Agricultural Sciences, 2024, 15, 1195-1222
https://www.scirp.org/journal/as
ISSN Online: 2156-8561
ISSN Print: 2156-8553

The Impacts of Louisiana's Changing Climate on Food Crop Production

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How to cite this paper: Twumasi, Y.A., Merem, E.C., Ning, Z.H., Yeboah, H.B., Loh, P.M., Osei, J.D., Ferchaud, V., Anokye, M., Dadzie, E., Gyan, D.T., Mjema, J.E., Kangwana, L.A. and Armah, R.N.D. (2024) The Impacts of Louisiana's Changing Climate on Food Crop Production. *Agricultural Sciences*, **15**, 1195-1222.
https://doi.org/10.4236/as.2024.1511065

Received: August 31, 2024
Accepted: November 11, 2024
Published: November 14, 2024

Abstract

While various prior studies have delved into the potential consequences of climate change on crop production in specific areas, notably in southeastern Louisiana, limited investigation has been carried out concerning some crops within the state of Louisiana. Consequently, there exists a dearth of knowledge regarding the specific hurdles and potential benefits confronting agricultural producers in this region. Therefore, the primary aim of this study was to explore and measure the impact of climate change on the yields of corn, rice, soybeans, and cotton in Louisiana, thereby addressing this informational void. The study uses data on average high temperatures and precipitation to assess the impact of climate change on these specific food crops in Louisiana. The researchers used ArcGIS and its symbology tool to create three separate maps depicting the spatial distribution of harvested cropland in Louisiana. The graduated color option was used on each map, which represented the years 2007, 2012, and 2017. Similarly, eight separate maps were created using the graduated color option to visually present the distribution patterns of Louisiana's corn, cotton, rice, and soybean crops. These maps provided a visual representation of the state's total crop production between 2007 and 2017. The researchers also created six bar charts to show the distribution of corn, cotton, rice, and soybean production in Louisiana over three time periods: 2007, 2012, and 2017. These charts also included information about the average high temperature and annual precipitation in each parish. The study revealed decreasing trends in Louisiana corn and cotton yields alongside consistent increases in rice and soybean yields, with projections suggesting future temperature rises may negatively impact crop yields, highlighting the need for research into climate-smart agricultural practices to mitigate these effects and safeguard global crop production. Louisiana's response to climate change in food crop production involves implementing a comprehensive Climate-Resilient Agriculture Program, focusing on developing climate-adaptive crop varieties, sustainable water management, climate-responsive insurance, farmer education, and outreach to safeguard food security, enhance agricultural resilience, and ensure sustainable crop production.

Keywords

Climate Change, Corn, Cotton, Precipitation, Soybean, Temperature

1. Introduction

Agriculture and climate change are inextricably linked and have numerous correlations [1]. The Earth's climate has changed, with mean global temperatures rising by 1˚C above pre-industrial levels and expected to reach 1.5˚C within the next two decades if current warming trends continue. Approximately 90% of man-made CO_2 emissions are attributed to the use of fossil fuels and cement production [2]. Climate change is widely acknowledged as a complex and multifaceted issue that affects the entire planet as well as all aspects of modern society [3]. Human activities, particularly since the beginning of industrialization, have significantly impacted the Earth's systems, leading to the crossing of various planetary boundaries, according to the Anthropocene discourse [4]. Agreeably, human activity is the primary cause of climate change, especially the rising global energy demand, which is heavily reliant on fossil fuel consumption [5]. Essentially, the burning of fossil fuel has substantially contributed to large emissions of heat-trapping gases such as carbon dioxide and other harmful greenhouse gases into the atmosphere, thereby significantly changing the Earth's climate. People are mostly concerned about the increasing frequency and severity of climate-related events such as sea-level rise, floods, fires, storms, droughts, and diseases. For instance, climate change is expected to increase the prevalence of a number of respiratory, water and food-related illnesses.

Climate change has a significant impact on land and agricultural systems. It is a primary cause of biotic and abiotic stresses, which have a negative impact on agricultural practices within a given region [1]. While there have been instances of positive crop yield changes in specific locations, the overall trend indicates a decrease in the global production of essential crops such as rice and wheat. This is because climate change causes rising temperatures during the day and night, as well as erratic rainfall patterns [6]. These changes have an immediate impact on cereal production by exposing it to abiotic stresses like heat and water scarcity (ibid). Furthermore, they have an indirect impact on cereal crops by increasing biotic stresses such as the proliferation of insect and weed pests, decreasing the presence of beneficial soil microorganisms, and so on [7]. While higher temperatures and changes in rainfall patterns are not expected to significantly reduce forest coverage in Louisiana, they may change the composition of tree species within forests. Droughts may become more common, reducing forest productivity, and climate change may exacerbate damage caused by insects and diseases [8].

Climate change has a significant impact on crops, especially on farms without irrigation, which increasingly experience severe droughts, causing more crop failures [8]. Also, as increased temperatures and precipitation patterns are threats to crop yields, regional temperature projections are more certain than precipitation changes. According to historical meteorological data, average annual temperatures in regions where wheat, rice, maize, and soybeans are grown have risen by about 1˚C over the last century [6]. Louisiana is expected to experience a significant increase in the number of days with temperatures exceeding 95˚F over the next 70 years, ranging from 35 to 70 days, up from the current 15 days. Even in the coming decades, hotter summers are expected to reduce crop yields like maize and rice. However, if enough water is available, elevated atmospheric carbon dioxide levels can boost crop yields by acting as a natural fertiliser, potentially offsetting the negative effects of heat on soybeans and cotton [8]. Although crop yield per hectare has increased significantly over the last five decades, the rate of growth has recently slowed in comparison to previous periods [9]. The aim of the study is to analyze the impacts of climate on four crops in Louisiana: 1) cotton, 2) rice, 3) corn and 4) sorghum using a Geographic Information System (GIS) approach.

2. Problem Statement

Louisiana's climate is characterized by a humid subtropical climate influenced by the Gulf of Mexico, resulting in long, hot summers and short, mild winters. Precipitation is consistent throughout the year, with more rain in the summer and less in October, with southern regions experiencing heavier rainfall. Summer temperatures typically exceed 90˚F (32˚C), reaching above 100˚F (38˚C) in the north and 105˚F (41˚C) in the north-central area. Winters are generally mild, with average highs around 66˚F (19˚C) in the south and 59˚F (15˚C) in the north, with sporadic snowfall ranging from one to three times annually in the northern parts of the state. Due to the location of Louisiana close to the Gulf of Mexico, the state has experienced several severe climate conditions. Notably, there have been 104 confirmed weather/climate disaster events such as 14 drought events, 10 flooding events, 1 freeze event, 44 severe storm events, 26 tropical cyclone events, and 9 winter storm events between 1980-2024 [10]. The state exhibits significant seasonal variations in cloud cover, with the clearest period lasting about 4.4 months from June 12 to October 25. August is notably the clearest month, with predominantly clear or partly cloudy skies around 69% of the time on average. Conversely, the cloudier phase spans around 7.6 months, from October 25 to June 12, with February being the cloudiest month, experiencing overcast or mostly cloudy skies about 54% of the time on average [11].

Climate fluctuations, according to studies conducted as early as 2007, account for approximately 30% of annual variations in crop yields per hectare [12]. According to forecasted reports, agriculture is the most vulnerable sector that will be significantly impacted by climate change. Food security and ecosystem resilience have emerged as critical global concerns [1]. Climate change impacts agricultural productivity differently across crops and regions. The southeastern United States (SE-US), in particular, regions with a diverse agroecological landscape, is heavily dependent on agriculture for its economy [7]. Rising temperatures are expected in Louisiana over the next few decades, as are the severity of floods and droughts. Louisiana, unlike many other parts of the country, did not experience significant warming over the last century. Nonetheless, the region has seen changes such as drier soils, increased annual rainfall, heavier downpours on a more frequent basis, and rising sea levels. Climate change is likely to exacerbate flood damage, reduce crop yields, and have a negative impact on fisheries. Furthermore, the number of uncomfortably hot days in the state may increase, increasing the risk of heat-related illnesses such as heat stroke [8].

The Intergovernmental Panel on Climate Change (IPCC) has also identified another significant change related to climate change, namely increasing heat and rainfall, which are gradually deteriorating land quality and leading to decreased soil productivity. This degradation is caused by the depletion of soil nutrients and organic matter, which has a negative impact on crop yields. Furthermore, rising sea levels will exacerbate these negative consequences by causing saltwater intrusions and permanent flooding of agricultural land [9]. Due to increasingly severe droughts, farms without irrigation systems may experience a higher frequency of crop failures [8]. Improvements in heat and drought tolerance resulted in a 33% increase in corn yields and a 20% increase in soybean yields between 1951 and 2017. However, maladaptation to normal conditions reduced corn yields by 41% and soybean yields by 87%, demonstrating significant spatial variation in the effects. Climate change is expected to reduce average corn yields by 39% - 68% and soybean yields by 86% - 92% by 2050 compared to the 2013-2017 period, depending on the warming scenario [13]. When the estimated impact of climate-neutral technological advancements is factored into the analysis, the net change in maize yield in 2050 ranges from a 13% decrease to a 62% increase over the 2013-2017 period. In 2050, the net change in yield for soybeans ranges from a 57% decrease to a 26% decrease when compared to the 2013-2017 period [13].

Despite the existence of several previous studies that examined the potential climate-related impacts on crop yields in specific regions, particularly in southeastern Louisiana, little research on cereal crops in Louisiana has been conducted. As a result, there is a lack of understanding about the challenges and opportunities that producers in the county face. As a result, the goal of this study was to investigate and quantify the effects of climate change on corn, rice, soybean, and cotton yields in Louisiana in order to close this knowledge gap.

3. Literature Review

3.1 The Impact of Climate Change on Food Crops

Climate change is an unavoidable occurrence with global consequences [14]. The situation is worrisome because changes in meteorological variables have a direct impact on crop yield [15]. The situation worsens as demand for cereal production must be increased by 70% - 100% to ensure food security for the projected global population of 9.8 billion by 2050 [16]. Climate change impacts agriculture in a variety of ways, including changes in annual precipitation, average temperature, heatwave occurrences, shifts in weed, pest, or microbial populations, changes in CO_2 and ozone levels in the atmosphere, and fluctuations in sea levels [1]. Extreme precipitation events have the potential to cause devastating floods, whereas extended periods of limited or no rainfall can result in drought-induced stresses. As global warming continues, it is expected that extreme precipitation events will become more common in many parts of the world. This is due to a higher concentration of atmospheric water vapour, which acts as a precipitation source [17]. The thermodynamic Clausius-Clapeyron relationship governs the increase in atmospheric water vapor, with a rise in temperature corresponding to a 6% - 7% increase in saturation concentrations [18].

Louisiana receives plenty of rain throughout the year, with varying amounts in different regions. Annual precipitation typically ranges from around 50 inches in the north to around 70 inches in some southeastern areas. Louisiana's statewide annual precipitation has varied greatly over the years, ranging from 36.6 inches in 1924 to 79.5 inches in 1991. The driest multiyear periods in Louisiana occurred in the early 1900s and late 1930s, while the wettest periods occurred in the early 1990s and late 2010s. The driest consecutive 5-year period was from 1914 to 1918, with an average annual precipitation of 49.2 inches. The wettest 5-year period was from 1989 to 1993, with an average annual precipitation of 65.6 inches [19].

Temperature also has a significant impact on plant development, making it a critical factor [20]. Extremely high or low temperatures can have a negative impact on crop growth, development, and, ultimately, yield. Temperature influences many aspects of crop growth, including the length of the growing season, rates of photosynthesis, respiration, and grain filling, all of which have an impact on crop yield and production [21]. Drought conditions aggravate crop water stress, whereas heavy rainfall can cause flooding and waterlogged soils [20]. Plant productivity will be impacted by the projected warming caused by climate change, as well as the likelihood of more frequent extreme temperature events [21]. Warmer temperatures contribute to increased evaporation, resulting in soil dehydration, increased plant stress, and significant consequences for agriculture, even in regions where significant changes in precipitation are not expected [22].

Climate change will have both negative and positive consequences for agriculture. It is predicted that over the next seventy years, Louisiana will experience a significant increase in the number of days with temperatures exceeding 95˚F, ranging from 35 to 70 days, compared to the current average of about 15 days. Due to hotter summers, this rise in temperature is expected to reduce maize and rice yields in the coming decades. However, increased levels of atmospheric carbon dioxide have a fertilizing effect on crops, which is likely to offset the negative impact of heat on soybeans and cotton, assuming adequate water availability [8].

3.2. Climate Change and Rice Production

Rice is important in the economic and historical context of southwest Louisiana. Rice production in the region relied on ponds and rainwater in the early 1700s. Due to a labour shortage, Carolina planters began importing enslaved Africans to cultivate and harvest rice. These African labourers brought with them their own knowledge of rice farming techniques such as planting, hoeing, harvesting, threshing, and polishing. Their contributions were critical in dramatically improving rice production capabilities. Production had surpassed 1.5 million pounds by 1710 and 20 million pounds by 1720 [23]. Rice cultivation is typically done in flooded conditions, so it is best suited to nearly level land. Louisiana's rice-growing regions are generally well-suited for rice production and require little land formation. Advances in technology, such as laser systems, have facilitated the implementation of precision levelling or grading techniques, making it both physically and economically feasible to create rice-growing fields with optimal conditions [24].

Rice cultivation is common in low-lying ecosystems such as deltas, which are highly vulnerable to sea level rise. Furthermore, rice is grown in areas that already experience extreme heat. Any further rise in temperature could push temperatures above critical levels, making it difficult for a viable crop to thrive [22]. Climate change's impact on major rice-growing regions, according to researchers, could result in a significant decrease in rice production, threatening essential food supplies. For instance, while rice production contributes $550 million to Louisiana's economy, extreme weather patterns due to climate change pose serious challenges to enhancing productivity [25]. This general decline in rice production has the potential to have serious consequences in regions that rely heavily on rice as a primary food source. According to a 2018 study published in the Archives of Agronomy and Soil Science, the intensification of hot weather in terms of both frequency and severity could result in a 40% reduction in rice yields by the end of the century. Although rice can grow in temperatures as high as 40 degrees Celsius (104 degrees Fahrenheit), heat stress can have a negative impact on flower pollination. Temperatures above 35 degrees Celsius can significantly reduce yields [22].

Furthermore, research shows that for every 1˚C increase in temperature, rice yield drops by 2.6% [26]. In Louisiana, the total state rice production is expected to reach 30.9 million hundredweight, a 4% decrease from the previous year's production of 32.3 million hundredweight. As of August 1, the estimated yield for all rice in 2021 is 6800 pounds per acre, a decrease of 20 pounds from the previous year. Rice producers anticipate harvesting 454,000 acres of rice, a 20,000-acre decrease from the acreage harvested in 2020 [27].

3.3. Climate Change and Corn Production

Northeast Louisiana is the state's primary corn production region. Corn yields in Louisiana have varied in recent years, with yields of 147 bushels per acre in the north, 139 bushels per acre in the central region, and 172 bushels per acre in the south [28]. According to projections, Louisiana's corn for grain production will reach 101 million bushels, a slight decrease from the August 1 forecast but a 15% increase over the previous year [27]. While the overall trend for corn yield has been consistently increasing with little year-to-year variation, the effects of seasonal weather patterns and climate trends become more apparent at the local level. Significant deviations from the trend line have been observed in years when adverse weather events have resulted in yield reductions in the United States [29].

Corn is susceptible to changes in environmental conditions such as increased air temperatures, increased radiation levels, variations in vapour pressure deficit, and humidity shifts [30]. Temperature and precipitation are the primary climate factors that influence corn phenology (growth stage timing) and productivity. Corn phenological development is expected to accelerate as the climate warms, because the number of thermal units required for leaf appearance remains relatively constant during the vegetative stage. Extreme temperature events during pollination, combined with water shortages, reduce maize productivity. Furthermore, warm temperatures above the upper threshold during the grain-filling period reduce yield. According to model estimates, each 1˚C increase in temperature results in a 10% decrease in corn yield [29]. Adjustment strategies such as changing planting dates, switching to different existing crop varieties, developing new crop varieties, and changing crop growing practices can help mitigate the negative effects of climate change and influence the extent to which it affects corn yield and production [31].

3.4. Climate Change and Cotton Production

Cotton has been the dominant crop grown in northeast Louisiana for over a century [32]. In 2016, the gross farm value of cotton sales in Louisiana reached $103.5 million, with value-added activities contributing an additional $25.9 million for a total production value of $129.4 million [33].

Climate change is posing an increasing threat to cotton production around the world [34]. Carbon dioxide (CO_2) levels in the atmosphere have an effect on cotton production. The increased CO_2 concentration has the potential to boost cotton plant growth, which could be beneficial in certain environments. This accelerated growth, however, would necessitate increased water and nutrient requirements [35]. Furthermore, increased CO_2 levels promote weed growth, which can reduce the efficacy of herbicides in controlling weed competition in cotton fields. Based on current climate change models, it is projected that corn yields could decrease by up to 15% in the next five decades. A variety of factors, including rising temperatures, drought, limited freshwater availability, and erratic rainfall patterns, are expected to have an impact on cotton production. Cotton plant growth and productivity are likely to be impacted by these changes. According to the most conservative climate change models, cotton yields in the United States could fall by 30 to 46 percent by 2100 [35].

Climate change is expected to have a significant impact on cotton production globally, owing to changes in temperature, rainfall patterns, and carbon dioxide (CO_2) concentration. Higher CO_2 levels can boost cotton yield by promoting photosynthesis, plant growth, and overall biomass production. These advantages, however, are conditional on optimal temperature conditions for cotton plants and adequate soil moisture levels [36]. Rising temperatures are expected to shorten growing seasons in approximately 40% of cotton-producing regions by 2040. Furthermore, during that time period, drought conditions have the potential to affect roughly half of the global cotton crop.

Temperature influences cotton growth and development by influencing fruit production, photosynthesis rates, and respiration. The specific outcomes and projections of climate change impacts on cotton production may differ across the globe [37]. Further increases in global temperatures are almost certain to result in significant decreases in cotton yield. Additionally, projected changes in precipitation can have an impact on cotton production, though the magnitude of the effect is much smaller than that of temperature. Mitigation strategies can help reduce the negative effects of climate change on cotton production [36].

3.5. Climate Change and Soybean Production

The United States is a significant global soybean exporter, with a significant concentration of production in the upper Midwest [38]. It is important to note that a large portion of this region lacks irrigation infrastructure, making the area's soybean production systems particularly vulnerable to weather fluctuations during the growing season [39]. Louisiana has a favourable climate that is ideal for growing a variety of energy crops for biofuel production. The region enjoys favourable conditions, such as an average temperature of 19 degrees Celsius, an annual precipitation of 162.6 cm, and a growing season that lasts between 230 and 290 days. The thriving sugar cane industry, which is the oldest and largest commercial enterprise of its kind in the United States, is a prime example of this. The presence of fertile organic soil, a semi-tropical climate, ample water resources, and abundant sunshine are all factors that contribute to the success of this industry in Louisiana [40]. The critical threshold temperature for soybean cultivation is 30˚C. Temperature increases up to the optimum level have a positive effect on soybean yield. However, beyond that optimal temperature, further temperature rise results in a sharp drop in yield [41].

Rolla *et al.* (2018) conducted a study in Argentina and discovered that increased precipitation during the growing seasons is expected to increase soybean yield [42].

Similarly, Lal *et al.* (1999) conducted simulations and discovered that future climates with higher CO_2 concentrations in the atmosphere would result in higher soybean yields. However, they discovered that doubling CO_2 to 660 ppm in the atmosphere would result in a 3 C increase in air temperature, cancelling out the positive "fertilisation" effect. Furthermore, they discovered that CO_2 levels have a greater impact on photosynthesis than transpiration due to stomatal closure [43]. In contrast, research by Mall, Lal, Bahatia, Rathore, and Singh (2004, as cited in Ma *et al.*, 2021) suggested that higher air temperature and doubled CO_2 concentration would reduce CROPGRO soybean yield in India [44]. Carbone *et al.* (2003) also ran simulations that showed a significant decrease in soybean yield in the southeastern United States [45]. Furthermore, Eulenstein *et al.* (2017) asserted that soybean yield would decline from 2071 to 2100, regardless of the climate circulation models (GCMs) used [46]. These differences in soybean yield responses to climate change may be due to differences in projected temperature and precipitation, as well as cultivar-related factors (Bao, Hoogenboom, McClendon, & Paz, 2015; cited in Ma *et al.*, 2021). A study conducted in the Midwest revealed a 40% variability in soybean yield on a yearly basis from 1981 to 2018, primarily due to climate changes. The researchers predict that future climate conditions will reduce soybean yield due to the negative effects of drought and heat stress. However, by implementing irrigation methods, it is possible to mitigate the negative effects of drought and heat stress [47].

3.6. The Current Food and Environmental Crisis in Louisiana

Increasing temperatures and more frequent extreme heat events in the Southeast United States, particularly in Louisiana, pose significant health risks, potentially resulting in more heat-related illnesses, hospitalizations, and deaths without preventive measures. Climate change impacts various sectors and environments, such as agriculture, energy, and forestry, and may expand the habitats of disease-carrying insects, heightening the risk of vector-borne diseases. Extreme weather events like heavy rainfall, droughts, and wildfires also affect infrastructure and the economy [48]. Rising sea levels and climate change pose significant challenges for Louisiana, including increased flood risks, intensified tropical storms, and coastal erosion leading to land loss. Efforts to mitigate these risks, such as diverting Mississippi River water, have had mixed results. Climate projections suggest changes in crop yields and tree species composition, with potential impacts on agriculture and forests. Fisheries reliant on coastal wetlands are also threatened. Hotter temperatures increase health risks, especially for vulnerable populations, complicating efforts to maintain air quality standards [8].

The current food crisis in Louisiana is primarily fueled by widespread poverty and income inequality [49]. This economic strain disproportionately affects low-income households, hindering their ability to access healthy food leading to food insecurity and malnutrition in vulnerable communities. Additionally, Louisiana's agricultural sector faces significant hurdles due to environmental challenges like hurricanes, floods, and soil degradation [50]. These natural disasters not only disrupt food distribution channels but also cause extensive damage to crops and livestock, worsening food shortages in the area. Beyond scarcity, the food crisis has profound impacts on individuals, communities, and the broader economy. Food insecurity contributes to physical and mental health issues, increasing the risk of chronic conditions such as obesity, diabetes, and hypertension [51]. Children from food-insecure households are particularly vulnerable to developmental delays and academic difficulties [52]. The burden of the food crisis is most deeply felt in communities already struggling with poverty and social disparities, further widening existing inequalities. Thus, in places such as Louisiana, food security is often a place-based problem disproportionately affecting neighborhoods.

Limited access to nutritious food exacerbates the challenges faced by these populations, compounding their vulnerability [53]. Recent USDA data indicates a decrease in food insecurity among Louisiana households from 18.4% to 15.8% between 2013-2015 and 2016-2018. However, this rate remains notably higher than the national average. Despite improvements, food insecurity persists, prompting reliance on programs like SNAP and the EITC. Louisiana's food insecurity rate exceeds national and regional averages, highlighting the need for continued investment in poverty alleviation efforts. Maintaining a robust safety net is crucial, particularly for vulnerable demographics, amidst threats to SNAP access [54].

4. Methodology

4.1. Data Sources

This study's primary method of data collection and analysis relied heavily on online resources. Data on total harvested cropland in 2007, 2012, and 2017 were obtained from reports issued by the United States Department of Agriculture (USDA) in 2009, 2014, and 2019, respectively. In addition, the USDA [55] [56] was used to collect data on the distribution of corn, cotton, rice, and soybean production in 2007 and 2017 [57] [58]. Supplementary data from Extreme Weather Watch (2023) and the National Centres for Environmental Information (NCEI, 2022) were incorporated to improve the study. The Extreme Weather Watch provided average high temperature data for Louisiana from 2000 to 2022, while the NCEI contributed data on Louisiana's total annual precipitation [59] [60].

4.2. Methods

The study used a Geographic Information System (GIS) approach to visually represent the total harvested cropland in Louisiana in 2007, 2012, and 2017, as well as corn, cotton, rice, and soybean production in the same state in 2007 and 2017. This was accomplished through the use of ArcGIS software, which enabled the combination of data on harvested cropland as well as corn, cotton, rice, and soybean production from various parishes in Louisiana. These datasets were organized in an attribute table and linked to a shapefile.

Three separate maps were created in ArcGIS using the symbology tool to show the distribution of harvested cropland. The graduated color option was used, with each map representing the total harvested cropland in Louisiana in 2007, 2012, and 2017. Similarly, eight separate maps were created using the graduated color option to depict the distribution of corn, cotton, rice, and soybean. These maps depicted total crop production in Louisiana in 2007 and 2017.

In addition, six bar charts were created to show the distribution of corn, cotton, rice, and soybean production in Louisiana in 2007, 2012, and 2017, as well as the county's average high temperature and annual precipitation. The purpose of these charts was to visually convey the information in a clear and concise manner.

5. Results

In 2007, the parishes with the largest harvested cropland were concentrated in the northeastern part of Louisiana, including Concordia, Avoyelles, Catahoula, Tensas, Madison, among others. Conversely, the parishes with the smallest harvested cropland were scattered in the southeastern and northwestern parts of the county, such as Sabine, Vernon, Orleans, St. Bernard, Tammany, Plaquemines, and more (refer to **Figure 1**). Similar patterns were observed in 2012 and 2017, as shown in **Figure 2** and **Figure 3**, respectively.

Figure 4 and **Figure 5** depict the distribution of total corn production in Louisiana in 2007 and 2017, respectively. In 2007, the parish of Morehouse produced the highest amount of corn (99,989), followed by Madison (95,348) and Jackson (90,234). In 2017, Franklin (73,816) emerged as the top corn producer, followed by Morehouse (62,261) and Madison (48,704).

Figure 6 and **Figure 7** illustrate the total rice production in Louisiana in 2007 and 2017, respectively. The three parishes with the highest rice production in 2007 were Jefferson Davis (73,989), Acadia (69,424), and Vermilion (50,266). In 2017, Calcasieu surpassed Jefferson Davis to become the leading rice producer in Louisiana (847,693), followed by Acadia (82,264) and Jefferson Davis (64,497).

Figure 8 and **Figure 9** present the total soybean production in Louisiana in 2007 and 2017, respectively. In 2007, St. Landry produced the highest amount of soybeans (69,416), followed by Avoyelles (55,445) and Pointe Coupee (52,153). The top three soybean-producing parishes in Louisiana in 2017 were Avoyelles (125,756), St. Landry (97,115), and Avoyelles (92,162).

Figure 10 and **Figure 11** demonstrate the cotton production in Louisiana in 2007 and 2017. In 2007, Catahoula (39,126), Concordia (18,817), and Avoyelles (16,784) were the leading cotton producers. In 2017, Catahoula (22,707), Concordia (17,905), and Rapides (9567) maintained their positions. Overall, cotton production in Louisiana has shown consistent trends over time.

Corn production in Louisiana has been declining over the years. In 2007, the county produced a total of 722,387 acres of maize. However, maize production decreased by 198,379 acres in 2012 compared to 2007. Furthermore, compared to 2012, maize production decreased by 35,427 acres in 2017. (**Figure 12**)

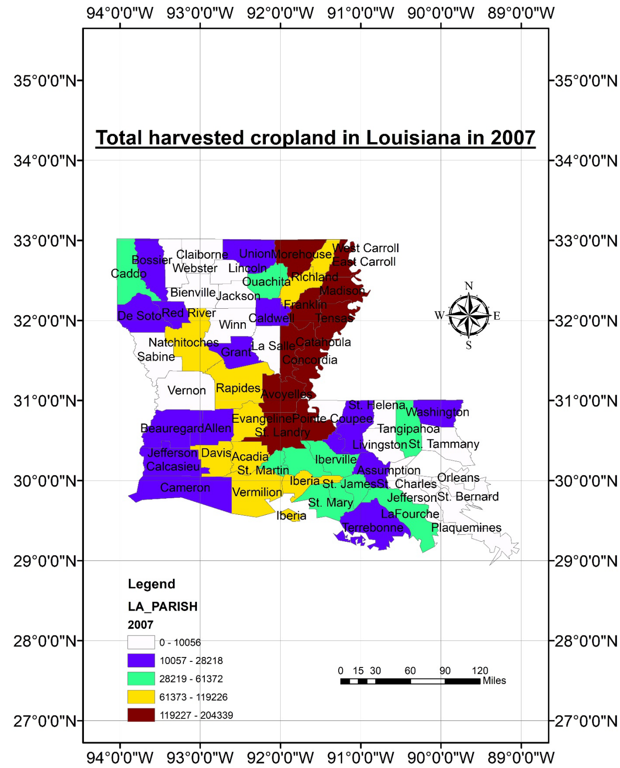

Figure 1. Total harvested cropland in Louisiana in 2007 (acres). Source: United States Department of Agriculture (2009).

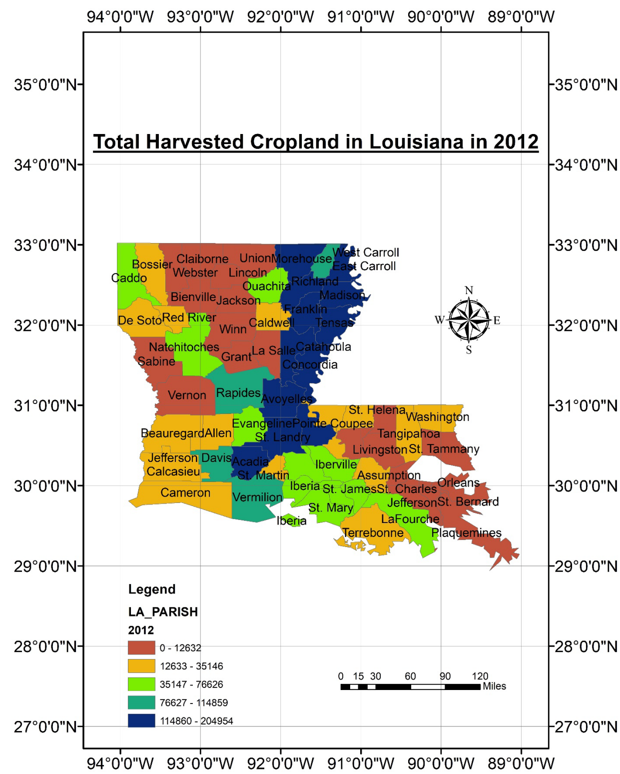

Figure 2. Total harvested cropland in Louisiana in 2012 in acres. Source: United States Department of Agriculture (2014).

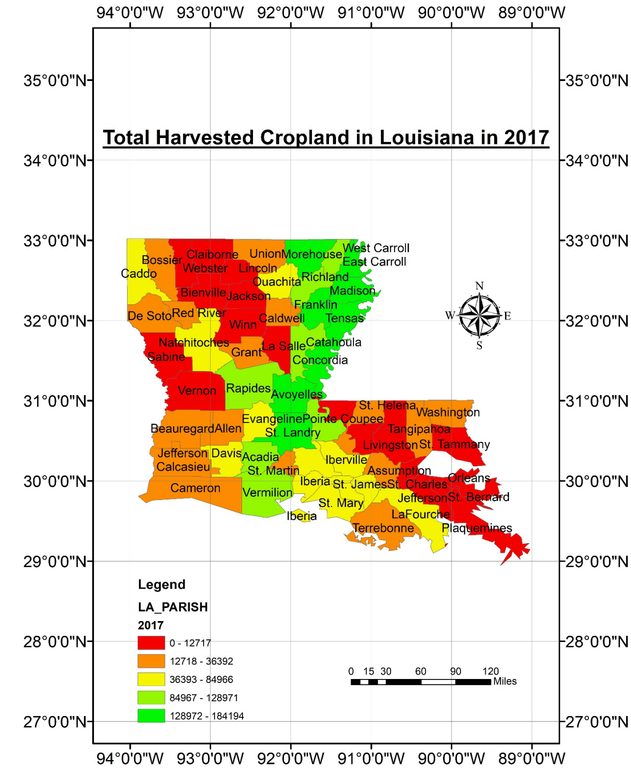

Figure 3. Total harvested cropland in Louisiana in 2017 in acres. Source: United States Department of Agriculture (2019).

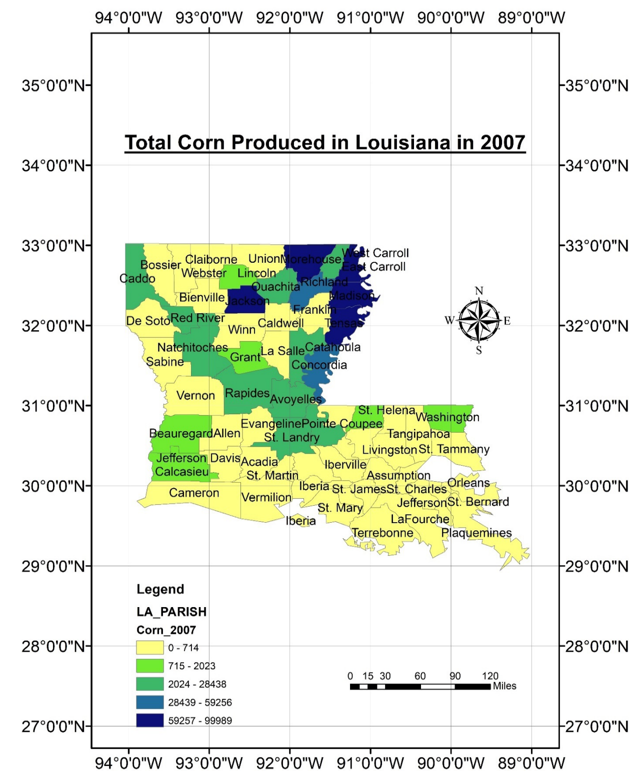

Figure 4. Total corn produced in Louisiana in 2007 in acres. Source: United States Department of Agriculture (2009).

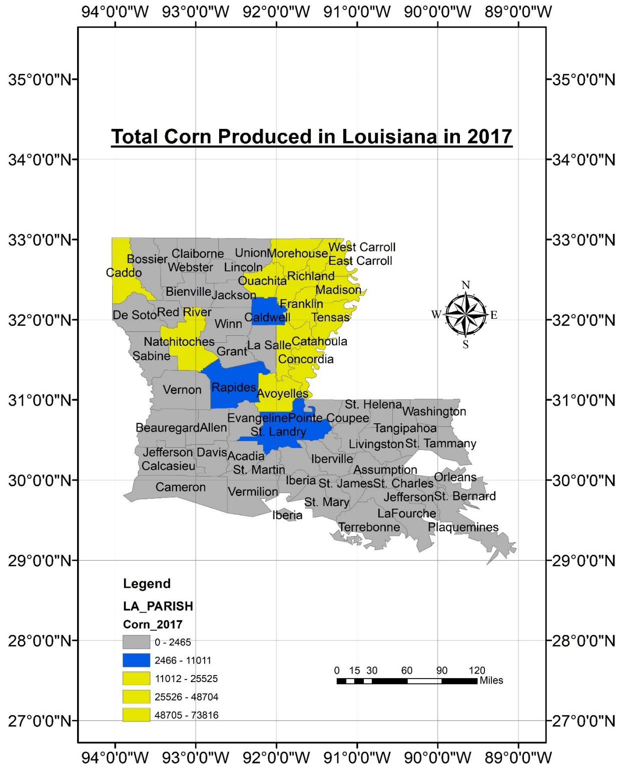

Figure 5. Total corn produced in Louisiana in 2017. Source: United States Department of Agriculture (2019).

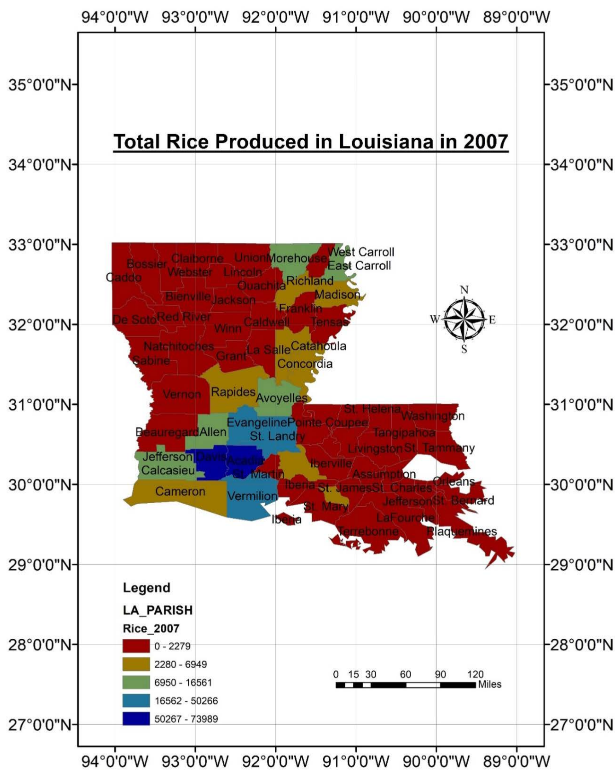

Figure 6. Total rice produced in Louisiana in 2007 in acres. Source: United States Department of Agriculture (2009).

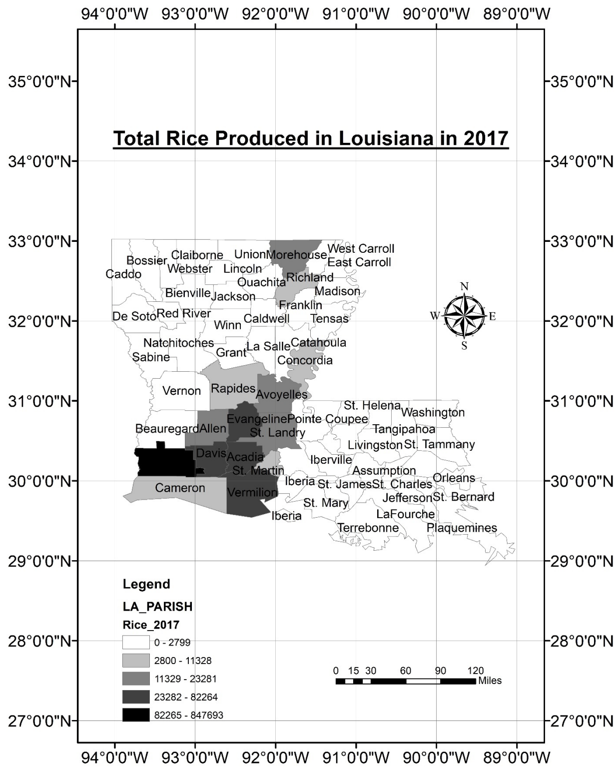

Figure 7. Total rice produced in Louisiana in 2017 in acres. Source: United States Department of Agriculture (2019).

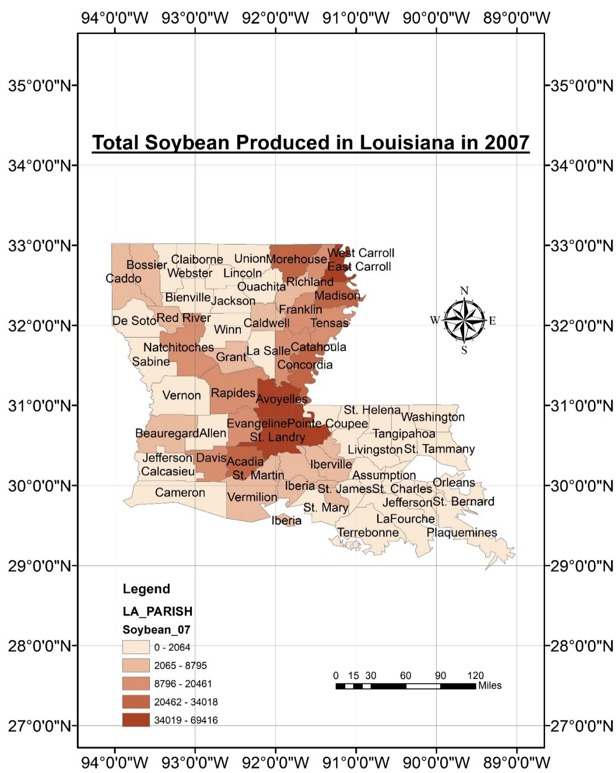

Figure 8. Total soybean produced in Louisiana in 2007 in acres. Source: United States Department of Agriculture (2009).

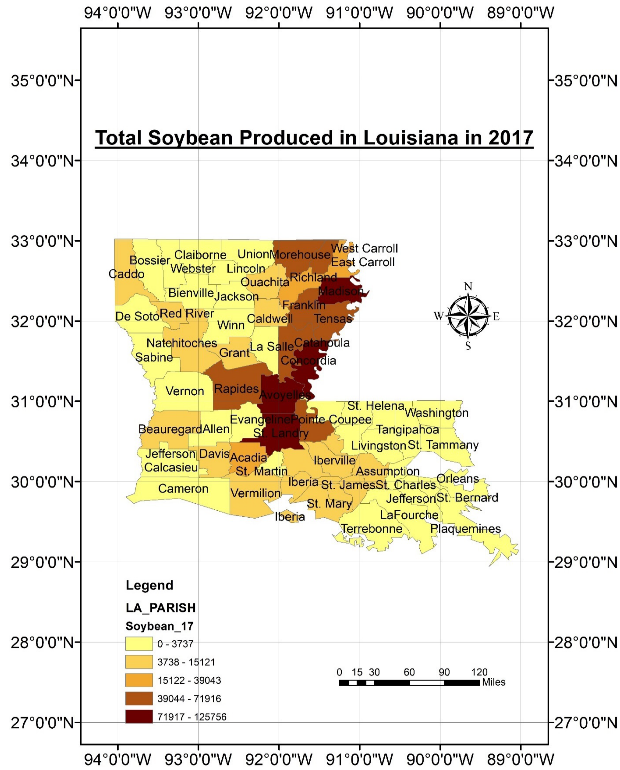

Figure 9. Total soybean produced in Louisiana in 2017 in acres. Source: United States Department of Agriculture (2019).

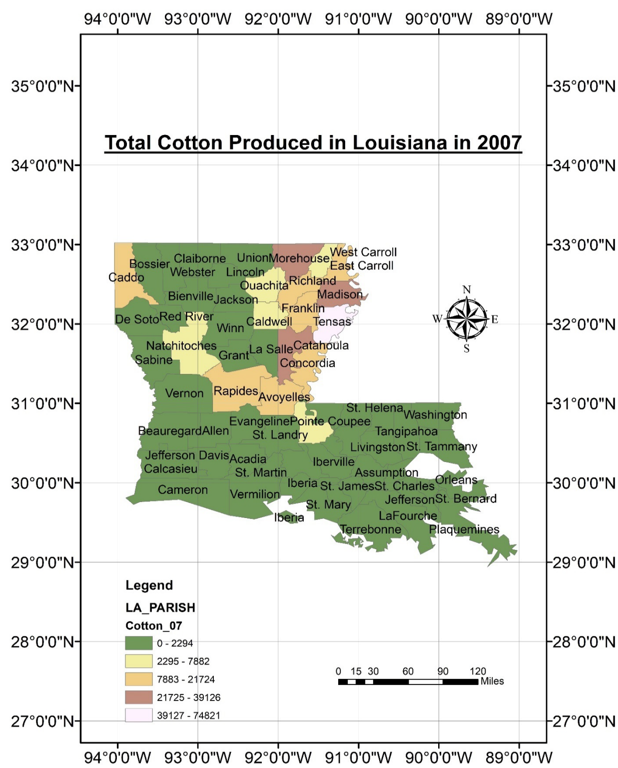

Figure 10. Total cotton produced in Louisiana in 2007 in acres. Source: United States Department of Agriculture (2009).

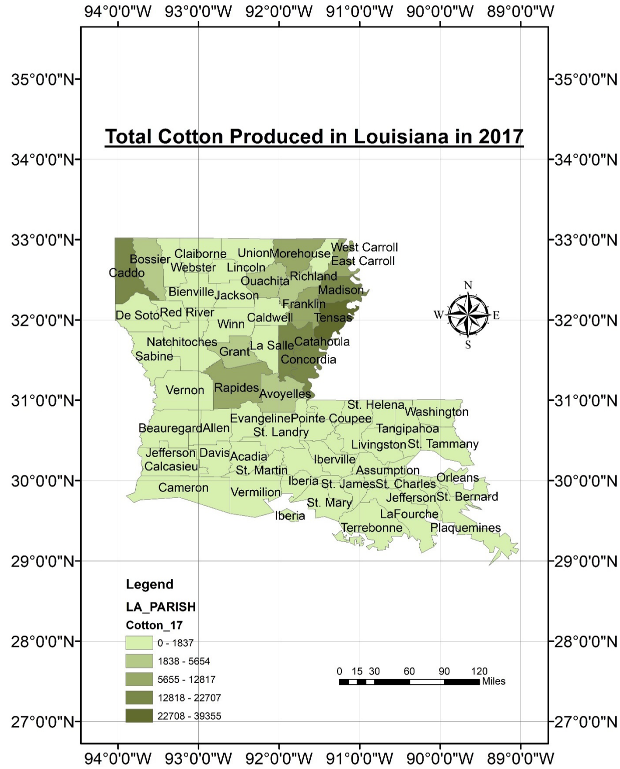

Figure 11. Total cotton produced in Louisiana in 2017 in acres. Source: United States Department of Agriculture (2019).

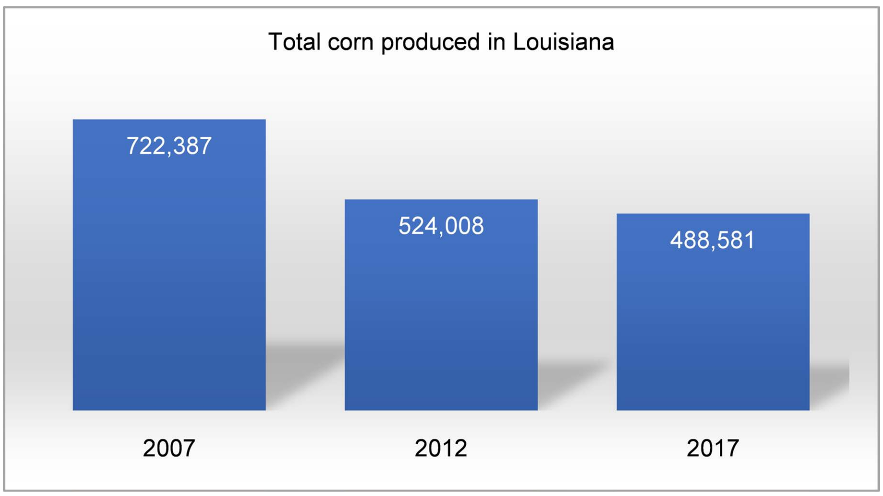

Figure 12. Total corn produced in Louisiana (acres). Source: United States Department of Agriculture (2009; 2014: 2019).

Cotton production in Louisiana has declined in recent years, as has maize production. Cotton was grown on a total of 333,804 acres in 2007. However, compared to the previous year, there was a decrease of 107,086 acres in 2012, with a total of 226,718 acres of cotton produced. Furthermore, cotton production decreased by 10,048 acres in 2017 compared to 2012, resulting in a total of 216,670 acres of cotton produced. (Figure 13)

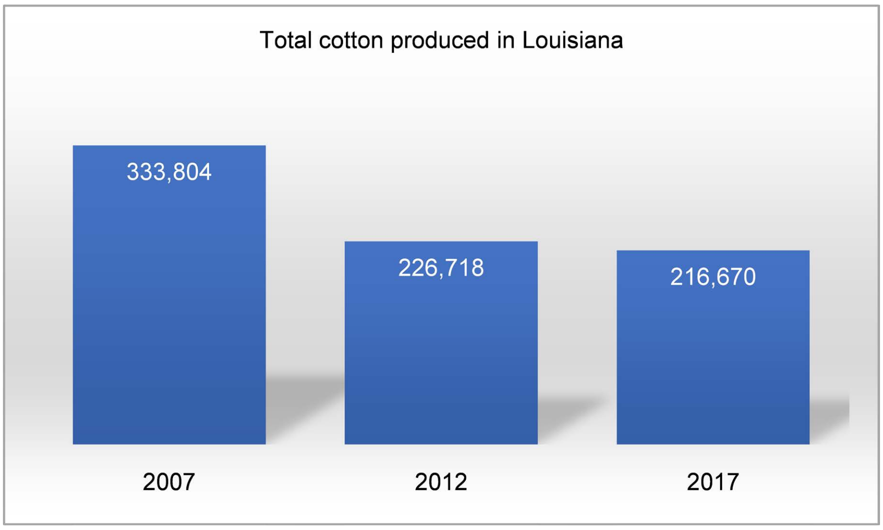

Figure 13. Total cotton produced in Louisiana (acres). Source: United States Department of Agriculture (2009; 2014: 2019).

In contrast to corn and cotton, rice production in Louisiana has increased over the years. In 2007, 377,115 acres of rice were produced. By 2012, production had increased to 395,063 acres, a 17.948-acre increase. Furthermore, rice production increased to 397,653 acres in 2017, representing an increase of 2590 acres over the previous year. (**Figure 14**)

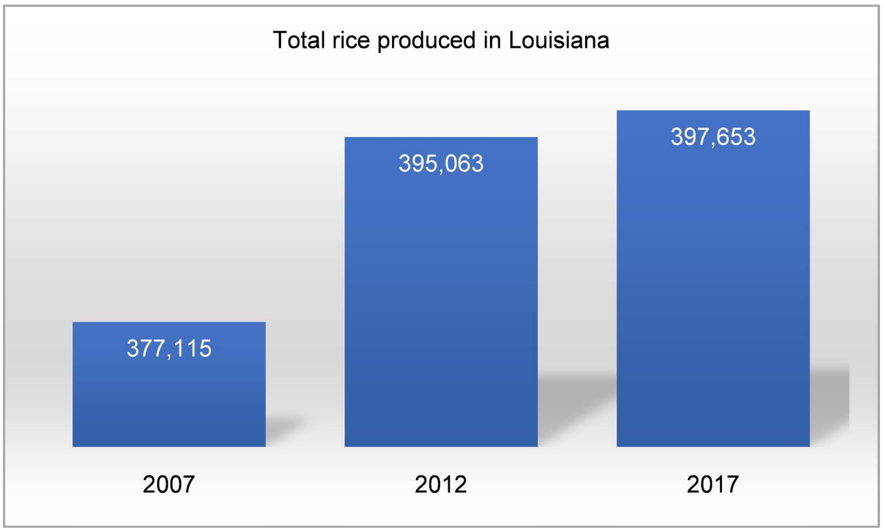

Figure 14. Total rice produced in Louisiana (acres). Source: United States Department of Agriculture (2009; 2014: 2019).

Soybean production in Louisiana has increased in recent years, similar to rice production. In 2007, 593,815 acres of soybeans were planted. This increased to 1,113,650 acres in 2012, a significant increase of 519,835 acres. Furthermore, soybean production increased to 1,250,093 acres in 2017, representing an increase of 136,443 acres over 2012. (**Figure 15**)

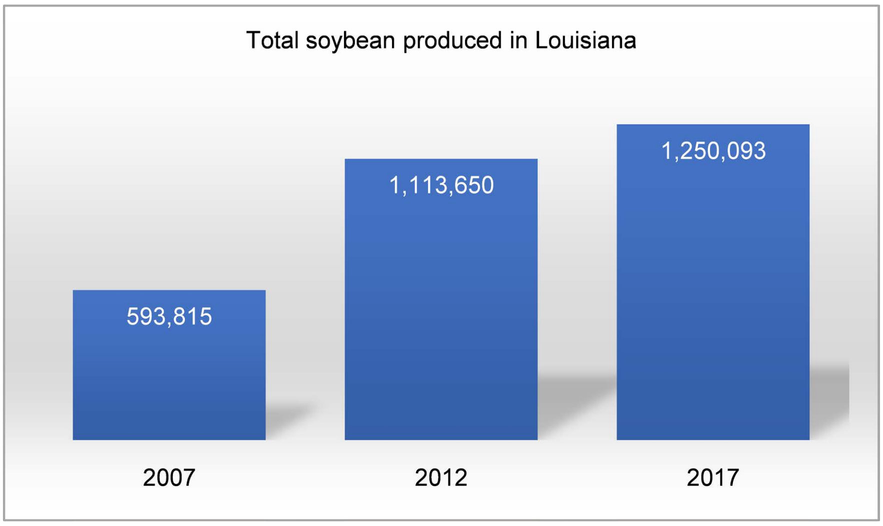

Figure 15. Total soybean produced in Louisiana (acres). Source: United States Department of Agriculture (2009; 2014: 2019).

The average high temperature in Louisiana fluctuated or undulated between 2000 and 2022, characterized by varying temperatures over time. Several years stood out with the highest average high temperatures during this time period, including 2012 (79.2˚F), 2011 (79˚F), 2016 (78.8˚F), 2017 (78˚F), and 2022 (78.3˚F). High temperatures were relatively lower in 2002 (76.7˚F), 2003 (76.8˚F), 2004 (77.2˚F), 2009 (77˚F), 2014 (75.4˚F), and 2013 (76.5˚F). Throughout the years, Louisiana has consistently experienced high temperatures. (Figure 16)

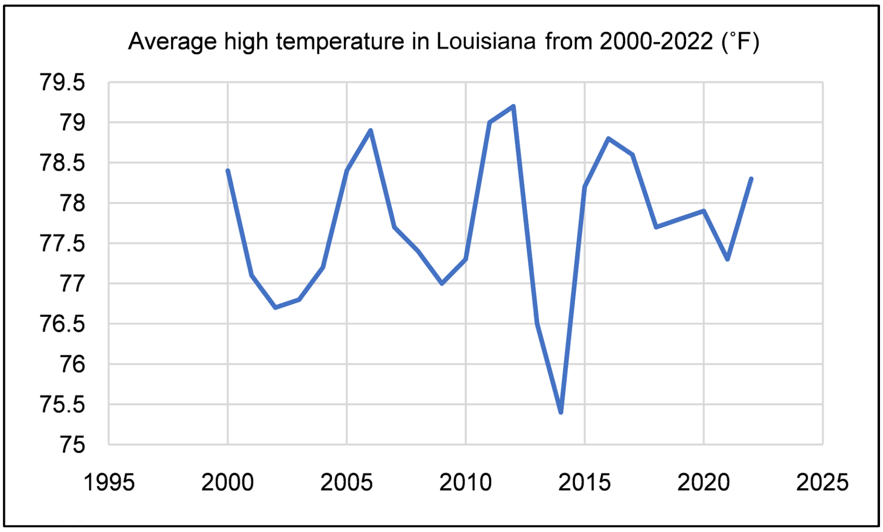

Figure 16. Average high temperature in Louisiana from 2000-2022 (acres). Source: Extreme Weather Watch (2023).

A graph depicting total annual precipitation in Louisiana from 1895 to 2020 shows annual values as dots, while bars represent 5-year averages (with the last bar representing a 6-year average). The long-term average precipitation of 57.2

inches is represented by the horizontal black line. Throughout the year, Louisiana receives a lot of rain. Notably, precipitation levels were above average during the most recent 6-year period (2015-2020) (National Centers for Environmental Information, 2022). (**Figure 17**)

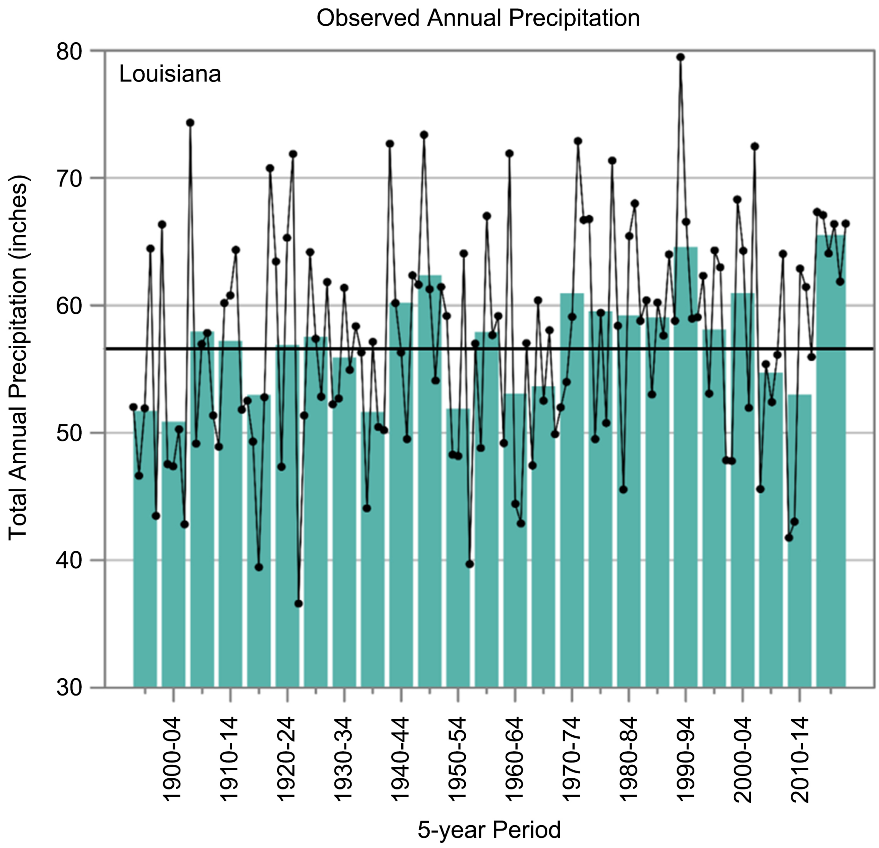

Figure 17. Total annual precipitation in Louisiana (inches). Source: National Centers for Environmental Information (2022).

6. Discussion

With reference to **Figure 16**, between 2000 and 2022, the average high temperature in Louisiana showed a fluctuating or undulating pattern, with varying temperatures throughout the years. Temperature oscillations can be attributed to a variety of climate-related factors and influences. Natural climate variability is a significant factor influencing Louisiana's average high temperature. Climate systems such as El Nio and La Nia, which occur in the tropical Pacific Ocean, can cause changes in weather patterns all over the world, including in Louisiana. These climate phenomena cause periods of warmer or cooler weather, contributing to the temperature variations seen over time. Furthermore, changes in atmospheric circulation patterns can contribute to temperature fluctuations. Temperature patterns can be influenced by changes in the intensity and location of high-pressure systems, variations in wind patterns, and the presence of weather systems such as frontal systems and atmospheric blocking. These variables can cause periods of warmer or cooler weather, which contributes to the observed undulating trend in average high temperatures. Furthermore, long-term climate change influences temperature patterns over long time periods. While short-term fluctuations are explained by natural variability, the gradual rise in global average temperatures caused by greenhouse gas emissions contributes to the overall warming trend observed in the climate system. However, even within this long-term warming trend, there may be periods of temperature fluctuation and variability, resulting in the observed undulating pattern. It is important to note that localised factors such as land use changes, urbanisation, and regional climate characteristics can all have an impact on temperature variations in specific areas of Louisiana. These factors can contribute to temperature fluctuations at the local scale, complicating the region's observed undulating temperature trend [8].

In Louisiana, the number of very hot days was above average in the early 20th century but was well below average during the late 1960s and 1970s. Since 1995, the number of very hot days has begun to increase but has generally remained below average. By contrast, the number of very warm nights has increased steadily since 2000, reaching a record-high level during 2015-2020 [8]. Since 1970, Louisiana's total annual precipitation has generally exceeded the long-term average. Although the years 2010 and 2011 were unusually dry, eight of the nine years that followed saw above-average precipitation. Snowfall is uncommon near the Gulf of Mexico, but it can occur in the northern part of the state on occasion when polar air masses intrude [60].

Climate change has had a variety of effects on crop cultivation in Louisiana. While acreage dedicated to rice and soybean production has increased steadily over time, acreage dedicated to maize and cotton has decreased. These changes can be attributed to the impact of climate change on agricultural practises and market dynamics in Louisiana. Climate change can have a wide range of effects on precipitation patterns, resulting in both excessive rainfall and drought conditions in various parts of the world. Climate change has increased precipitation in Louisiana, which can have both positive and negative effects on crop production. On the plus side, increased precipitation may provide more water resources for irrigation. However, it can also cause problems such as high soil moisture content and waterlogging, especially if drainage systems are inadequate. Such conditions can impede root growth and nutrient absorption, resulting in reduced crop yields or even crop losses [60]. The examination of climate change's effects on crop farming in Louisiana reveals patterns in cropland usage, showing rises in rice and soybean cultivation while witnessing decreases in maize and cotton. This underscores the intricate nature of climate change's impact, as heightened precipitation presents both advantages and drawbacks for farming. Vital adaptive measures such as enhancing drainage systems become imperative. The wider implications for agricultural sustainability and food security demand holistic strategies like the Climate-Resilient Agriculture Program to navigate evolving environmental conditions, stressing the importance of integrated approaches to confront challenges and seize potential benefits.

Based on the data in **Figure 12** and **Figure 13**, it is clear that corn and cotton yields in Louisiana have been declining for several years. **Figure 14** and **Figure 15** show, on the other hand, that rice and soybean yields in Louisiana have been steadily increasing. The cultivation of crops in Louisiana has experienced notable transformations due to the impacts of climate change, resulting in changes in the distribution of acreage across different crops. One significant shift has been the increasing allocation of land to rice and soybean production, which can be attributed to various factors associated with climate change. One key factor is the alteration in temperature and precipitation patterns. The changing climate has created conditions that are advantageous for the growth and development of rice and soybeans. These crops thrive in warmer and wetter environments, which have become more prevalent due to climate change. With rising temperatures and increased rainfall, the growing seasons have extended, providing more favorable circumstances for cultivating rice and soybeans. Consequently, farmers in Louisiana have responded by dedicating larger areas of land to the cultivation of these crops. Furthermore, the increase in rice and soybean acreage in Louisiana can be attributed to rising demand for these crops in both domestic and international markets. Changing dietary preferences, population growth, and increased global trade have all contributed to rising demand for rice and soybeans. In response to these high demands, Louisiana has initiated projects to help rice growers for instance, to increase their productivity while reducing yield losses. For instance, the Louisiana State University has been awarded a $10 million grant from USDA's National Institute of Food and Agriculture (NIFA) to improve sustainability and profitability of rice farming through research innovations that advance climate-resilient crops [25].

Conversely, the reduction in acreage dedicated to maize (corn) and cotton can be attributed to the effects of climate change. Maize is especially sensitive to water scarcity and extreme temperatures. Hotter summers and the potential for water stress caused by climate change have made maize cultivation less feasible in some areas of Louisiana. As a result, farmers may have shifted their focus to other crops better suited to changing climate conditions, resulting in a decrease in maize acreage. Similarly, cotton has faced challenges as a result of climate change, such as rising temperatures affecting crop quality and yield, as well as changing market dynamics, which have influenced farmers' decisions to reduce cotton acreage. Cotton, another crop impacted by climate change, has seen acreage decline due to a variety of factors. Rising temperatures caused by climate change have had a negative impact on cotton quality and yield, affecting its profitability. Changes in global market dynamics, competition from other cotton-producing regions, and changes in consumer preferences have also influenced farmers' decisions to reduce cotton acreage [29] [35].

It is critical to recognise that the effects of climate change on crop cultivation are complex and diverse. While some crops may benefit from climate change, others may face difficulties and require adaptation strategies. Farmers' crop allocation decisions are influenced not only by climate change, but also by economic considerations, market dynamics, and policy factors. These findings are consistent with the findings of the Intergovernmental Panel on Climate Change (IPCC), which states that rising global temperatures and extreme weather events caused by climate change will reduce food production dependability [12]. Implementing climate-smart agriculture practices is viewed as the most important strategy for mitigating the negative effects of climate variability on crop adaptation, thereby reducing the potentially disastrous consequences on global crop production [1].

7. Conclusion

Louisiana is anticipated to witness a significant uptick in the frequency of days surpassing 95˚F in the forthcoming decades. Projections indicate that the tally of such scorching days may fluctuate between 35 and 70 over the next 70 years [8]. This projected surge in instances of extreme heat corresponds to broader patterns of climate change observed worldwide, wherein escalating emissions of greenhouse gases drive up mean temperatures and escalate the occurrence of heatwaves [2]. This contrasts with the present average of approximately 15 days. Even in the coming decades, this rising temperature is likely to have a negative impact on maize and rice yields. However, there is one advantage to consider. Higher levels of carbon dioxide in the atmosphere can boost crop yields. If sufficient water resources are available, the fertilizing effect of elevated carbon dioxide levels is expected to offset the negative impact of heat on soybeans and cotton. Nonetheless, farms without access to irrigation systems may experience more frequent and severe droughts, potentially leading to a higher number of crop failures [61]. Clearly, climate change is indeed real [62], whereby extreme weather affects livestock and crops, and droughts have impacts on the stability and price of food [63]. To address the harmful and beneficial effects of Louisiana's changing climate on food crop production, we recommend the implementation of a comprehensive Climate-Resilient Agriculture Program. The primary objective of the Climate Resilient Agriculture Program in Louisiana is to confront the challenges posed by climate change and ensure the long-term sustainability of the state's agricultural sector [8]. This initiative advocates for the development and adoption of crop varieties capable of withstanding Louisiana's changing climate conditions. Farmers will be encouraged to cultivate crops resilient to temperature fluctuations, water scarcity, and other climate-related adversities. Moreover, the program emphasizes sustainable water resource management in response to the impact of climate change on precipitation patterns [60]. By addressing these challenges while also capitalizing on potential opportunities, the program seeks to secure a sustainable future for crop producers in Louisiana. This program should encompass initiatives to promote the development and adoption of climate-adaptive crop varieties, invest in sustainable water resource management and infrastructure, and establish climate-responsive insurance and risk mitigation mechanisms. Additionally, it should prioritize farmer education and outreach to foster climate-smart agricultural practices. By addressing both the challenges and opportunities presented by climate change, this policy aims to safeguard the state's food security, enhance the resilience of its agricultural sector, and ensure a sustainable future for Louisiana's crop producers.

Funding

The authors would like to acknowledge the USDA National Institute of Food and Agriculture (NIFA) McIntire Stennis Forestry Research Program funded project with award number NI22MSCFRXXXG077.

Conflicts of Interest

The authors declare no conflicts of interest regarding the publication of this paper.

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