# Effect of hurricanes on cotton yield and output in Georgia and Texas

by

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**ABSTRACT**

Over the past 50 years, Georgia and Texas have both experienced multiple storms and hurricanes with different intensities. Their cotton production industries have successfully remained buoyant despite the challenges imposed by these storms, from flooding and wind damage to nutrient loss and diseases. The overall objective of this research is to assess the impact of major storms on cotton production in the two largest cotton producing states, i.e., Texas and Georgia. Specifically, the study characterized the major storms experienced in the two states over five decades and compared the effects of these storms on cotton yield and output. It is hypothesized that major storms can have significant adverse effects on cotton yield and output if they arrive when the cotton is most vulnerable, i.e., when it is flowering or at the boll stage. High rainfall that often occurs with storms would break the cotton ball and have significant adverse impact on yield and output. Similarly, if the storms are packed with high winds, then they might destroy the cotton plants by blowing them down, breaking stems and destroying bolls. However, if the storms come when the crop is not yet in boll, then they may have little or no impact on yield and/or output. It is also important to note that while a storm may make landfall, it may not have enough energy in it to reach cotton growing areas, and will therefore have not impact on yield and/or output.

The study’s results show that storms have had no statistical impact on either cotton yield or output in Texas. In Georgia, yield in years before 1995 when there are storms is statistically significant different from yield in years without storms in the same period. However, yield in years after 1995 when there are storms and in years when there are no

storms are both higher than the yield in years before 1995 without storms. Both of them are statistically different at the 5% level of significance. The difference in output followed the same pattern, but the level of statistically significant was at the 1% level. It was found that yield in both states responded to price lagged one period, suggesting that getting a higher price for cotton allowed farmers to make the necessary investment in the following year's crop to improve yield and output. While lagged price influenced output in Texas, its effect was not statistically significant in Georgia.

The results suggest that over the past 50 years, on average, storms may not have the long-term impact on cotton production as may be thought. However, this does not mean that in the year that a storm hit, cotton farmers do not experience real challenges. Using the long-term analysis would lead to the suggestion that focusing on technologies that improved the ability of the cotton plant to withstand winds and heavy rain could address the challenges that occur on cotton farms during storms. It will be prudent, however, to focus on strategies that improved cotton prices so that farmers can make the necessary investments in their production to improve yields. Better financial performance would help cotton farmers deal with adverse natural events like storms because they could improve their financial resilience through savings. Future research should explore this further.

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# CHAPTER I: INTRODUCTION

On October 9, 2018, Hurricane Michael made landfall in the Florida panhandle as a Category 5 hurricane. It was the first Category 5 storm to make landfall in the United States, after Hurricane Andrew in 1992 (Facts + Statistics: Hurricanes 2020). Throughout the next twenty-four hours, it cut a path of destruction through southeastern Alabama and southwestern Georgia. Damage to beach towns in Florida was widely reported by the media. However, the inland agricultural communities in Hurricane Michael's path, which also sustained significant and long-lasting economic effects, did not become front page news in many communities. Farmers in southwest Georgia continue to struggle in their attempts to overcome their devastating losses to crops, cattle, timber, and equipment, such as irrigation systems. Since Hurricane Michael, the cotton crop experienced the highest immediate economic losses while wind damage caused long-term total loss to timber. Studies show that, showed that 2,368,226 acres of forestland were impacted by Hurricane Michael with 20,510,889 tons of pine and 17,178,721 tons of hardwood being damaged with an estimated value of $762,683,909 of timber damages in Georgia (Commission 2018). Category 5 hurricanes making landfall are rare. In their rarity lies the challenge of dealing with their consequences. Therefore, southwest Georgia farmers who were affected by Hurricane Michael are still dealing with its effects, more than a year after.

August 25, 2017 was the day that Hurricane Harvey made landfall in Texas as a Category 4 hurricane. Hurricane Harvey became the country's first major — Category 3 or higher — hurricane to strike southern Texas since Hurricane Celia in 1970. It kicked off a historically destructive 2017 storm season for the Caribbean and the southern U.S. Causing about $125 billion in damage, Harvey was ranked one of the most destructive and costly hurricanes to hit the U.S. mainland since the early 1900s (Huber, World Vision 2018). The agricultural losses attributed to Hurricane Harvey were also staggering: About $8 million for rice and soybeans; $93 million for livestock; and $100 million for cotton (Fannin 2017). Totaling an agricultural loss approximately over $200 million, which was devasting to many in the agricultural sector due to an already declining economy.

While Hurricane Michael and Hurricane Harvey may be the most recent and most destructive hurricanes to hit Georgia and Texas, , the region has seen intermittent destructions from storms throughout history. Prior to Hurricane Michael, Georgia had not had a direct hit by a storm with Michael's rain and wind ferocity in more than 40 years. Hurricane David (1979), Opal (1995) and Irma (2017) all made landfall in Georgia. But they did not have the winds or the amount of rain seen with Michael. Texas, on the other hand, has not been as fortunate. Hurricane Celia (1970), Allen (1980), Alicia (1983), Bret (1999), Rita (2005), and Ike (2008) are some of the hurricanes to have impacted Texas over the years.

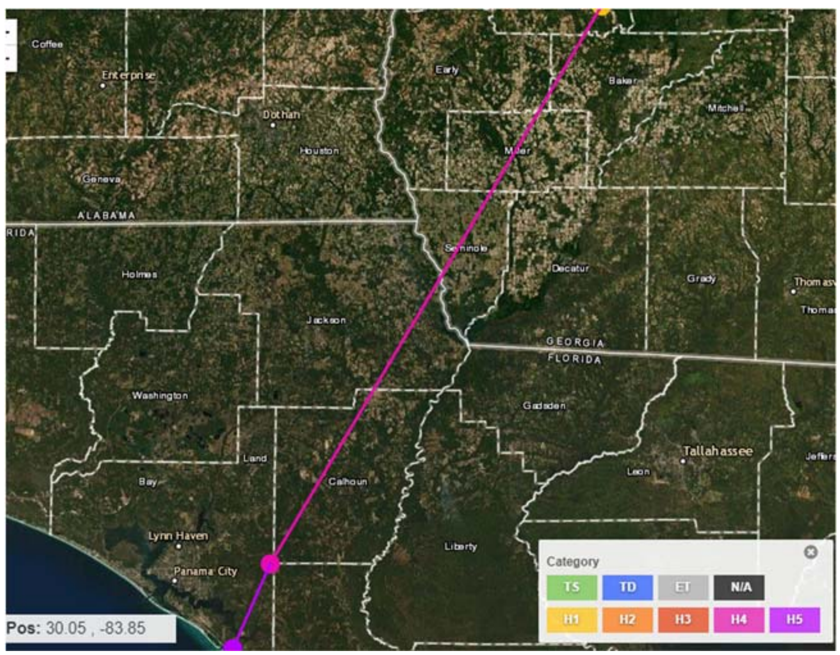
Agriculture is one of the largest essential sources of revenue for Georgia at approximately over $70 billion (About Georgia Agriculture 2020) and Texas at approximately over $20 billion (Texas Department of Agriculture 2020). Row crop farming is an agricultural occupation that is responsible for many people's livelihoods, not just the farmer, farm family or farm land owner. Other agricultural businesses such as: crop insurance companies, seed and chemical companies, equipment companies, crop consultants and many other businesses depend on farming. Those whom may not have an abundance of knowledge in agriculture or row crop farming, may not know just how much these hurricanes, tropical storms or the weather patterns in general may potentially and has already impacted a crop and all other aspects of agriculture.

Farming is a risky business. Many factors that contribute to a profitable crop are entirely out of farmers' control. Although farmers try to mitigate most of the risks that affect their business, many are difficult to control completely. For example, while farmers may use irrigation to control drought, storms may dump too much rain and create flooding, destroying crops. Hurricanes, by their very nature, are uncertain events against which effective mitigation is impossible. Frank Knight (1921) discusses this impossibility of dealing with uncertainty in his work separating the nature of risk from uncertainty. These uncertainties are anticipated, and risk management strategies are usually employed to combat them.

### 1.1 History of Hurricanes in Georgia and Texas

Southwest Georgia farmers were utterly blindsided when Hurricane Michael remained a Category 4 hurricane more than 100 miles inland (Figure 1). Prior to Hurricane Michael, it had been almost 120 years since a major hurricane had hit the state of Georgia, much less Southwest Georgia. Consequently, very few people were unprepared for its impact. , The last major hurricane made landfall in 1893 on the East Coast close to Savannah, Georgia. In 2017, Hurricane Irma had decreased to a tropical storm by the time it arrived in Georgia and mostly consisted of rainfall estimated around five inches with none of the damaging winds accompanying Hurricane Michael. While Texas has ultimately been impacted by more hurricanes and tropical storms than Georgia, the same can be said for Texas farmers when they were hit by Hurricane Harvey. In 2017, Hurricane Harvey first made landfall on San Jose Island, Texas as a Category 4 hurricane with winds of 130 miles per hour (Figure 2). The hurricane then stalled over Texas as a tropical storm, and in the Houston metropolitan area many locations recorded over 30 inches of rain within a three-day period. (Geoscience News and Information 2020)  Figure 1.1 tracks the final path and intensity of Hurricane Michael. Hurricanes don't always follow a straight line as shown in Figure 1.2. Hurricane Harvey made its initial landfall in Texas, curved back into the Gulf and made a second landfall in Louisiana. Historically most of all U.S. Hurricanes come through the Gulf before making landfall as depicted in Figure 1.3.

**Figure 1.1 Track and Intensity of Hurricane Michael**




(Source: NOAA)

**Figure 1.2 Track and Intensity of Hurricane Harvey**


(Source: NOAA)

## 1.2 Agriculture in Georgia and Texas

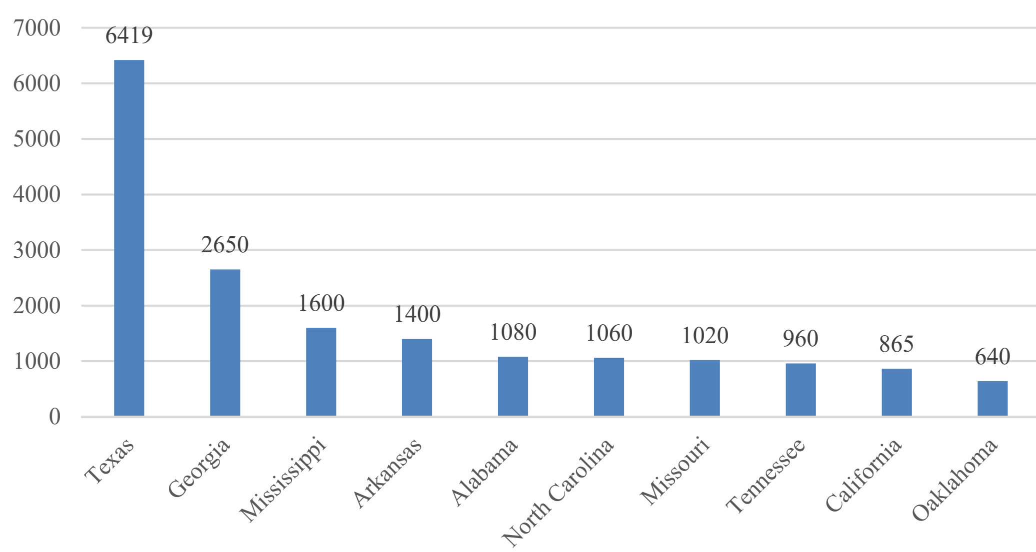
Cotton and peanuts are indisputably the cash crops of southwest Georgia, but other farming enterprises were harmed as well. According to University of Georgia Extension agents and agricultural economists, Georgia's agricultural industry is estimated to have incurred more than $2.5 billion in losses due to Hurricane Michael in October of 2018. (University of Georgia Cooperative Extension, 2018). Some of the direct losses from Hurricane Michael are estimated at: timber $763 million, pecans $100 million, and cotton $550-600 million (University of Georgia Cooperative Extension 2018). Vegetables, poultry, livestock, peanut, soybeans, nursery, greenhouses, and turf all sustained significant losses as well.

As listed below in Figure 1.3, Texas leads all other states in numbers of farms and ranches with cotton being one of the States most essential cash crops. Dr. John Robinson, AgriLife Extension cotton marketing economist in College Station, observed that prior to Hurricane Harvey,

> You either had cotton that was on the stalk ready to be harvested and then taken out by Hurricane Harvey, or you had cotton modules sitting in the field only to have been damaged by wind, rain and/or flood water. The Southeast Texas cotton crop was set to be one of the best of all time. You've got reports from ginners who have ginning quality concerns related to seed coat problems, poor leaf grade and trash (Fannin 2017).

Due to a declining economy, no control over the weather, yield prices being at an all-time low, tariff wars, and the overall cost of production increasing, most Texas farmers are in the same predicament as the Georgian farmers.

**Figure 1.3: Leading U.S. States in Cotton Production 2019 in 1,000 bales**




Source: (Merritt 2020)

### 1.3 The Problem: Hurricanes and agricultural performance in Georgia and Texas

Hurricanes have two major factors that can play a role in crop destruction; one is the rain, and the other is the wind.

Hurricane Harvey along with other past hurricanes and tropical storms have caused some of these same effects to the row crops in Texas. Extreme winds and rainfall from hurricanes are not the only things that can be damaging to the cotton crop. On a normal day without hurricanes and tropical storms, weather still plays a vital role in the growth and picking ability of row crops, cotton in particular.

The vast majority of the farmers had already picked their peanut crops during the time of impact from Hurricane Michael and Hurricane Harvey, but those who planted their peanut crop later in the season were not able to finish gathering their crop and ultimately suffered damages to their peanut crop as well. However, hurricanes, tropical storms and common weather issues can also cause peanut harvest acreage to have a few different kinds of damage, just like cotton. If the peanut vines have been flipped and the peanuts were on top of the ground, they could potentially be exposed to flooding rains and high winds. In the case of the peanut fields where they have not been plowed before these extreme weather situations, those legumes can remain in very wet conditions for an extended length of time. Peanut fields that are too wet to enter after the hurricanes or extreme weather conditions, can potentially lead to output losses in terms of poor yield and low-grade products associated with the storm.

Unlike peanuts, cotton is a much weaker row crop and is not able to withstand as much damage as peanuts. Not only is cotton more costly to grow, cotton also requires a lot more assistance during its life cycle. Hurricane Harvey along with other past hurricanes and tropical storms have caused some of these same effects to the row crops in Texas. Extreme winds and rainfall from hurricanes are not the only things that can be damaging to the cotton crop. On a normal day without hurricanes and tropical storms, weather still plays a vital role in the growth and picking ability of row crops, cotton in particular. Detrimental impacts from storms and hurricanes could destroy a whole cotton crop, making it a total loss. Excessive amounts of rainfall and high winds could very likely destroy a cotton drop due to it being a much weaker crop and not being able to withstand such blows and still be able to make a recovery afterwards. The major effects that rainfall and wind have on the cotton crop during its lifecycle are discussed below:

### *1.3.1 Rainfall*

In the beginning stages of the cotton crop life cycle before it has bloomed, tropical Storms and hurricanes that may occur early in the growing season have the potential to dump large amounts of rainfall into the affected regions, resulting in significant amounts of erosion or flooding of the fields. This could potentially cause the planted crop to be a total loss. Not only can these same rains cause flooding, they can cause loss of fertilizer due to leaching. Run off of fertilizer, pesticides and nutrient loss can also be responsible for a much lower cotton yield, resulting in a loss of profit. Rainfall is also a good indicator used to predict common crop disease and can greatly help the crop consultant identify such issues. Excessive rainfall in the early stages can cause devasting effects to the crops for future planning and cause complications for a crop rotation Crop rotations are used by farmers and their consultants, the rotations of row crops help keep minerals, nutrients and fertilizer in the field. Planting of the same row crop in the same field in consecutive years can strip the fields of their vital components. Without the vital components in the soil, you can expect a poor yield.

In the latter stages of the cotton life cycle, rain can still be detrimental to the cotton crop. Storms that occur during the blooming stages can have the same affects as listed above on the cotton crop, if not worse effects. Wet conditions that occur during the time cotton is opening, generally results in greater losses in cotton lint due to boll rot and hard-lock. Boll rot is a common rot of cotton bolls caused by various fungi (such as Glomerella gossypii or Diplodia gossypii), (Merriam Webster 2020). Unfortunately, once boll rot has set in on the cotton bolls, rarely is the boll able to be saved from this. What is cotton root rot? This disease is caused by the fungus Phymatotrichum omnivorum. "Omnivarium" indeed. The fungus colonizes the roots of a plant, gradually killing them off and reducing its health. This voracious fungus is one of the most destructive diseases of cotton (Gran 2018). A lot like boll rot, root rot is also very had to get rid of and usually only affects the cotton crop in latter stages of the lifecycle and after an abundance of rainfall.

*1.3.2 Wind*

A lot like rainfall, wind effects cotton differently depending on the stages it is in during its lifecycle. Early season storms can have different effects than those in the latter stages of the growth periods. Early season storms have the potential to blow over the cotton over, but young cotton can typically recover and stands back up if it's over 2 inches tall. Too much wind leads to breakage of the plants themselves. With damaged plants come poor harvest, resulting in lower yields.

In the event storms occur when the cotton begins blooming can have the same impacts as stated above, but can also blow the cotton over to the point that it will not stand back up, as it would if it were in the earlier stages. The application of fertilizer or spray applications can no longer be made once the cotton has been blown over past recovery.

Also, cotton that has blown down at this stage will make harvesting nearly impossible. The outcome of trying to harvest this cotton was diabolical. Cotton did not come off of the stalk as it should because of the wind. Such strong winds caused stalks to blow to the ground and entangle with each other.  The entanglement of stalks makes it hard for the cotton picker spindles to properly function to remove the cotton from the stalks.  Also causing damage to the cotton picker machines. Realizing the futility of their efforts, many farmers halted the picking.  Cotton blown over or down has more bark in the lint, resulting in a grade deduction at the classing office when it's being graded.  The greatest period of loss for cotton is once it is fully opened, has been defoliated and ready for harvest. Also, in other situations, the exposed cotton was still intact, and the plants were upright, just bent slightly by the wind.

### 1.4 Research Question

The aforementioned phenomena elicit the following question: What are the potential impacts of large storms on cotton production in Georgia and Texas?  This question is important because answering it will help determine whether cotton production in Texas and Georgia are affected differently by storms over the years.  It will also allow farmers in those two states and their policymakers to determine whether storm intensity and timing have effect on cotton production.

### 1.5 Research Objectives

Based on the foregoing question, the overall objective of this research is to assess the impact of major storms on cotton production in the two largest cotton producing states, i.e., Texas and Georgia. The specific objectives are as follows:

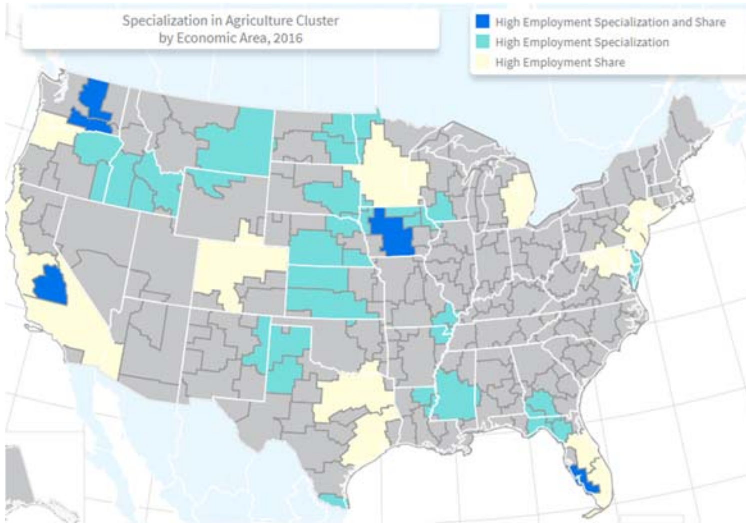
1. Characterize the major storms over the past several decades and identify the characteristics of those that have made landfall in Georgia and Texas.

2. Compare the effects of the major storms that have made landfall in Georgia and Texas and determine the relationship between the intensity of the storm and its impact on cotton production in Georgia and Texas.
3. Use the results to develop some preparatory strategies for cotton farmers and their policymakers in Georgia and Texas.

### 1.6 Significance of Study

This study is critical to these states because the economic health of rural Georgia and Texas communities is highly dependent on agriculture. Non-agricultural businesses rely heavily on farmers as well as owners and employees of agribusiness for their customer base in rural areas. According to the United States Economic Development Administration, there is high employment specialization in the agriculture cluster in the Southwest Georgia region (Figure 1.5). An increase in employment specialization can make people less mobile between occupations. One out of seven Georgians work in agriculture, forestry, or similar related fields. Georgia is perennially the number one state in the nation in the production of peanuts, broilers (chickens), pecans, blueberries and spring onions. Georgia is also at or near the top when it comes to cotton, watermelon, peaches, eggs, cucumbers, sweet corn, bell peppers, tomatoes, cantaloupes, rye and cabbage (Georgia Farm Bureau 2020). Like Georgia, agriculture employs one out of every seven working Texans. Texas is one of the leading exporters of agricultural commodities. Some of Texas' top agricultural exports are live animals and meat, cotton and cottonseed, feed grains and products, hides and skins, wheat and products, and feeds and fodder (Staples 2013). So in regards to weather, States who have that much dependency on agriculture it creates long-lasting problems for people beyond the farmers on whom we have placed the focus of this study.

**Figure 1.4 Specialization in Agriculture Cluster**




Source: US Economic Development Administration

Farmers affected by crop losses are joined by employees and agricultural-related industries including those selling seed, chemicals, and equipment and those in the processing business. Even local businesses unrelated to agriculture, clothing stores, gift shops, and restaurants, for instance, are indirectly impacted. The weather-related disaster and crop losses result in fewer dollars circulating in the local economy. In addition, the tax base can shrink when farmers are unable to pay outstanding taxes, resulting in a budget crunch for local city, and county governments and the school system. Therefore, an examination of the losses and their effects is a significant inquiry.

1.7 Outline of the Thesis

The foregoing chapter, Chapter 1, provided an overview of the research problem and the objectives. A review of literature is presented in Chapter 2. Chapter 3 provides the data and methods used to answer the foregoing research problem and the objectives. Chapter 4 provides the results from the provided storm and yield data and ends with a discussion of the ending results.  Lastly, Chapter 5 provides the conclusion and future recommendations for any future research.

# CHAPTER II: LITERATURE REVIEW

This chapter is divided into four major sections. The first looks at the nature of risks and vulnerability. It assesses the frequency, duration and intensity of storms that have made landfall in Georgia and Texas over the past several decades. Cotton is important to Georgia and Texas. Cotton production, like other agricultural production, is susceptible to storms, especially big storms that pack wind and rain. Wind breaks stalks and make harvesting difficult. Rain causes flooding, which leads to leaching of nutrients, root rot, fungal infestation and other diseases. The effect of the storms may be captured in the harvested area and output/yield over time. The second section presents an overview of Georgia and Texas' agricultural sector and its distribution by county. The section also explores the areas that have been most prone to storm hits over the past. The third section presents the literature on storms and their impact on agricultural production. The last section presents a review of the economic impacts of storms on Georgia and Texas over the years.

## 2.1 Storm trends in Georgia and Texas

Hurricane Michael is one of the strongest storms to hit southwest Georgia in over 120 years. Previous hurricanes, such as Hurricane Irma in 2017, brought mostly rain without the high winds that accompanied Hurricane Michael (www.weather.goc/ffc/2017_Irma, n.d.). Hurricane Harvey is also one of the strongest hurricanes to hit Texas even though the state experiences more tropical storm activity than Georgia. Hurricane Harvey's damage exceeded that caused by any of the preceding hurricanes in recent memory, such as Hurricane Patricia and Hurricane Newton (Wikipedia n.d.).

According to National Oceanic and Atmospheric Administration (NOAA),the peak hurricane season for the Atlantic Basin, which includes the Gulf of Mexico, is mid-August through late October. Unfortunately, this period coincides with pre-harvest and harvest season for cotton in both Georgia and Texas. Hurricane Michael made landfall prior to cotton harvest. However, the crop was at its most vulnerable stage, with bolls open and exposed to the high winds and heavy rain. Texas was in the same situation with its cotton crop when Hurricane Harvey made landfall in 2017.

There are three categories of storms: tropical storms, hurricanes, and major hurricanes. Within each storm category, there are different intensity of storms, labeled 0 through 4, with Category 4 storms being the most damaging in terms of speed and probable rainfall. The distribution of these have already been presented in Chapter 2. What is left to say here is that there is potential relationship between the storm category and its intensity on the performance of the cotton industry.

A major hurricane is classified as a Category 3 or higher on the Saffir-Simpson Hurricane Wind Scale. A “0” represents no recorded tropical activity for that storm type or year. Texas has far more tropical activity than the state of Georgia, often hurricanes downgrade to tropical storms by the time they get to Georgia rarely does the state have a hurricane make landfall on the Atlantic coast due the way the state aligns with the Bermuda High, a large high pressure system, where the air circulates clockwise causing most storms to end up on the left side of the pressure system making the storm curve and head northward away from the Georgia coast. Only 7% of tropical storms originating in the Atlantic Ocean affect Georgia (Strother 2019). Both states still having very few “Major Hurricanes.” This helped to organize all of the research data gathered to better be able to run models and distinguish different aspects to better determine our results to the objectives.

Table 2.1 shows the number of thunderstorms that have hit Georgia and Texas over the past 50 years (1970-2019). Thunderstorm column representing the number of thunderstorms in a number of years. 0 representing no storms for that year, 1 representing 1 storm for the year, 2 representing 2 storms for the year and 3 presenting 3 thunderstorms. As listed below, 62 percent of the time there were no thunderstorms in Georgia, 34 percent of the time there was 1 thunderstorm and 4 percent of the time there was 2 thunderstorms in Georgia in a given year. In regards to Texas, 34 percent of the time there were no thunderstorms in a year, 46 percent of the thunderstorms happened in one year, 16 percent of the time there was 2 thunderstorms and 4 percent of the time there was 3 or more thunderstorms in Texas. Table 2.2 represents the number of hurricanes in Georgia in Texas (1970-2019)

**Table 2.1: Number of Thunderstorms in Georgia and Texas (1970-2019)**

| Thunderstorm | Georgia | Texas |
|---|---|---|
| 0 | 62.00 | 34.00 |
| 1 | 34.00 | 46.00 |
| 2 | 4.00 | 16.00 |
| 3 | - | 4.00 |

Table 2.2 shows the number of hurricanes that have hit Georgia and Texas over the past 50 years (1970-2019). The hurricane column representing the number of hurricanes in a number of years. 0 representing no storms for that year, 1 representing 1 hurricane for the year, 2 representing 2 hurricanes for the year, 3 presenting 3 hurricanes for the year and 4 representing 4 of more hurricanes for that given years. As listed below, 88 percent of the time there were no hurricanes in Georgia, 12 percent of the time there was 1 hurricane. At no point has Georgia experienced 2 or 3 hurricanes in a given year. In regards to Texas, 38 percent of the time there were no hurricanes in a year, 44 percent of the time they were

impacted by 1 hurricane in a year, 10 percent of the time there was 2 hurricanes, 6 percent of the time there was 3 hurricanes and 2 percent of the time Texas has been hit by 4 or more hurricanes in given year. Table 2.3 represents the number of major hurricanes in Georgia in Texas (1970-2019).

**Table 2.2: Number of Hurricanes in Georgia and Texas (1970-2019)**

| Hurricane | Georgia | Texas |
|---|---|---|
| 0 | 88.00 | 38.00 |
| 1 | 12.00 | 44.00 |
| 2 | - | 10.00 |
| 3 | - | 6.00 |
| 4 | - | 2.00 |

Table 2.3 shows the number of major hurricanes that have impacted Georgia and Texas over the past 50 years (1970-2019). The major hurricane column representing the number of major hurricanes in a number of years. 0 representing no major hurricanes for that year and1 representing 1 major hurricane for the year. As listed below, 94 percent of the time there were no hurricanes in Georgia, 6 percent of the time there was 1 major hurricane. At no point has Georgia experienced 2, 3 or 4 major hurricanes in a given year. In regards to Texas, 88 percent of the time there were no hurricanes in a year and 12 percent of the time the state was impacted by 1 hurricane in a year. Also, at no point has Texas experienced 2, 3 or 4 major hurricanes in a given year.

**Table 2.3: Number of Major Hurricanes in Georgia and Texas (1970-2019)**

| Major Hurricanes | Georgia | Texas |
|---|---|---|
| 0 | 94.00 | 88.00 |
| 1 | 6.00 | 12.00 |
| 2 | - | - |
| 3 | - | - |

### 2.3 Crop performance and how it is affected by storms

Cotton and peanuts are the two main crops that are produced during hurricane season in Georgia and Texas. They are both at risk of having too much rain and wind in the event of hurricanes or major storms (cottongower.com n.d.).

Annually, agriculture contributes approximately $73.3 billion to Georgia's economy. University of Georgia College of Agricultural and Environmental Sciences estimated Hurricane Michael caused a Georgia cotton crop loss from $550 million to $600 million in lost lint and seed and an estimated $10 million to $20 million in peanut crop loss. Before the storm, 40 to 45 percent of Georgia's peanuts crop was still in the field and due to being unable to dig peanuts at the quality time to harvest, most farmers did not make a good yield with good quality. The peanut industry also felt a hardship as most buying points and peanut shellers were damaged or destroyed during the storm.

The agronomy of the cotton plant and timing of the storms plays a big role in the industry's performance. Too much rain early in the season delays planting, resulting in late gathering. The gathering season typically is during hurricane season. A late planting, therefore, exposes cotton crop to the adverse effects of storms when the season happens to have active storm activity. When hurricanes pass over areas where plants are growing, the crops suffer the effects of strong winds and heavy rains that accompany it, damaging the plants by causing fractures, bends or other injury, all of which lead to decreased yield. After the hurricanes or tropical storms, cotton plants that manage to survive the winds are still in at risk of pathogens that can take up in fields due to high concentrations of humidity. These pathogens can be viral, bacterial, or fungal. They all either kill or reduce the vitality of the plants, causing yields to decline. Another effect of heavy rains accompanying storms is leaching and/or washing away of nutrients. The loss of nutrients to crops in the most vulnerable stage of growth also contribute to yield reductions.

**2.4 Economic impacts from storms in Georgia and Texas**

In 2018, agriculture economist John McKissick predicted to state legislators that Georgia likely would not regain its spot as one of the nation's top producing state in cotton for many years. Legislators and the governor approved $75 million in low-interest agriculture loans, and the Georgia Department of Agriculture quickly distributed it (Kempner 2019). Aging farmers who did not have crop insurance had to file for bankruptcy in order to cover existing farm loans ( (Kempner 2019). Others had to increase debt by using long time paid-off property as collateral in attempts to keep their operations going. Some Georgia farmers were still dealing with losses from difficult weather in 2017. The drought in the previous months prior to the hurricane, along with intense internal competition and depressed prices, had already increased to existing debts.

Texas, being another large cotton producing state, has also suffered economically from the impacts of hurricanes. After Hurricane Harvey, Texas had an estimated $100 million worth of cotton losses. Many farmers stated that 2017 was to be "the best crop year of all times". As stated above, aging farmers who did not have crop insurance had to file bankruptcy. Low interest loans were given to assist the struggling farmers and debt was increased on existed debt in order to keep operations moving.

Storms can have devastating effect on states. However, it is their effect on individuals that often becomes lost in the analysis. The literature review has shown that the after effects of storms can put significant financial burden on farmers when their yields are affected and their financial cushions are limited. Sometimes, these storms put people out of business, and the recovery of those who survive can take years, if not decades. The original intent of this research was to survey farmers to get to these human stories of economic damage from storms.  However, time and resource constraints prevented such as study. However, this current study becomes the pre-study to the original study, allowing future researchers into how storms disrupt the business life cotton producers in Georgia and Texas develop a foundation of the role of storms in cotton production.

# CHAPTER III: DATA AND METHODS

This chapter discusses the data and methods used to conduct the analyses in this research. It is organized into three sections: the first section discusses the data used; the second discusses the conceptual and analytical methods; and the last section presents the summary statistics of main variables used in the models.

## 3.1 Data

The research used data collected from the National Oceanic and Atmospheric Administration (NOAA) on the number tropical storms, hurricanes and major hurricanes that have impacted Georgia and Texas over the past 50 years. Also, this study used secondary data from the United States Department of Agriculture's National Agricultural Statistics Service (NASS) on production and prices.

The storm data were collected for the two major cotton producing states in the country: Georgia and Texas. Georgia is included in the study because the author lives and works in Georgia and her family is involved in Georgia's agriculture. From Figure 1.1, we show why Texas is included in the study: it is the leading cotton producing state in the country. Table 3.1 provides a summary of the justification of the inclusion of Texas in the study. It shows that it accounted for an average of about 55% of the total area planted to cotton in the US between 2016 and 2019 and 48.3% of total harvested acreage in the country. Georgia, on the other hand, contributed an average of 12.1% and 10.5% of harvested and planted acreage in the US over the same period. Georgia and Texas together accounted for more than half of the cotton produced in the US on average, between 2016 and 2019. Georgia's average share of national cotton production was almost 12% compared to Texas' share of about 40%. What is interesting in the table is that Georgia's share of production decreased in 2016 and did not come back up until 2019, and Texas' share also decreased in 2017 and it is still not back to its original share. While this may be a result of other states improving their production, there is no doubt that the impact of Hurricane Michael and Hurricane Harvey are still lingering on in both states.

**Table 3.1: Georgia and Texas in National Cotton Production**

| | Georgia | | | Texas | | |
|---|---|---|---|---|---|---|
| | Cotton Production | Planted | Harvested | Cotton Production | Planted | Harvested |
| 2016 | 12.7% | 11.7% | 12.3% | 47.4% | 56.3% | 54.8% |
| 2017 | 10.6% | 10.1% | 11.4% | 44.4% | 55.2% | 49.7% |
| 2018 | 10.6% | 10.1% | 12.8% | 37.5% | 55.1% | 42.8% |
| 2019 | 13.2% | 10.2% | 11.8% | 31.9% | 51.4% | 45.8% |

Source: National Agricultural Statistics Service (NASS)

### 3.2 Conceptual and Analytical Methods

A central objective of the research is to determine the effect of storms on the cotton industry in Georgia and Texas. The storm effect is assessed on two industry indicators: yield; and production. It is hypothesized that the yield for the cotton crop in the two states being studied is affected by storms occurring in the production year. Because there are not enough observations for the different categories of storms, the storm data were re-organized into a binary variable, where 0 corresponded with years without any storm activity, and 1 represented years with storm activity, regardless of the type and intensity. The effects of storms on production and yield were controlled by cotton price.

The empirical model is based on the ordinary least square (OLS) regression. The generic model is specified as follows:

$$Y = a + bP_{t-1} + cS_i + \varepsilon$$

Where Y is yield, P is price, S is the storm counter and ε is the regression error term, assumed to have zero means and a constant variance. When the variance assumption is violated, then the problem of heteroscedasticity rears its head into the analysis. The price variable is lagged one period based on the assumption that current year's prices influence the acreage and other agronomic investments that farmers make in order to boost yield in the following year.

### *3.2.1 Hypothesis*

It is hypothesized that the coefficient on price would be positive, i.e., higher prices in the preceding year would motivate farmers to make the necessary investments to increase their yield in the current year.  This is understandable since a higher price in the preceding year implies better income position for farmers in the current year, *ceteris paribus*, giving them the wherewithal to purchase better seeds, chemicals, fertilizer and above all hope for a better price in the current year. This hypothesis may be presented thus:

$$H0: b > 0$$

It is hypothesized that the coefficient that the storm counter is to intensify the impact on the crops. Intensified impact on the crops will lead to a larger impact in yields. Farmers would turn to alternate means to protect their crops and such investment in the crops. This will likely be in the form of changing brands of seed and chemicals, or simply changing when crops are planted and harvested.

## **3.3 Summary Statistics of Data**

Storm and hurricanes were categorical or binary, depending on how they were coded.  The first coding format was based on whether there was a storm/hurricane activity in the year. The second format the severity of storms occurring. The third was the major hurricanes occurring over time. The final structure was a continuous variable, presenting the number of storm/hurricane events occurring in any year.

Table 3.2 presents the summary statistics for cotton acreage planted and harvested in Georgia and Texas over the study period. The table shows that the average area planted in Georgia was about 821,140 acres per year compared to more than 5.95 million acres per year in Texas. The harvested area in Georgia was 793,680 acres per year, approximately, implying that an average of about 27,460 acres per year of planted cotton acreage was not harvested. The unharvested cotton acreage in Texas was about 1.1 million acres per year. The range of planted acreage and harvested in Georgia were, respectively, 1.48 million acres and 1.38 million acres over the 50 years. In Texas, the range was 3.85 million for planted and 4.35 million acres for harvested. The below data shows that the probability of a major hurricane in Georgia over the past 50 years (1970-2019) was 0.06 compared to 0.12 in Texas.

**Table 3.2: Summary of Statistics of Cotton Acreage Planted and Harvested in Georgia and Texas (1970-2019)**

| Variable | Average | Std. Dev. | Minimum | Maximum | Coef. Var. |
|---|---|---|---|---|---|
| GA_COTTON - ACRES PLANTED | 821,140 | 536,612 | 120,000 | 1,600,000 | 0.653 |
| GA_COTTON - ACRES HARVESTED | 793,680 | 521,821 | 115,000 | 1,495,000 | 0.657 |
| TX_COTTON - ACRES PLANTED | 5,951,116 | 930,099 | 4,022,400 | 7,873,000 | 0.156 |
| TX_COTTON - ACRES HARVESTED | 4,860,772 | 1,065,897 | 2,868,500 | 7,217,600 | 0.219 |

The ratio of harvested to planted acreage for Georgia and the incidence of storms, hurricanes and major hurricanes are presented in Figure 3.1. The figure shows that the though the ratio trends in general coincide with a storm or hurricane activity. There are few years that low ratio of harvested to planted cotton acreage did not coincide with a storm or hurricane. For example, Hurricane Michael (a major hurricane) in 2018 coincided with a ratio of about 91% while the lowest ratio in the 50 years of about 74% was also a hurricane year.

In Table 3.3, the summary of statistics of Georgia's cotton acreage in years with and without storms are presented. The table shows that there was a decrease in the average ratio of acres harvested compared to planted regardless of a storm or no storm.

**Table 2.3: Summary of Statistics for Georgia Cotton Acreage With and Without Storms (1970-2019)**

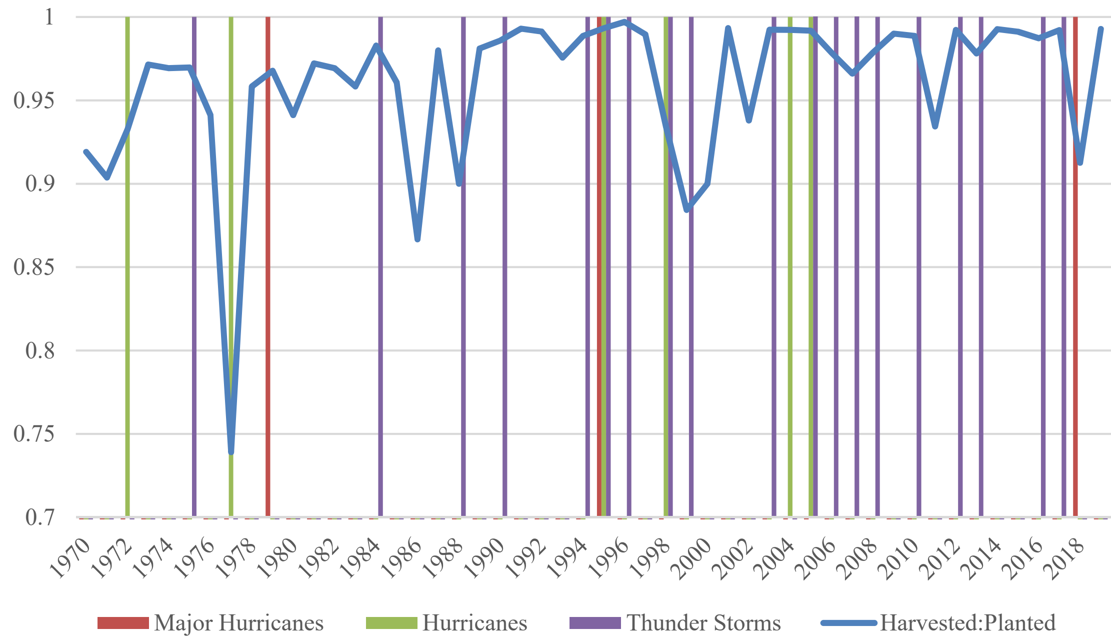
| Variable | Average | Std. Dev. | Minimum | Maximum | Coef. Var. |
|---|---|---|---|---|---|
| | | | **No Storm** | | |
| Planted Acreage | 674,654 | 543,840 | 120,000 | 1,600,000 | 0.806 |
| Harvested Acreage | 650,615 | 525,532 | 115,000 | 1,495,000 | 0.808 |
| | | | **Storm** | | |
| Planted Acreage | 979,833 | 491,373 | 155,000 | 1,500,000 | 0.501 |
| Harvested Acreage | 948,667 | 481,361 | 150,000 | 1,490,000 | 0.507 |

In Table 3.4, the summary of statistics of Texas' cotton acreage in years with and without storms are presented. The table shows that Texas had a more drastic decrease in the average ratio of acres harvested compared to planted.

**Table 3.3: Summary Statistics for Texas Cotton Acreage With and Without Storms (1970-2019)**

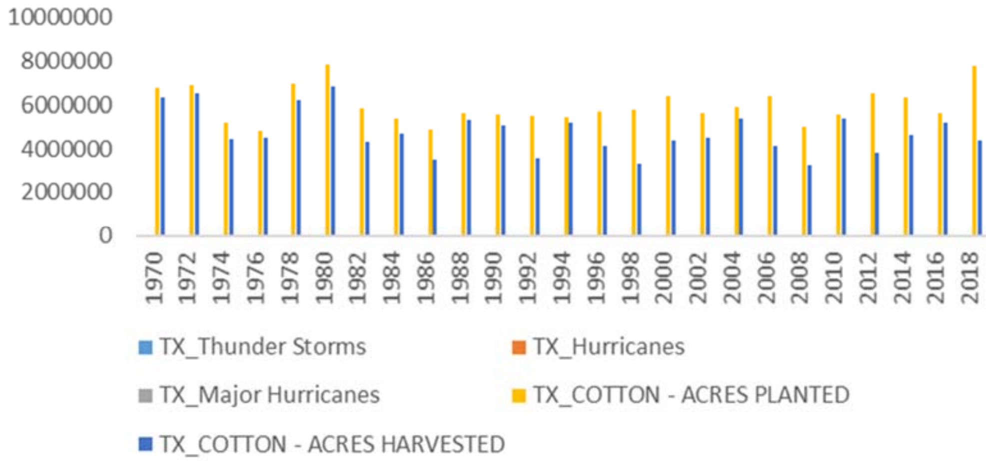
| Variable | Average | Std. Dev. | Minimum | Maximum | Coef. Var. |
|---|---|---|---|---|---|
| | | | **No Storm** | | |
| Planted Acreage | 6,257,150 | 1,334,938 | 4,808,600 | 7,768,000 | 0.213 |
| Harvested Acreage | 5,151,875 | 975,309 | 4,367,500 | 6,500,000 | 0.189 |
| | | | **Storm** | | |
| Planted Acreage | 5,924,504 | 902,291 | 4,022,400 | 7,873,000 | 0.152 |
| Harvested Acreage | 4,835,459 | 1,079,594 | 2,868,500 | 7,217,600 | 0.223 |

**Figure 3. 1: Trend in the Ratio of Harvest: Planted Acreage Ratio and Incidence of Storms and Hurricanes in Georgia (1970-2019)**




The ratio of harvested to planted acreage for Texas and the incidence of storms, hurricanes, and major hurricanes are presented in Figure 3.2. The figure also shows that the though the ratio trends in general coincide with a storm or hurricane activity. A lot like Georgia, there are few years, if not more, that low ratio of harvested to planted cotton acreage did not coincide with a storm or hurricane. In the event that the low ratio harvest to planted acreage did not coincide with a storm or hurricane, factors such as dry land cotton fields and a possible drought could potentially explain the decrease in acres harvested to planted.

**Figure 3.2 Trend in the Ratio of Harvest: Planted Acreage Ratio and Incidence of Storms and Hurricanes in Texas (1970-2019)**



# CHAPTER IV: RESULTS AND DISCUSSION

In this chapter, the results from the analyses are presented. The chapter is laid out as follows. First, the average cotton yield in years with and without storms in Georgia (1970-2019), average cotton production in years with and without storms in Georgia (1970-2019), and the average cotton planted in years with and without storms in Georgia (1970-2019). Lastly, the average cotton yield in years with and without storms in Texas (1970-2019), average cotton production in years with and without storms in Texas (1970-2019), and the average cotton planted in years with and without storms in Texas (1970-2019).

## 4.1 Georgia Cotton

Yield in years without any storm activity averaged 139.23 pounds/acre compared to 1.70 pounds/acre in years with storm activities. The difference of 137.53 pounds/acre average statistically significant at the 1% level, with a t-value of 2.63 and P>|t| of 0.01. Interestingly, the difference is in the opposite direction, i.e., yield in years with storms were higher than yields in years without storms. The results are presented in Table 4.1.

**Table 4. 1: Average Cotton Yield in Years With and Without Storms in Georgia (1970-2019)**

| Yield (Lbs./Acre) | Coeff. | Std. Err. | t | P > \|t\| | [95% Conf. Interval] | |
|---|---|---|---|---|---|---|
| **No Storm or hurricane (0)** | 139.23 | 52.85 | 2.63 | .01 | 31.9 | 246.53 |
| **Storm or Hurricane (1)** | 1.70 | .49 | 3.48 | .001 | .71 | 2.69 |
| **Difference between Average Yield (No Storm and Storm Years)** | 137.53 | 53.99 | 1.42 | 0.00 | 31.19 | 243.64 |

If the harvest area is lower in years with storm than without storm and production is not very different, then it may explain the foregoing results. To address this, the total output in years with storm and years without storm were compared. The results, presented in Table 4.2, confirms the yield results, with the output in years with storms being, on average, 1,606,733 480-pound bales less than output in years without storms. This was statistically significant at less than 10% level.

**Table 4. 2: Average Cotton Production in Years With and Without Storms in Georgia (1970-2019)**

| Production (480-Pound Bales) | Coef. | Std. Err. | t | P>t | [95% Conf. Interval] | |
|---|---|---|---|---|---|---|
| **No Storm (0)** | 1,608,973 | 145629.8 | 11.05 | 0.00 | 1,313,329 | 1,904,617 |
| **Storm (1)** | 2239.527 | 1347.81 | 1.66 | 0.106 | -496.6726 | 4975.727 |
| **Difference (No Storm & Storm Years)** | 1,606,733.47 | 144281.99 | 9.39 | 0.106 | 1,313825.67 | 1899641.27 |

Since these results are counterintuitive, further assessment of the data was conducted, this time on production trends. Figure 3.1 shows that cotton production in Georgia exhibited a major shift in area plants between 1990 and 1995: Area planted increased from 355,000 acres to 1.5 million acres. This created a dichotomy in the data, and breaking the data up to evaluate the effect of storms could generate expected results. Table 4.3 shows the yield comparison for the two periods :1970-1992; and 1995-2019. The results show that the average cotton yield in storm years in the first period was 492.14 pound/acre compared to 539.50 pounds/acre in non-storm years. Thus, there is a difference of 45.36 pounds/acre in the average yield in the first period. This is as expected; however, the difference was not statistically different from zero. This implies that storms do not present any statistically significant effect on cotton yield or output. This may be a result of the timing of the storms. Storms' adverse effect on cotton will be immense if they come when the cotton is flowering or when the cotton is ready to be picked.

**Figure 4. 1: Trend in Area Planted to Cotton in Georgia (1970-2019)**

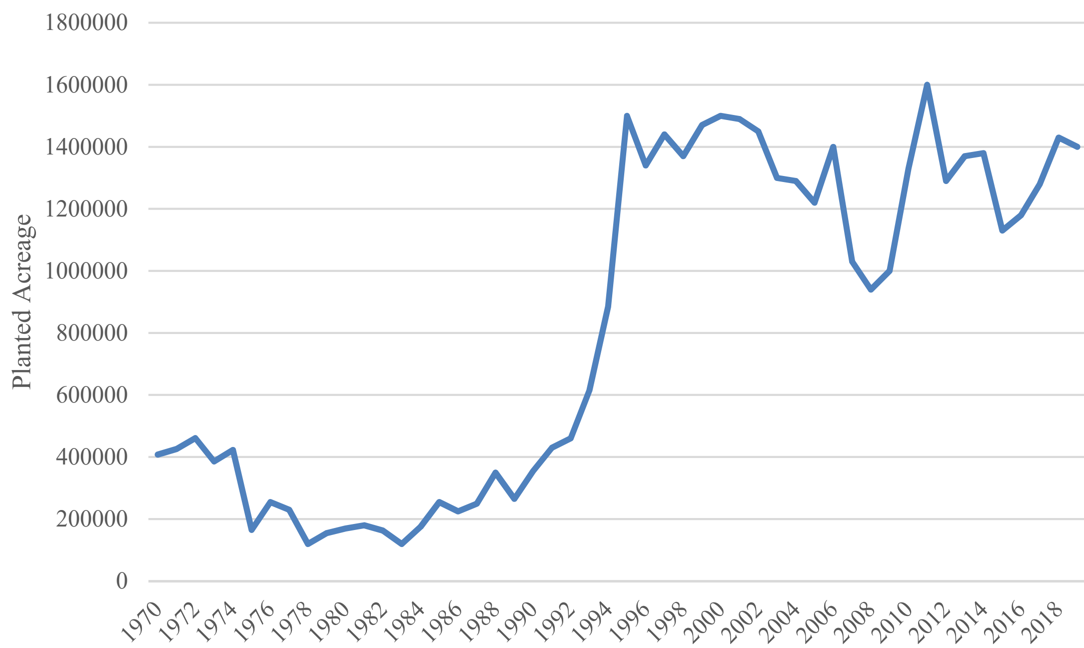



**Table 4. 3: Average Cotton Yield in Years With and Without Storms in Georgia for Period 1970-1992 and 1995-2019**

| Yield | Coef. | Std. Err. | t | P>t | [95% Conf. Interval] | |
|---|---|---|---|---|---|---|
| | | | **1970-1992** | | | |
| **No Storm (0)** | 539.50 | 40.86 | 13.20 | 0.00 | 454.52 | 624.48 |
| **Storm (1)** | 494.14 | 61.78 | 8.00 | 0.00 | 365.67 | 622.62 |
| **Difference** | -45.36 | 74.07 | -0.61 | 0.55 | -199.40 | 108.68 |
| | | | **1995-2019** | | | |
| **No Storm (0)** | 776.44 | 46.04 | 16.87 | 0.00 | 681.21 | 871.68 |
| **Storm (1)** | 780.75 | 34.53 | 22.61 | 0.00 | 709.32 | 852.18 |
| **Difference** | 4.31 | 57.55 | 0.07 | 0.94 | -114.74 | 123.35 |

Planted acres following a year with storms will be impacted and not always for the good. Georgia saw a vast decline in cotton acres planted following storms. Table 4.4 presents the results as such. The acres planted in Georgia were at a deficit following storms.

**Table 4.4 Average Cotton Acres Planted in Years With and Without Storms in Georgia (1970-2019)**

| GA cotton acres planted | Coef. | Std. Err. | t | P>t | [95% Conf. Interval] | |
|---|---|---|---|---|---|---|
| **No Storm (0)** | 1053369 | 67966.11 | 15.50 | 0.00 | 915390.7 | 1191348 |
| **Storm (1)** | -1487.2 | 629.03 | -2.36 | 0.24 | -2764.20 | -210.21 |
| **Difference (No Storm & Storm Years)** | 1054856.2 | 67337.08 | 17.86 | 0.24 | 918154.9 | 1191558.21 |

### 4.2 Texas Cotton

In contrast Texas saw the following results. Yield in years without any storm activity averaged 219.95 pounds/acre compared to 0.65 pounds/acre in years with storm activities. Table 4.5 states the difference of over 219 pounds/acre average statistically significant at the 5% level, with a t-value of 5.12 and P>|t| of 0.00. Unlike the opposition that Georgia faced Texas results were more in line with rational thought. The difference in yield in years with storms were less than yields in years without storms.

**Table 4.5 Average Cotton Yield in Years With and Without Storms in Texas (1970-2019)**

| Yield (Lbs./Acre) | Coef. | Std. Err. | t | P>t | [95% Conf. Interval] | |
|---|---|---|---|---|---|---|
| **No Storm (0)** | 219.95 | 43.00 | 5.12 | 0.00 | 132.66 | 307.25 |
| **Storm (1)** | .65 | .33 | 1.98 | 0.56 | -.02 | 1.32 |
| **Difference (No Storm & Storm Years)** | 219.3 | 42.67 | 3.14 | 0.56 | 132.68 | 305.93 |

The results of harvested cotton in Texas, presented in Table 4.6, coincides with the yield results. The output in years with storms being, on average, less than 2.1 million 480-pound bales more than output in years without storms.  This was statistically significant at almost the 46% level

**Table 4.6 Average Cotton Production in Years With and Without Storms in Texas (1970-2019)**

| Production (480-Pound Bales) | Coef. | Std. Err. | t | P>t | [95% Conf. Interval] | |
|---|---|---|---|---|---|---|
| **No Storm** | 2163236.00 | 636817.3 | 3.40 | .002 | 870428.4 | 3456044 |
| **Storm** | 3573.99 | 4886.72 | 0.73 | 0.469 | -6346.58 | 13494.57 |
| **Difference (No Storm & Storm Years)** | 2159662.01 | 631930.58 | 2.67 | -0.467 | 864081.82 | 3442549.43 |

Texas showed a decline in number of planted not as staggering as Georgia, but a decline all the same. Table 4.7 confirms the deficit.

**Table 4.7 Average Cotton Acres Planted in Years With and Without Storms in Texas (1970-2019)**

| TX cotton acres planted | Coef. | Std. Err. | t | P>t | [95% Conf. Interval] | |
|---|---|---|---|---|---|---|
| **No Storm (0)** | 286579.7 | 389453.1 | 0.74 | 0.47 | -504052.2 | 1077212 |
| **Storm (1)** | 1627.36 | 2988.53 | 0.54 | 0.59 | -4439.69 | 7694.40 |
| **Difference (No Storm & Storm Years)** | 284952.34 | 386464.57 | 0.15 | -0.12 | -499612.51 | 1069517.60 |

By looking at all of the figures listed above you can see the variance in all of the variables. Leading into the last chapter the discussion for these difference in variables will be discussed along with future discussion and recommendations.

Because of the radical shift in the production of cotton in Georgia in 1995, the data were reorganized into two time periods to conduct the storm effect analysis: Before 1995 (0); and After 1995 (1). The estimated model explored the effect of storm (1) and no storm (0) years in the two periods as well as the effect of a lagged price on cotton yield measured in pounds per acre. The regression results of Georgia's yield response are presented in Table 5. The model was statistically significant at less than 1% level of significance, with an F(4, 35) of 6.97 and a probability that F-value is statistically different from zero at 0.0003. The R-square was 44.35%, suggesting that about 45% of the variability in yield is explained by the independent variables in the regression.

The results show that cotton yield in Georgia can be expected to be 125.77 pounds per acre higher in years without storm in the post-1995 period and 139.23 pounds per acre higher in years with storm in the post-1995 compared to years without storm in the pre-1995 period. Both of these coefficients are statistically different from zero at the less than 5% level of significance. On the other hand, the yield in storm years in the pre-1995 period is estimated at about 54.0 pounds per acre, and it is not statistically different from the yield in the years without storm in the pre-1995 period. The results also show that an increase of a dollar in previous years price may be expected to increase yield by about 1.7 pounds per acre. This may be due to the higher revenue resulting from price increases allowing farmers to invest in production in the year following a good price year.

**Table 4.8: Regression Results of Georgia's Storm Effect on Cotton Yield**

| **Independent Variables** | **Coef.** | **Std. Err.** | **t** | **P>t** | **[95% Conf. Interval] LB** | **UB** |
|---|---|---|---|---|---|---|
| Storm Event # Time Effect | | | | | | |
| 0 1 | 125.77 | 60.81 | 2.07 | 0.046 | 2.31 | 249.22 |
| 1 0 | 54.02 | 76.88 | 0.70 | 0.487 | -102.05 | 210.09 |
| 1 1 | 139.23 | 52.85 | 2.63 | 0.012 | 31.93 | 246.53 |
| Cotton Price ($/ton) | | | | | | |
| L1. | 1.70 | 0.49 | 3.48 | 0.001 | 0.71 | 2.69 |
| _cons | 433.01 | 60.61 | 7.14 | 0.000 | 309.96 | 556.05 |

The regression results of Georgia's yield response are presented in Table 6. The model was statistically significant at less than 1% level of significance, with an F(4, 35) of 49.60 and a probability that F-value is statistically different from zero at 0.0000. The R-square was 85.00%, suggesting that about 85% of the variability in yield is explained by the independent variables in the regression.

The results show that cotton production in Georgia can be expected to be 125.77 pounds per acre higher in years without storm in the post-1995 period and 139.23 pounds per acre higher in years with storm in the post-1995 compared to years without storm in the pre-1995 period. Both of these coefficients are statistically different from zero at the less than 5% level of significance. On the other hand, the yield in storm years in the pre-1995 period is estimated at about 54.0 pounds per acre, and it is not statistically different from the yield in the years without storm in the pre-1995 period. The results also show that an increase of a dollar in previous years price may be expected to increase yield by about 1.7 pounds per acre. This may be due to the higher revenue resulting from price increases allowing farmers to invest in production in the year following a good price year.

**Table 4.9: Regression Results of Georgia's Storm Effect on Cotton Production**

| **Independent Variables** | **Coef.** | **Std. Err.** | **t** | **P>t** | **[95% Conf. Interval]** | |
|---|---|---|---|---|---|---|
| Storm Event # Time Effect | | | | | | |
| 0 1 | 1,689,906 | 167,555 | 10.09 | 0.000 | 1,349,752 | 2,030,060 |
| 1 0 | 230,995 | 211,827 | 1.09 | 0.283 | -199,035 | 661,026 |
| 1 1 | 1,608,973 | 145,630 | 11.05 | 0.000 | 1,313,329 | 1,904,617 |
| Cotton Price ($/ton) | | | | | | |
| L1. | 2,240 | 1,348 | 1.66 | 0.106 | -497 | 4,976 |
| _cons | 154,670 | 166,996 | 0.93 | 0.361 | -184,349 | 493,689 |

There was no major shift in production in Texas as seen in Georgia. Therefore, there was no need for looking at the effect of time on the dependent variables of interest. The estimated yield effect was hypothesized to be determined by storm and price. The results are presented in Table 7. They show that although yield in storm years was lower by about 89.6 pounds per acre than yield in years without storms, the difference was not statistically significant. They also show that a dollar increase in price in the previous year may be expected to increase yield by about 1.4 pounds per acre in the current year. This coefficient is statistically significant at less than 1% level. The model was statistically significant, with an F(2,37) of 7.31 and probability of F being different from zero at 0.0021. The R-square was 28.3%, implying that about 28% of the variability in Texas cotton yield was explained by the independent variables.

**Table 4.10: Regression Results of Texas Storm Effect on Cotton Yield**

| Independent Variables | Coef. | Std. Err. | t | P>t | [95% Conf. Interval] | |
|---|---|---|---|---|---|---|
| 1: Storm Event | -89.58 | 92.77 | -0.97 | 0.340 | -277.54 | 98.38 |
| Cotton Price ($/ton) | | | | | | |
| L1. | 1.39 | 0.38 | 3.70 | 0.001 | 0.63 | 2.15 |
| _cons | 431.11 | 103.43 | 4.17 | 0.000 | 221.53 | 640.69 |

The model was statistically significant, with an F(2,37) of 2.60 and probability of F being different from zero at 0.08. The R-square was 12.3%, implying that about 12% of the variability in Texas cotton yield was explained by the independent variables. Despite this model being statistically significant, it is deemed weak, suggesting that there are more variables that determine total cotton production in Texas than storms and price. Unfortunately, these have not been explored in this research. Despite this, Table 8 shows that although storms have a negative effect on production, reducing production by more than 988,803 bales, the difference between storm and no storm production was not statistically different from zero. However, a dollar increase in cotton price from the previous period would increase cotton production by more than 10,250 bales in the current year.

**Table 4.11: Regression Results of Texas Storm Effect on Cotton Production**

| **Independent Variables** | **Coef.** | **Std. Err.** | **t** | **P>t** | **[95% Conf. Interval]** | |
|---|---|---|---|---|---|---|
| 1: Storm Event | -988,803 | 1,189,759 | -0.83 | 0.411 | -3,399,484 | 1,421,878 |
| Cotton Price ($/ton) | | | | | | |
| L1. | 10,250 | 4,826 | 2.12 | 0.040 | 472 | 20,029 |
| _cons | 4,670,735 | 1,326,591 | 3.52 | 0.001 | 1,982,806 | 7,358,664 |

# CHAPTER V: SUMMARY AND CONCLUSION

As discussed previously, agriculture is one of Texas and Georgia's greatest sources of revenue partly due to the cash crop; cotton. While agriculture may be an enormous source of revenue for the states, farming is still nothing short of a gamble and risk. Ultimately the weather is always going to be one of its greatest risks. However, the risk of the weather may not be the only variable responsible for decreases in yield and prices. The purpose of this research was to follow the research objectives by: characterizing the past storms and characteristics of those that made landfall, comparing the effects of the storms that made landfall, and using the results to develop some preparatory strategies. These objectives helped to answer the research question: determining if hurricanes and major storms are the factors responsible for the decrease in cotton yield, and acres harvest versus acres planted.

## 5.1 Discussion

As shown in Chapter 4, once the research was gathered from the past 50 years (1970-2019) it was found that while storms are impactful on the cotton crop, the storms did not seem to be the sole reason for a decrease in cotton yield and output in both Texas and Georgia. The critical variable that seemed to have the biggest impact was price in the prior year/period. Yield and commodity prices offer an explanation for a decrease in acres planted and harvested. If it is projected that there will be a lower yield price for the upcoming harvest season, it is likely that the acreage planted will have a significant decrease compared to past years due to the price to grow the cotton crop compared to the price per pound received for the cotton crop. For example, in 2019 Georgia local farmers planted more acres of other row crops in areas in order to make up for losses from the year before due to decreased cotton prices. Prices were decreased in Georgia due to the trade war between United States and other countries along with the increased cotton planting in Texas. World supply and world demand for cotton impacts the price of cotton in the United States and around the world. Competition from other natural fibers, such as bamboo and hemp, also play a role in the decreased yield price for cotton. Ultimately, U.S. cotton growers need domestic cotton consumption to increase as a result of textile industry in the U.S. Otherwise, U.S. relations with China will need to greatly improve to result in greater cotton exports to China and to other countries, raising the commodity prices. Currently, the cotton prices make it nearly impossible for the farmer to gain any revenue off of the crop which ultimately diminishes any chances at resilience. However, in the event that policies change, prices increase, and better strategic marketing plans are made against the competing natural fibers the amount of acreage planted will increase in hopes of an increase in revenue if the cotton produces a higher yield.

It is safe to say that the cotton crop and the agriculture sector as a whole have come a long way over the years. However, the risks are still inevitable, and weather is only one risk factor. Ultimately, cotton is a very expensive row crop to grow and not knowing if the yield will be substantial enough to produce positive net returns remains a challenge in this industry, as it does all agriculture.

**5.2 Recommendations and Future Research Ideas**

Will cotton production economics return to the days when it was called the white gold? As stated above, changes in cotton acreage in the United States are often directly related to the price of cotton compared to other commodities grown in the same area rather than the storms. Unfortunately, during this study there were a few gaps that were not able to fully be researched due to lack of time and resources. Technology, storm specific impacts and county demographics being three of the main focuses for future research.

Technology today is ever evolving and changing. Technological advances in agriculture have been significantly in agriculture. Genetic engineering, for example, has changed cotton and the cotton industry over the past 25 years. Some argue that it has been a beneficial change and others argue the opposite. Another area of technological advances is in the use of guidance systems in tractors, sprayers, and cotton pickers. This has been a vital factor in the improvement, helping farmers cover larger acreage, know what areas have already been sprayed and what areas need to be sprayed. Yield monitors in cotton pickers can develop maps that are useful for soil sampling purposes, which ultimately cuts down the time taken to pull soil samples. Equipment technological advances can also be a vital role in the increase in cotton acreage planted. Equipment advances make planting, harvesting, spraying, and watering much quicker and efficient compared to those in the past. While all of the things listed previously are great advancements to the cotton crop, further research in storm resistant technologies would be helpful to see just how much technology has affected production in Georgia and Texas.

Storm specific impacts and county demographics are also areas where further research could be done to extend this project. A cross-sectional study of storm specific impacts and county demographics of the counties impacted by these storms would help broaden the research and ultimately gain a better understanding of how farmers fare in these storm years. Not only would it show how farmers fare in the storms, it would allow for an assessment of how their businesses are organized and prepared to help minimize the risks and challenges that may be presented in these specific storm years, allowing them to continue their operations.  By exploring the time series at a county level, viewing the county demographics of farmers and how they deal with storms risks is able to be evaluated.  Also, by looking at other crops grown in the county during these storm years could potentially determine if the storms affect multiple crops grown by the farmer, as they have cotton.

While the study's time series analysis showed that storms could not explain yield and output in cotton in Georgia and Texas, exploring the impact of individual storms in specific counties and at the farmer level instead of the state level could reveal novel insights.  These should help reveal specific needs confronting farmers and provide direction for policymaking.  There is so much to do and know about cotton. This research is only a very small contribution to the opportunities that lay ahead for future researchers.

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## APPENDIX A

| Year | GA_COTTON - ACRES PLANTED | GA_COTTON - ACRES HARVESTED | TX_COTTON - ACRES PLANTED | TX_COTTON - ACRES HARVESTED |
|---|---|---|---|---|
| 2019 | 1,400,000 | 1,390,000 | 7,062,000 | 5,410,000 |
| 2018 | 1,430,000 | 1,305,000 | 7,768,000 | 4,367,500 |
| 2017 | 1,280,000 | 1,270,000 | 7,014,000 | 5,513,000 |
| 2016 | 1,180,000 | 1,165,000 | 5,667,000 | 5,215,000 |
| 2015 | 1,130,000 | 1,120,000 | 4,817,000 | 4,515,000 |
| 2014 | 1,380,000 | 1,370,000 | 6,317,000 | 4,616,000 |
| 2013 | 1,370,000 | 1,340,000 | 5,809,000 | 3,108,500 |
| 2012 | 1,290,000 | 1,280,000 | 6,508,000 | 3,807,500 |
| 2011 | 1,600,000 | 1,495,000 | 7,570,000 | 2,868,500 |
| 2010 | 1,330,000 | 1,315,000 | 5,567,000 | 5,366,500 |
| 2009 | 1,000,000 | 990,000 | 5,018,000 | 3,517,800 |
| 2008 | 940,000 | 920,000 | 5,015,600 | 3,265,000 |
| 2007 | 1,030,000 | 995,000 | 4,925,000 | 4,724,000 |
| 2006 | 1,400,000 | 1,370,000 | 6,431,000 | 4,130,000 |
| 2005 | 1,220,000 | 1,210,000 | 5,974,800 | 5,624,000 |
| 2004 | 1,290,000 | 1,280,000 | 5,871,000 | 5,370,500 |
| 2003 | 1,300,000 | 1,290,000 | 5,620,000 | 4,370,000 |
| 2002 | 1,450,000 | 1,360,000 | 5,618,500 | 4,518,300 |
| 2001 | 1,490,000 | 1,480,000 | 6,017,000 | 4,266,500 |
| 2000 | 1,500,000 | 1,350,000 | 6,416,000 | 4,416,000 |
| 1999 | 1,470,000 | 1,300,000 | 6,183,000 | 5,132,000 |
| 1998 | 1,370,000 | 1,280,000 | 5,755,000 | 3,332,000 |
| 1997 | 1,440,000 | 1,425,000 | 5,532,000 | 5,232,000 |
| 1996 | 1,340,000 | 1,336,000 | 5,737,000 | 4,136,000 |
| 1995 | 1,500,000 | 1,490,000 | 6,436,000 | 5,783,000 |
| 1994 | 885,000 | 875,000 | 5,478,500 | 5,177,000 |
| 1993 | 615,000 | 600,000 | 5,581,000 | 5,080,000 |
| 1992 | 460,000 | 456,000 | 5,537,000 | 3,585,000 |
| 1991 | 430,000 | 427,000 | 6,360,000 | 5,457,000 |
| 1990 | 355,000 | 350,000 | 5,560,000 | 5,057,000 |
| 1989 | 265,000 | 260,000 | 4,732,000 | 3,828,000 |
| 1988 | 350,000 | 315,000 | 5,642,000 | 5,341,500 |
| 1987 | 250,000 | 245,000 | 4,732,000 | 4,431,000 |
| 1986 | 225,000 | 195,000 | 4,876,400 | 3,476,200 |
| 1985 | 255,000 | 245,000 | 5,019,500 | 4,669,400 |
| 1984 | 175,000 | 172,000 | 5,369,600 | 4,719,300 |

| | | | | |
|---|---|---|---|---|
| 1983 | 120,000 | 115,000 | 4,022,400 | 3,572,300 |
| 1982 | 163,000 | 158,000 | 5,819,600 | 4,319,500 |
| 1981 | 180,000 | 175,000 | 7,477,700 | 7,217,600 |
| 1980 | 170,000 | 160,000 | 7,873,000 | 6,872,500 |
| 1979 | 155,000 | 150,000 | 7,731,100 | 6,830,900 |
| 1978 | 120,000 | 115,000 | 6,979,000 | 6,228,000 |
| 1977 | 230,000 | 170,000 | 6,673,000 | 6,472,500 |
| 1976 | 255,000 | 240,000 | 4,808,600 | 4,508,000 |
| 1975 | 165,000 | 160,000 | 4,375,600 | 3,923,500 |
| 1974 | 423,000 | 410,000 | 5,233,900 | 4,432,800 |
| 1973 | 386,000 | 375,000 | 6,225,000 | 5,850,000 |
| 1972 | 461,000 | 430,000 | 6,920,000 | 6,500,000 |
| 1971 | 426,000 | 385,000 | 7,080,000 | 6,560,000 |
| 1970 | 408,000 | 375,000 | 6,800,000 | 6,325,000 |

## APPENDIX B

Georgia Storm Data 1970-2019

| | Tropical Storms | Hurricanes | Major Hurricanes |
|---|---|---|---|
| 1970 | 0 | 0 | 0 |
| 1971 | 0 | 0 | 0 |
| 1972 | 0 | 1 | 0 |
| 1973 | 0 | 0 | 0 |
| 1974 | 0 | 0 | 0 |
| 1975 | 1 | 0 | 0 |
| 1976 | 0 | 0 | 0 |
| 1977 | 0 | 1 | 0 |
| 1978 | 0 | 0 | 0 |
| 1979 | 0 | 0 | 1 |
| 1980 | 0 | 0 | 0 |
| 1981 | 0 | 0 | 0 |
| 1982 | 0 | 0 | 0 |
| 1983 | 0 | 0 | 0 |
| 1984 | 1 | 0 | 0 |
| 1985 | 0 | 0 | 0 |
| 1986 | 0 | 0 | 0 |
| 1987 | 0 | 0 | 0 |
| 1988 | 1 | 0 | 0 |
| 1989 | 0 | 0 | 0 |
| 1990 | 1 | 0 | 0 |
| 1991 | 0 | 0 | 0 |
| 1992 | 0 | 0 | 0 |
| 1993 | 0 | 0 | 0 |
| 1994 | 1 | 0 | 0 |
| 1995 | 1 | 1 | 1 |
| 1996 | 1 | 0 | 0 |
| 1997 | 0 | 0 | 0 |
| 1998 | 1 | 1 | 0 |
| 1999 | 1 | 0 | 0 |
| 2000 | 0 | 0 | 0 |
| 2001 | 0 | 0 | 0 |
| 2002 | 0 | 0 | 0 |
| 2003 | 1 | 0 | 0 |
| 2004 | 0 | 1 | 0 |
| 2005 | 2 | 1 | 0 |
| 2006 | 1 | 0 | 0 |
| 2007 | 2 | 0 | 0 |
| 2008 | 1 | 0 | 0 |
| 2009 | 0 | 0 | 0 |
| 2010 | 1 | 0 | 0 |

| | Tropical Storms | Hurricanes | Major Hurricanes |
|---|---|---|---|
| 2011 | 0 | 0 | 0 |
| 2012 | 1 | 0 | 0 |
| 2013 | 1 | 0 | 0 |
| 2014 | 0 | 0 | 0 |
| 2015 | 0 | 0 | 0 |
| 2016 | 1 | 0 | 0 |
| 2017 | 1 | 0 | 0 |
| 2018 | 0 | 0 | 1 |
| 2019 | 0 | 0 | 0 |

## APPENDIX C

Texas Storm Data 1970-2019

| | Tropical Storms | Hurricanes | Major Hurricanes |
|---|---|---|---|
| 1970 | 1 | 1 | 0 |
| 1971 | 1 | 1 | 0 |
| 1972 | 0 | 0 | 0 |
| 1973 | 2 | 0 | 0 |
| 1974 | 0 | 1 | 0 |
| 1975 | 0 | 1 | 0 |
| 1976 | 0 | 0 | 0 |
| 1977 | 0 | 1 | 0 |
| 1978 | 2 | 0 | 0 |
| 1979 | 3 | 0 | 0 |
| 1980 | 1 | 1 | 1 |
| 1981 | 1 | 1 | 0 |
| 1982 | 1 | 0 | 0 |
| 1983 | 0 | 2 | 1 |
| 1984 | 1 | 0 | 0 |
| 1985 | 0 | 2 | 0 |
| 1986 | 1 | 4 | 0 |
| 1987 | 1 | 0 | 0 |
| 1988 | 2 | 1 | 0 |
| 1989 | 1 | 3 | 0 |
| 1990 | 1 | 0 | 0 |
| 1991 | 1 | 0 | 0 |
| 1992 | 0 | 1 | 0 |
| 1993 | 1 | 1 | 0 |
| 1994 | 0 | 1 | 0 |
| 1995 | 2 | 1 | 0 |
| 1996 | 1 | 1 | 0 |
| 1997 | 0 | 0 | 0 |
| 1998 | 2 | 1 | 0 |
| 1999 | 1 | 0 | 1 |
| 2000 | 1 | 0 | 0 |
| 2001 | 1 | 0 | 0 |
| 2002 | 2 | 0 | 0 |
| 2003 | 2 | 3 | 0 |
| 2004 | 1 | 2 | 0 |
| 2005 | 0 | 1 | 1 |
| 2006 | 0 | 2 | 0 |
| 2007 | 1 | 1 | 0 |
| 2008 | 1 | 3 | 1 |
| 2009 | 0 | 1 | 0 |
| 2010 | 2 | 1 | 0 |
| 2011 | 3 | 0 | 0 |

| | Tropical Storms | Hurricanes | Major Hurricanes |
|---|---|---|---|
| 2012 | 1 | 2 | 0 |
| 2013 | 0 | 1 | 0 |
| 2014 | 1 | 1 | 0 |
| 2015 | 1 | 1 | 0 |
| 2016 | 0 | 1 | 0 |
| 2017 | 0 | 0 | 1 |
| 2018 | 0 | 0 | 0 |
| 2019 | 1 | 0 | 0 |