*The Effects of Agricultural Land Use in North Central Utah on Wildfire Conditions*

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## Introduction

Over the last several decades, a steady rise in the frequency and intensity of wildfires in the United States can be observed (National Interagency fire center, 2021). Wildfire policy in the United States first began in 1910 as a response to the fires of the same year in Yellowstone national park, fires were outright suppressed across the United States until 1968 when research and experience from the prior 50 years of wildfire fighting was compiled and the first action to allow some natural fires to burn was initiated by the national parks service (Aplet, 2006). From 2013 to 2022, wildfires resulted in the destruction of an average of 7.2 million acres annually across the United States (Wildfire statistics, Hoover et al. 2023). The primary cause of wildfires is anthropogenic, with 85% of all fires being started by humans (Wildfire causes and evaluation, National park service). While humans are a majority cause of wildfires, the primary driver of wildfires is ultimately climate change, leading to longer and more active fires (wildfire climate connection, NOAA). As climate change worsens, the duration and intensity of these fires progresses accordingly, becoming more severe. In the state of Utah, one of the industries that contributes the most to the state's gross domestic product is that of agriculture (USDA/NASS Utah Field Office, 2012), which has been a staple in the economy of Utah since it was first settled in 1896. Utah is the home of livestock such as cattle, hogs, sheep, goats, chicken, turkey and honeybees to name a few and other agricultural products like onions, pumpkins and corn. In the state of Utah, wildfires threaten agriculture every fire season which lasts roughly from July to October (Visit Utah.com, 2022). When a wildfire is started naturally it is often the result of a lightning strike connecting with a dead tree or dry brush. In the case of anthropogenically started fires, causes can range from unattended fires and lit cigarettes not being properly disposed of, to improper pyrotechnic use and arson. Whether a fire is started naturally or anthropogenically, a fire needs to reach a temperature of 572 degrees fahrenheit for wood to ignite, if a fire originates in an area that is mostly small dry vegetation like dead shrubs and grasses, a lower temperature is required for that fuel to combust. The moisture content of the available fuel and fuel loads are key factors in a fire's ability to sustain and spread. If a fire has less available fuel, it will spread slowly and not burn as intensely as a fire with an abundance of fuel, allowing a faster spreading and more intense fire (Bonsor, How Wildfires Work).

Wasatch, Utah and Sanpete counties are going to be the focus of this study, situated in an arid region at the base of the Rocky Mountains in north east Utah where the biome is semi arid with average annual temperatures falling above 40 degrees fahrenheit and average annual precipitation falling under 40 inches annually. The landscapes found in the region that Sanpete, Utah and Wasatch counties occupy primarily consists of  semi-arid foothills and mountain valleys, falling into what is considered Utah's central basin and range (Woods Et al, 2001). When taking a look at fires, an observable effect is the ability of wildfires to quickly move up hill and mountain sides, consuming more fuel as the fire rises. The semi arid nature of the region coupled with the amount of available fuel and mountainous terrain make this area a prime location for wildfire to spread quickly. Sanpete county is a county of 29,106 people (2021 census data, United States Census bureau 2021) and 301,691 acres of farmland (USDA Census of agriculture, 2017) accounting for nearly 30 percent of the county's total land. Of the three selected counties, last year the average precipitation for the ten year period examined was 22.017 inches and the annual average air temperature 47.6 degrees fahrenheit. (NOAA county time series, 2022). Davies et al (2016) takes a look into how the activities of grazing before a wildfire changes the biological makeup of areas in the Eastern great basin in Utah. The great basin is an area of continuous watersheds with no outlets that spans parts of Utah, Nevada, California, Oregon and Wyoming. This study focuses on how grazing before a fire and its effect after and the effect on the temperature of a given fire, but does not address if there is any effect on the duration or acreage covered by a fire. The study found that moderate consumption of foliage prefire, increases the resistance of plant communities to postfire invasion and dominance by exotic grasses. Seigel et al (2022)examines whether grazing has an overall impact in reducing the risk of a wildfire starting in the first place. The study shows that in two out of three regions studied in California , there is an overall reduction of risk of wildfire when there is increased grazing, as grazing reduces the amount of biomass on the ground to fuel fires. Taylor et al (2014) takes a look at the effect of wildfires on the growth of vegetation and reseeding after a fire has occurred, and how wildfires can potentially positively alter a biome's ability to be resilient towards exotic invasive weeds. It is important to look at different manners in which the

grazing-fire interaction occurs so that the research can be understood. The study found that a loss in terrestrial carbon stores resulting from harvest could potentially be compensated for by suppressing wildfire over an equal area. In Allred et al. (2011) the preference of native bison and yearling cows towards recently burned areas is examined in the tallgrass prairie biomes of Oklahoma. This study uses gps placed on the animals to track their movements over the selected area, some of which has been previously burned, allowing the researchers to determine the probability of the animals to select the burned patches of land over unburned land. The study concluded that spring fires created areas where environmental conditions were conducive for plant growth and also created conditions that were attractive to foraging bison. In a study conducted by Mena et al (2016) the focus is on the issue of wildfires and their cause in Mediterranean mountains and analyzes steps taken to decrease the intensity, duration and/or the probability of having a fire start at all. The steps taken by the regional government of La Rioja are relevant as the primary plan undertaken by the regional government is shrub clearing accomplished through prescribed burns and focused livestock grazing.

The goal of my research is to determine the effects, if any, of agricultural land use on the volume of wildfires in the three selected counties in Utah. The manner in which I have conducted my research was through the analysis of data primarily accessed through the Bureau of land management and Utah department of agriculture and food, to determine if agriculture in Utah, Wasatch and Sanpete counties has an adverse effect on the volume of wildfires in those three selected counties. I used process tracing, which is a qualitative method used primarily in political science applications to draw inferences from selected mechanisms(INTRAC, 2017). In this case those mechanisms are agricultural land use and weather conditions. The inferences drawn from utilizing collected data with the prescribed tests then allow us to make a determination regarding the accuracy of the initial hypothesis. The purpose of process tracing is to establish whether, and how, a potential cause or causes influenced a specified change or set of changes by applying formal tests to examine the strength of evidence linking potential causes to the changes.

## Methods

Process tracing was used to analyze the connection between annual average precipitation, annual average air temperature, agricultural land use and wildfires in Utah. Primarily used in social sciences, but can and has been applied to earth sciences (Parker, 2010). Process tracing is used to evaluate the weight of evidence based on the results of tests. I am primarily choosing to do process tracing to provide a different lens to view the data of this project from. Process tracing is applicable for a study of this nature because of its ability to rigorously assess causal change in case analysis utilizing four empirical tests that bring different amounts of scrutiny to the plausibility and confirmation of a given hypothesis. Process tracing revolves around compiling a case that addresses the effects under investigation, the hypothesized cause and events that link the hypothesized cause and the effect. There are three different types of process tracing that are used when different information is known. Theory testing process tracing is used when both the cause and outcome are known, there is reason to think that there is a causal link between the cause and outcome and the link between the cause and outcome is known. With the second type of process tracing, theory building, there are two types; version one is used when the cause and outcome are known and there is reason to believe there is a causal link, version two is used when the outcome is known but the cause is not, meaning that the outcome is know but the cause is not. Explaining outcome process tracing is used when the outcome is known, but the cause is unknown. In this project, theory building version two was used as the outcome (increased reported wildfires) is known, but the cause of the outcome is not.(Centre for Development Impact, 2015)

The first of the four tests, straw in the wind, is conducted by examining the hypothesis that agricultural land use has an effect on wildfire behavior, and utilizing the evidence constituting the test to determine the plausibility. In the case of the straw in the wind test, the evidence constituting the test is presented in figures 1-3 and figure 4, showing heightened wildfires over the ten year period. What can be taken away from this evidence is that there may be a connection given the data, however the straw in the wind test increases the plausibility of the hypothesis, but

does not firmly prove or disprove it. In the second of the tests, the hoop test, another piece of evidence is added, the heightened annual average temperature and the declining annual precipitation, shown in figures 1-3, 5 and 6. The evidence of the change in weather patterns is necessary for keeping the hypothesis in consideration, if the evidence showed that precipitation had increased and air temperature had decreased, it would significantly weaken the hypothesis. The evidence also disproves that wildfire behavior is changing without input from elements of the weather. In the third test, the smoking gun test, all of the evidence shown in figure 1-6 is examined which shows increasing temperatures and reported wildfires, and decreasing precipitation across all three counties, with decreasing agricultural land use across 2 of the three counties. This evidence proves the hypothesis of agricultural land use having an effect, negative or positive, on wildfire behavior.

The study was conducted using precipitation and air temperature data collected from the National Oceanic and Atmospheric Administration, and land use data from the Utah department of agriculture and food, US department of Agriculture and the Bureau of land management. Wildfire data was collected from the National Interagency fire center and Utah department of public safety, and general county data was collected from the United States census bureau. The data is coming from state and federal government agency reports ranging from 2010 to 2020, allowing a manageable but broad enough range to show any possible connection between the variables being studied. The data was interpreted with the impact that the aforementioned variables may have on each other.

I used wildfire frequency data, precipitation and air temperature and land use data to determine if my research goal is observable within the data sets, then proceeded to make conclusions based off of the data sets to utilize within the tests prescribed by process tracing. When I began collecting and analyzing data, I started with a single hypothesis that land use may have an effect on wildfire conditions in the selected counties in Utah, however as my research and analysis progressed I found myself asking if the converse could also be the case. That being said, I examined both the possibilities that wildfires may have an effect on land use and land use could have an effect on wildfires. The data for natural vegetation only covers those that were reported to fire departments in Wasatch, Sanpete and Utah counties may not reflect the actual volume of

wildfires that occurred in those counties. The actual occurrence of fires is not known as they are not reported

and therefore not treated by any of the reporting agencies in Utah. When utilizing process tracing, I first had to consider my initial hypothesis; does agriculture, increasing air temperature and declining precipitation have any effect, positive or negative, on the volume of wildfires in these three counties? I also explored the other side of the hypothesis; does the volume of farmland have any effect on the volume of fires?". I made the decision to examine the second question based on the data I found that is displayed in figures 1-6, that shows a decline in farmland between 2012 and 2017, but contrary to my initial question, also shows an increase in fires. In all of these tests the independent variables are precipitation and temperature in all cases. In some cases farmland volume may be examined as an independent variable. In some cases both fire volume and farmeland volume can be examined as dependent variables as there may be an influence on wildfire volume, either positive or negative, caused by farmland volume.

## Results

In my research, I found that in all three counties being examined there was a notable rise of reported natural vegetation fires coupled with a decline of annual average precipitation in inches between 2010 and 2020, and an increase of annual average air temperature. The addition of farmland per county was how the three became connected, the only data available was from the Utah Agricultural Statistics and Utah Department of Agriculture and Food 2019 annual report, with data from the 2012 and 2017 census' of agriculture providing per county cropland data, which only provides the ability to observe a change in land use in the 5 year range between the census'. With the addition of cropland volume per county from the Utah census of agriculture, I found that the counties with greater volume of cropland (Utah county and Sanpete county) had higher rates of reported natural vegetation fires.

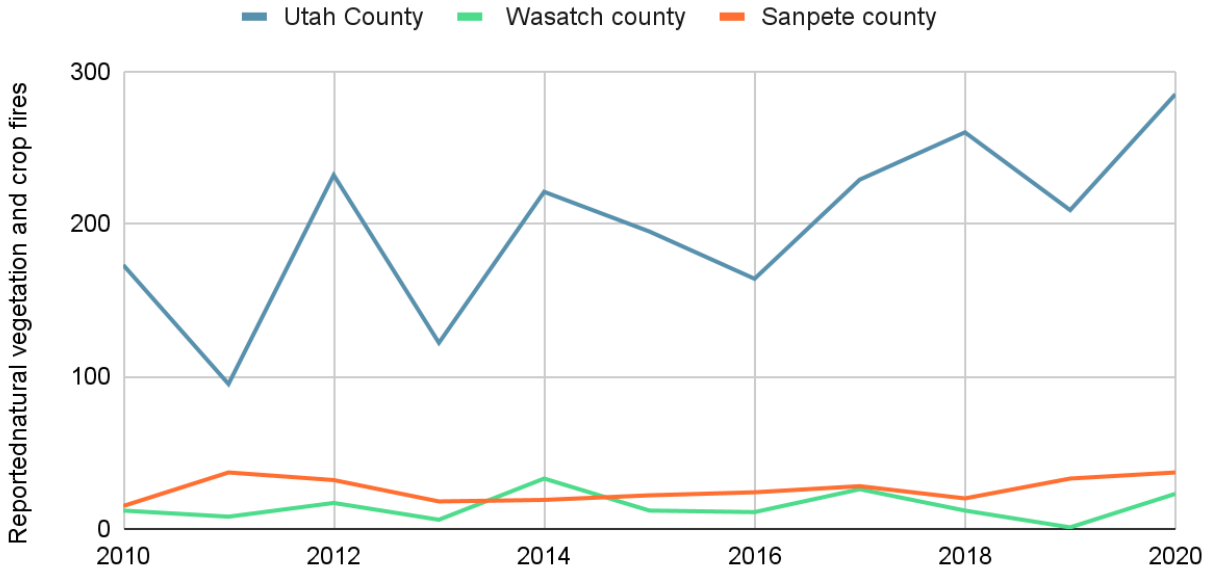
In Utah county, with the exception of 2014 and 2019, reported fires gradually rose, with a several year decline in precipitation. Utah county has a significant volume of agricultural use land, taking up 22 percent of the county [1]. Utah county has a significantly higher volume of agricultural land use and number of reported natural vegetation fires when compared to Sanpete and Wasatch counties, with a similar decline in annual precipitation from 2010 to 2020. Figure 1 contains precipitation, farmland acreage, temperature and reported natural vegetation for Utah county spanning from 2010 to 2020.

[1] Utah county is 1,372,160 acres according to the US census bureau and farmland takes up 303,795 of it

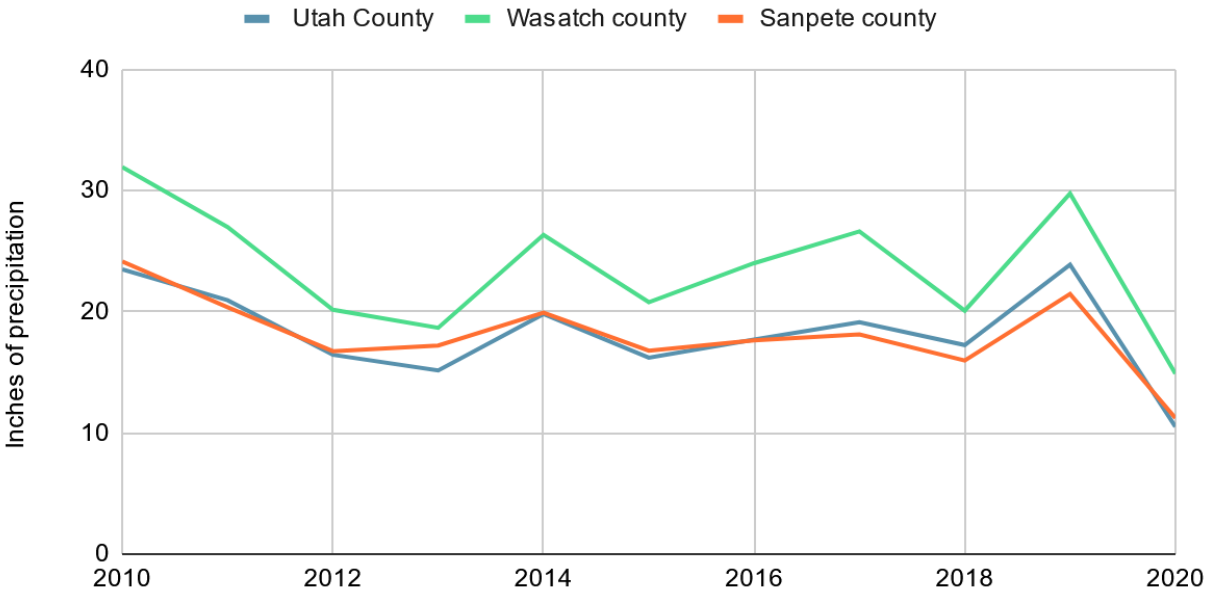
**Data for Utah county, Utah (Figure 1)**

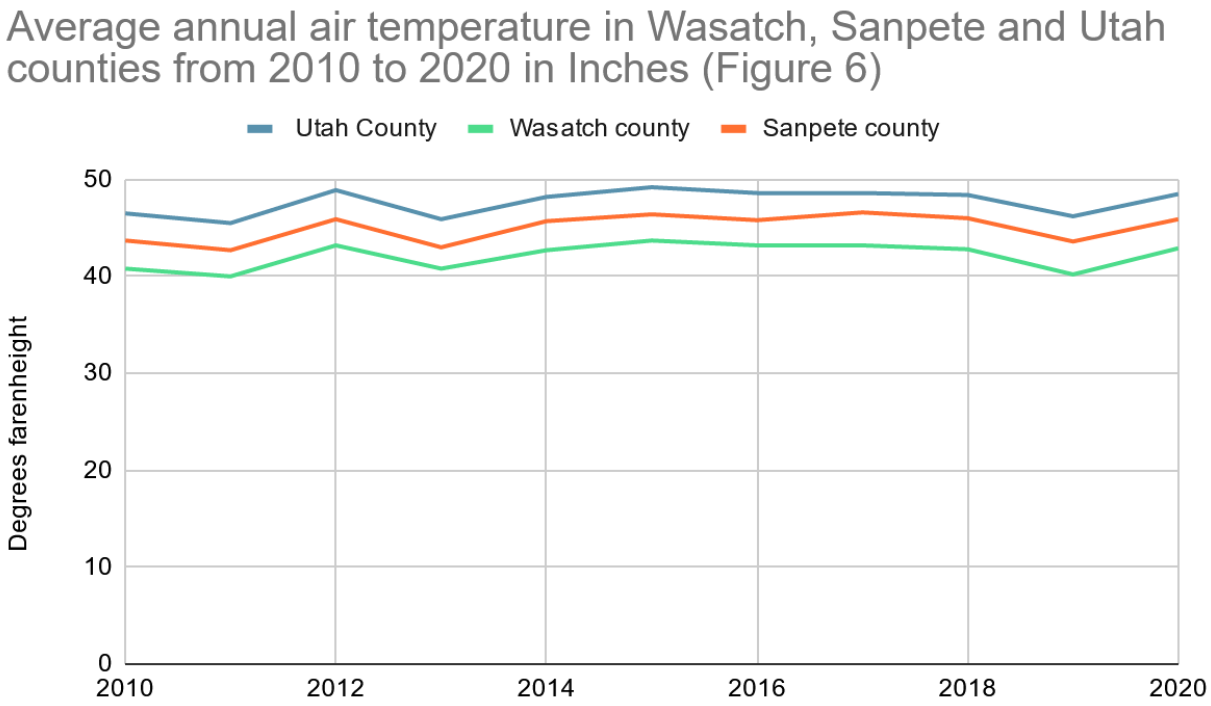
| | Reported natural vegetation and crop fires | Annual precipitation (inches) | Annual average temperature (fahrenheit) | Farm land (acres[2012 census of agriculture]) | Farm land (acres[2017 census of agriculture]) |
|---|---|---|---|---|---|
| 2010 | 173 | 23.50" | 46.5 | 343077 | 303795 |
| 2011 | 95 | 20.95" | 45.5 | 343077 | 303795 |
| 2012 | 232 | 16.45" | 48.9 | 343077 | 303795 |
| 2013 | 122 | 15.15" | 45.9 | 343077 | 303795 |
| 2014 | 221 | 19.81" | 48.2 | 343077 | 303795 |
| 2015 | 195 | 16.21" | 49.2 | 343077 | 303795 |
| 2016 | 164 | 17.71" | 48.6 | 343077 | 303795 |
| 2017 | 229 | 19.13" | 48.6 | 343077 | 303795 |
| 2018 | 260 | 17.25" | 48.4 | 343077 | 303795 |
| 2019 | 209 | 23.88" | 46.2 | 343077 | 303795 |
| 2020 | 285 | 10.51" | 48.5 | 343077 | 303795 |

## Reported natural vegetation and crop fires in Wasatch, Sanpete and Utah counties from 2010 to 2020 (Figure 4)




## Average annual precipitation in Wasatch, Sanpete and Utah counties from 2010 to 2020 in Inches (Figure 5)






In Sanpete county, the number of annually reported natural vegetation fires is only a fraction of what Utah county experienced, but still shows the same trend of a county with a high volume of agriculture, a decreasing annual precipitation, increasing air temperature and heightened reported natural vegetation fires. Figure 2 contains the data for Sanpete county.

**Data for Sanpete county, Utah (Figure 2)**

| | Reported natural vegetation and crop fires | Annual precipitation (inches) | Annual average air temperature (fahrenheit) | Farm land (acres[2012 census of agriculture]) | Farm land (acres, [2017 census of agriculture]) |
|---|---|---|---|---|---|
| 2010 | 15 | 24.15" | 43.7 | 284311 | 301691 |
| 2011 | 37 | 20.37" | 42.7 | 284311 | 301691 |
| 2012 | 32 | 16.75" | 45.9 | 284311 | 301691 |
| 2013 | 18 | 17.22" | 43 | 284311 | 301691 |
| 2014 | 19 | 19.93" | 45.7 | 284311 | 301691 |
| 2015 | 22 | 16.79" | 46.4 | 284311 | 301691 |
| 2016 | 24 | 17.63" | 45.8 | 284311 | 301691 |
| 2017 | 28 | 18.13" | 46.6 | 284311 | 301691 |
| 2018 | 20 | 15.97" | 46 | 284311 | 301691 |
| 2019 | 33 | 21.47" | 43.6 | 284311 | 301691 |
| 2020 | 37 | 11.23" | 45.9 | 284311 | 301691 |

In Wasatch county, there is a much lower volume of agricultural land. With a county similar in size to Sanpete county( 1206 square miles and 1603 square miles respectively), there is significantly less agricultural land use with Wasatch county utilizing 152 square miles for agricultural land and Sanpete county utilizing 471 square miles. The volume of land use is important to consider because the fire data for Wasatch county seems like a list of outliers, with yearly reported natural vegetation fires from 2010 to 2020 never exceeding their height of 33 reported in 2014. Figure 3 contains the data for Wasatch county.

**Data for Wasatch county, Utah (figure 3)**

| | Reported natural vegetation and crop fires | Annual Precipitation (inches) | Annual average air temperature (fahrenheit) | Farm land (acres[2012 census of agriculture] | Farm land (acres[2017 census of agriculture]) |
|---|---|---|---|---|---|
| 2010 | 12 | 31.95" | 40.8 degrees | 149,224 | 97,098 |
| 2011 | 8 | 26.99" | 40 degrees | 149,224 | 97,098 |
| 2012 | 17 | 20.17" | 43.2 degrees | 149,224 | 97,098 |
| 2013 | 6 | 18.68" | 40.8 degrees | 149,224 | 97,098 |
| 2014 | 33 | 26.35" | 42.7 degrees | 149,224 | 97,098 |
| 2f015 | 12 | 20.79" | 43.7 degrees | 149,224 | 97,098 |
| 2016 | 11 | 24.01" | 43.2 degrees | 149,224 | 97,098 |
| 2017 | 26 | 26.63" | 43.2 degrees | 149,224 | 97,098 |
| 2018 | 12 | 20.09" | 42.8 degrees | 149,224 | 97,098 |
| 2019 | 1 | 29.76" | 40.2 degrees | 149,224 | 97,098 |
| 2020 | 23 | 14.90" | 42.9 degrees | 149,224 | 97,098 |

## Discussion

Counties that have a higher volume of farmland experience a higher rate of annual wildfires. From 2010 to 2020 wildfires have been increasing. Cropland has decreased from 149,224 acres in 2017 to 97,098 acres in 2012, however wildfire volume has risen. Weather patterns have changed to promote the start of natural wildfires with lower precipitation and higher temperatures. Conversely the lower historical volume of cropland suggests that there may be a link between cultivated cropland and rangeland having a preventative effect on wildfires. This motions to the possibility that farmland negatively affects wildfire volume by promoting the start of the fires by contributing to the driving factor of climate change, however it also can be used to examine the possibility that farmland positively affects the start of wildfires. For the same reasons as the first test, the second test, the hoop test, is passed. The difference between the straw in the wind test and the hoop test is that the straw in the wind test is neither necessary nor sufficient to establish any kind of causation. If the second hypothesis("does the volume of farmland have any effect on the volume of fires?") were to be introduced, the hoop test would be passed by only the new one, as the data suggests that the decrease in farmland volume, coupled with rising temperatures and lower precipitation, is related to an increase in wildfires. The only county in which the data does not support the theory of farmland preventing wildfires is Utah county, possessing the same increase in wildfire volume, decreased precipitation and increased temperature as Sanpete and Wasatch counties, however also possessing an increased volume of cropland. A possible cause of the increase in wildfires in the data set that also contains an increase in cropland over the last decade is semi drought conditions being caused by poor irrigation practices coupled with decreasing precipitation. The third test, the smoking gun test, is sufficient to establish causation but not necessary. The smoking gun test is passed because the data shows that counties with higher volume of farmland experience a higher volume of reported natural vegetation fires. In the cases of Sanpete and Wasatch counties, the counties are of similar size, however Sanpete county uses almost triple the amount of land for agriculture when compared to Wasatch and experiences a notably higher rate of reported natural vegetation fires. While Utah and Sanpete counties both experience an increase in wildfires, both of these counties

have experienced a notable decrease in agricultural land use. Sanpete county was the only county that experienced an increase in agricultural land use and was also the only of the three counties to have a number of annual fires that remained in the double digits, even remaining below 40 annual reported fires for the entire time period being examined. The fourth and final test is the doubly decisive test, which is both sufficient and necessary to establish causation and if passed confirms the hypothesis. The first hypothesis presented that agricultural land use causes wildfires to become more intense, does not pass the final test as the data suggests that rising fire volume in counties where the fire volume is already significantly higher than others does not fall as agricultural land decreases, thus confirming the second hypothesis. As shown in Sanpete county, there is an increase in wildfires, but nowhere near the volume that is observed in the other two counties. Sanpete is the only of the three counties to have an increase in cropland between 2010 and 2020, suggesting that there is a connection between farmland and lower rates of wildfires.

## Conclusion

This study sought to utilize process tracing to determine whether agricultural land use has an affect on the intensity and/or duration of wildfires, negatively or positively, focusing on 3 counties in north central Utah from 2010 to 2020 I found that while the primary drivers of more intense wildfires to be climate change, directly affecting the fires through lower average annual precipitation and higher annual average air temperature, agricultural land use created a preventative effect on wildfires by depriving the fires of hardwood fuel and unobserved land where a fire can grow before it is reported. Regardless of my findings that agricultural land use is reducing wildfires, agricultural land use may still be contributing to climate change and still resulting in more intense and longer fires. When conducting the process tracing portion of this study, I found that for other studies examining quantitative data without examining social factors,

process tracing is ill suited and the application of a purely statistical analysis may be required to come to a more definite conclusion.

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