procedures that may make you feel uncomfortable, with no penalty to you, and no effect on your relationship with any organization other organization or service that may be involved with the research.

As a participant you are encouraged to answer all the questions. Individuals can choose not to participate if you are uncomfortable with these conditions.

If you have questions:

The main researcher conducting this study is Natalie Furness, a graduate student at Western Washington University. Please ask any questions you have now.

If you have questions later, you may contact Natalie Furness at furnesn@wwu.edu.

A copy of this form is available for you to take with you.

If you have questions about your rights as a research participant, you may contact the Western Washington University Office of Research and Sponsored Programs at compliance@wwu.edu or (360) 650-2146.

This consent form will be kept by the researcher for six years beyond the end of the study.