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Bioenergy Crops as a Promising Alternative to Fossil Fuels in Louisiana: A Geographic Information System (GIS) Perspective

Yaw A. Twumasi[1*], Zhu H. Ning[1], John B. Namwamba[1], Abena B. Asare-Ansah[1], Edmund C. Merem[2], Harriet B. Yeboah[3], Judith Oppong[1], Matilda Anokye[1], Diana B. Frimpong[1], Priscilla M. Loh[1], Julia Atayi[1], Rechael N. D. Armah[1], Caroline Y. Apraku[1], Opeyemi I. Oladigbolu[1], Cynthia C. Ogbu[1], Leah W. Njeri[1], Joyce McClendon-Peralta[1]

[1]Department of Urban Forestry and Natural Resources, Southern University and A&M College, Baton Rouge, USA
[2]Department of Urban and Regional Planning, Jackson State University, Jackson, USA
[3]Department of Geography and Tourism Studies, Brock University, St. Catharines, Canada
Email: *yaw_twumasi@subr.edu, *yaw.twumasi@gmail.com

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Abstract

Rising greenhouse gas emissions are causing climate change, and the world's focus has shifted to the need to reduce our reliance on fossil fuels. There has been a rise in the published literature on the utilization of crops for bioenergy production in Louisiana. However, very few scholarly documents have used Geographic Information Systems (GIS) to map the distribution of potential bioenergy crops in Louisiana. This study seeks to fill the void by evaluating the potential of bioenergy crops in Louisiana for energy production using GIS. Given this objective, the agricultural census data for 1999, 2009, 2019, and 2020 obtained from the U.S. Department of Agriculture were used in the analysis. The quantities of various crops produced in the state were loaded into an attribute table and joined to a shapefile using ArcGIS software. The symbology tool's graduated option was used to create five maps representing each of the bioenergy crops in Louisiana. The findings of the GIS analysis show that some of the parishes, such as Franklin produced the most bushels of corn (13,795,416), Iberia produced the most tons of sugarcane (1,697,980), East Carroll produced the most bushels of soybean (8,237,991), Tensas harvested the most bales of cotton (80,898) and Avoyelles produced the most bushels of sorghum (630,694). The abundance and availability of crops as raw materials for energy production will translate into lower prices in terms of energy use, making bioenergy crops a promising alternative to fossil fuels. In addition, gasoline price data from 1993-2022 was obtained from U.S. Energy Information Administration. A regression model for the average annual gasoline price over the years was constructed. The results show that the average annual gasoline price variation with respect to years is statistically significant ($p < 0.05$). This suggests that gasoline prices will generally rise despite a price drop over the years. The paper concludes by outlining policy recommendations in the form of assessing the availability and viability of other crop types, such as wheat, oats, and rice, for energy production in the state.

Keywords

Bioenergy Crops, Biomass, Fossil Fuel, Gasoline, Geographic Information System (GIS), Regression Analysis, Louisiana

1. Introduction

Even though the earth's form cannot change, the world is becoming an increasingly global village due to people's increasing demand for energy. As the world's population and economy grow, the demand for energy and related services will increase [1]. In 2004, fossil fuels provided approximately 88% of commercial energy usage, with approximately 467 Energy Joules (EJ). It has been predicted that energy consumption will at least double during the next century, if not triple. As greenhouse gas concentrations rise, the majority of this increase is due to carbon dioxide emissions from fossil fuels [2]. Dipti [3] notes that increasing carbon dioxide emissions are causing climate change, and the world's attention has shifted to the need to reduce fossil fuel dependence. However, according to Schwartz [4], the supply of sustainable energy, especially when it comes to fighting climate change, will be a major challenge for humanity in the decades to come. As we panic and seek to reduce emissions and develop alternative energy sources, various sources have emerged in response to the crisis. Future energy needs can be met sustainably with bioenergy. With considerable room for growth in the production of heat, power, and transportation fuels, it is now the world's largest renewable energy supplier [5].

Union of Concerned Scientists [6] also explains that bioenergy is the largest renewable energy source. In 2017, bioenergy accounted for 70% of all renewable energy usage. The contribution of bioenergy has been declining by a few percentage points (about 0.5% to 1%) every year, owing to a decrease in the usage of conventional biomass sources [6]. Compared to fossil fuels, biomass-based energy may substantially reduce GHG emissions when produced sustainably. It is accessible in most nations or might be developed, making it a more globally distributed energy supply choice. It is also a flexible energy source that may generate electricity, heat, liquid, and gaseous fuels [7]. According to Buen *et al.* [5], bioenergy is already contributing significantly to addressing global energy needs. This contribution has the potential to grow significantly in the future, resulting in reduced greenhouse gas emissions and other environmental benefits, as well as increased energy security, improved trade balances, opportunities for social and economic development in rural communities, and better resource and waste management. In the year 2050, bioenergy might provide between a quarter and a third of the world's primary energy supply. It is the only renewable energy source that can completely replace fossil fuels in all energy markets, including heat, electricity, and transportation fuels [5], bioenergy is one of several components of a comprehensive climate plan that can decrease anticipated US oil usage by half by 2030 and assist the country's transition away from coal-fired power generation [6].

Schultz *et al.* [7] also assert that renewable energy's continuous rise in the United States presents a significant economic potential for the agriculture and forestry industries and rural areas. Renewable energy frequently promotes energy independence and security, improves wildfire prevention, decreases greenhouse gas (GHG) emissions, and has some direct economic advantages. For instance, corn ethanol and biodiesel production reduce the United States' dependency on imported petroleum products by billions of gallons per year. In contrast, renewable energy production can improve agricultural enterprises' resilience to grid power outages. Following the harvest of major crops, Louisiana has several sources of plant material that could be used to produce ethanol and electricity. Rice hulls, for instance, have been used to generate electricity in southwest Louisiana, and sugarcane bagasse is used as a burning fuel by sugar factories [8]. The majority of ethanol plants in the United States are located in rural areas where agriculture is the primary economic activity. Since the economic impact of ethanol production is very much local, it is an attractive industry because wages in ethanol production are generally higher than in many other alternatives. Whether or not, this industry develops in Louisiana would necessitate a deeper investigation of the economic feasibility and risks associated with markets, technologies, and natural factors [8].

Union of Concerned Scientists also argues that it is worth noting that the use of crops for biofuels accounts for a relatively tiny percentage of total agricultural utilization [6]. Crop yields are growing worldwide, which is an essential indicator of considerable advancements in agricultural operations. The yields of the most important crops, such as cereals, oil crops, and sugar crops, have increased by double digits globally, but the area harvested for these crops has not increased at the same rate. Sugarbeet, barley, and sorghum, for example, have lowered the amount of land harvested while improving yields. More food is produced effectively from the same amount of land on a global scale than ever before. Due to their expanding use in the Americas (maize) and Asia (wheat), key crops such as maize, rice, and wheat dominate crop output globally (rice and wheat). Although only a small portion of maize is exploited for biofuel production, the energy potential of rice and wheat lies in the efficient utilization of leftovers such as husks and straws, which are currently underutilized and can create environmental issues. To give another illustration, soybean and rapeseed output has nearly quadrupled globally, owing to considerable soybean production in South America (the Americas account for 90% of global soybean production) and rapeseed production in the Americas, Europe, and Asia [6]. Due to the large cropping areas required, bioenergy cannot completely replace fossil fuels at this time. Nonetheless, it has the potential to reduce total fossil fuel usage.

This research aims to propose that future energy needs can be met sustainably with bioenergy. Twumasi *et al.* [9] recommend using GIS mapping in each agricultural district to enable researchers and farmers to determine factors that contribute to the increasing and decreasing trends in the production of bioenergy crops. Using GIS, this research assesses the availability and utilization of crops in Louisiana for energy production as a promising alternative renewable resource. The significance of his study is to provide an insight into the actual seriousness of what is happening to the ecosystem and offer helpful suggestions to government officials, scholars, agriculturalists, and energy specialists on the availability and importance of bioenergy crops in Louisiana as an alternative to fossil fuels. Bioenergy crops are one energy source that might positively influence the environment by lowering carbon dioxide levels and greenhouse gas emissions, thus slowing climate change and its harmful consequences. Economically, farmers will be encouraged to cultivate more crops and have a ready market for their produce, increasing their yields and earning more profits. Finally, energy stakeholders will discover a safer and more sustainable alternative renewable resource for energy production.

The global abundance of crops as a workable solution to energy production while maximizing net carbon security has validated bioenergy as a viable energy resource. There has been a rise in the published literature on the utilization of crops for bioenergy production in Louisiana. However, very few scholarly documents have used Geographic Information Systems (GIS) to map the distribution of potential crops in Louisiana to produce bioenergy in the state, which will be a gap in this research. Also, few studies that used GIS in this research area included limited crops in the survey, making the study's results not comprehensive enough. This paper seeks to provide a bridge to the current knowledge gap that exists in the subject area. This research is among the few that use GIS to map the distribution of bioenergy crops such as sugarcane, cotton, sorghum, corn, and soybean in all the sixty-four parishes in Louisiana. Using GIS, this paper argues that the availability and utilization of crops in Louisiana for bioenergy production is a promising alternative renewable resource. However, bioenergy cannot completely replace fossil fuels at this time due to the large cropping areas considered. Notwithstanding, it has the potential to lower total fossil fuel consumption.

1.1. Bioenergy Crops in Louisiana

Yadav *et al.* [10] accentuate that bioenergy crops that have been genetically modified have superior tolerance to harsh environments, a faster growth rate, and a higher caloric value. Though there is no widely agreed-upon definition, bioenergy crops are frequently divided into distinct "generations" based on their stages of development and the feedstocks they consume [7]. According to Yadav *et al.* [10], first-, second-, and third-generation bioenergy crops, dedicated energy crops, and halophytes are the five different types of bioenergy crops.

The biofuel production initiative began with first-generation bioenergy crops (FGECs). These crops are also a common food source in the local or worldwide community. Sweet sorghum, corn, sugarcane, oil palm, and rapeseed were among the first FGECs utilized to make ethanol. However, first-generation bioenergy crops have limited capacity to substitute for petrol-oil products due to greater production costs. In general, developed technology for the manufacture of bio-ethanol from sugar and starch crops, biodiesel and renewable diesel from oil crops and animal fats, and biomethane from anaerobic digestion of wet biomass are all examples of first-generation biofuels [7]. FGECs are used to manufacture the vast majority of existing liquid biofuels. As a result, they can be utilized for food; raw materials compete with food for fertile land and inputs. Corn, sugar-cane, oil palm, and rapeseed are just a few examples. Biofuels made from FGECs are made by fermenting sugars to make ethanol or trans-esterifying plant oils to make biodiesel [3].

Second-generation biofuels cover a broad spectrum of innovative biofuels made from new feedstocks. Switchgrass, reed canary grass, alfalfa, Napier grass, and Bermuda grass are examples of second-generation bioenergy crops [10]. SGECs are predicted to be more efficient than FGECs in producing cellulose-based fuels and non-oxygenated, pure hydrocarbon fuels like biomass-to-liquid fuel. Biofuels made from lingo cellulosic SGECs biochemically or thermochemically have higher energy content (than most FGEC biofuels [3].

Third-generation biofuels, otherwise known as advanced biofuels, are biofuel production pathways that are still in the research and development stage or are a long way from commercialization [7]. Boreal plants, crassulacean acid metabolism (CAM) plants, eucalyptus, and microalgae are examples of third-generation bioenergy crops (TGECs). Direct fermentation of cellulosic biomass uses CAM and boreal plants as feedstock [10]. Boreal and CAM plants might be used as feedstock for direct cellulose fermentation, and eucalyptus could be used to produce bioenergy via thermo-conversion. In contrast, algae could be used to make biodiesel. African palm (22% oil), coconut (55% to 60% oil), castor bean grain (45% to 48% oil), and peanut (40% to 43% oil) are among the TGEC oleaginous crops being researched for biodiesel production. They can aid in reducing GHG emissions by absorbing CO_2 emitted by power plants or creating biomass through photosynthesis [3].

Again, dedicated energy crops (DEC) have been presented as a solution for generating energy while minimizing the impact on food security and the environment. They are useful in delivering ecosystem services such as carbon sequestration, biodiversity enhancement, salinity reduction, and soil and water quality improvement [3]. Cellulosic plants (eucalyptus, poplar, willow, birch, and others), perennial grasses (giant reed, reed canary grass, switchgrass, elephant grass, and others), non-edible oil crops (castor bean, physic nut, oil radish, Pongamia, and others), and oil plants are among the dedicated bioenergy crops. Since such crops have a shorter life cycle, they can be harvested many times each year over a lengthy period [10]. Lastly, acacia, Eucalyptus, Casuarina, Melaleuca, Prosopis, Rhizophora, and Tamarix are some of the genera that make up bioenergy halophytes [10].

Hazell and Pachauri [11] highlight that because some energy crops, such as trees and grasses, require little input, they may occasionally be cultivated on the ground that would otherwise be unsuitable for food crops. These energy crops have the potential to increase the amount of land accessible for agricultural operations and provide farmers with new markets. These beneficial effects on the rural economy's dynamics might help to reduce the customary outflow to cities and provide a more favorable economic climate for increased investment in rural infrastructure, health, and education.

1.2. The Utilization of Bioenergy Crops for Bioenergy Production

With growing energy costs and the unpredictability of fossil fuel supplies, it is critical to keep an eye on cheaper, safer, and more sustainable bioenergy. As a source of energy, bioenergy crops might play an essential role as an ecologically safe and commercially successful substitute for coal [3]. According to Hazell and Pachauri [11], agricultural biofuels are currently centered on ethanol production from sucrose or starch generated from vegetative biomass or grain and biodiesel production from the more direct use of vegetable oils and animal fats. Ethanol has a high-octane rating and may be combined with gasoline in small amounts for use in standard internal combustion engines. Plants may produce more cellulose per hectare than sucrose or starch, and plant biomass is a plentiful and renewable source of hydrocarbons [11]. Benedict *et al.* [8] also explain that ethanol is used to supplement gasoline in small amounts. While corn starch is the most common fuel source, research into converting various plant fibers (cellulose) into ethanol is ongoing.

With reference to [4], farms and specialized production facilities might develop a crop cycle with crops dedicated to energy production to create biomass. Algae are an excellent example of how this works. Algae are gathered in vats that are kept out in the sun, and they produce biomass that can be harvested and utilized as fuel as a result of photosynthesis. Farmers might gather plant debris from food crops that would otherwise be discarded and send it to biomass refineries with the energy crops, resulting in even more energy and additional cash. Developing the technology, techniques, and regulations required to use agricultural biomass resources properly would benefit communities across the country both financially and environmentally while reducing its reliance on oil and coal and its emissions of greenhouse gases. However, taking advantage of this potential will require private investment and sound public policies. Following a rational bioenergy path, increasing vehicle economy, and developing sophisticated vehicle technologies can help the country reduce its expected oil consumption by half in twenty years [6].

1.3. Benefits and Costs of Using Crops for Bioenergy Production

Bioenergy crops are one energy source that might positively influence the environment by lowering carbon dioxide levels, greenhouse gas emissions, and soil erosion. Biofuel production from fast-growing, photosynthetically efficient bioenergy crops is gaining traction as a viable replacement for fossil fuels. Plants that produce bioenergy enhance soil carbon and fix carbon in the atmosphere [10]. Similarly, [3] explains that they help reduce greenhouse gas emissions, thus slowing climate change and its harmful consequences.

Again, Yadav *et al.* [10] explain that bioenergy crops have several environmental benefits. Due to their perennial nature, they resist illnesses and parasites. Bioenergy designs' phenotypic, architectural, biochemical, and physiological characteristics have improved, which are favorable properties in biofuel production. Bioenergy crop cultivars are also more resistant to biotic and abiotic stressors, developing more quickly than conventional crops. Furthermore, bioenergy crops require fewer biological, chemical, or physical pre-treatments, lowering biomass processing costs. Therefore, to meet energy demands, there is a need to develop new high-yielding energy crop types, which might be done via global screening of efficient botanical plants [10].

On the other hand, Schultz *et al.* [7] argue that renewable energy development might have detrimental environmental and land-use consequences. Expanding bioenergy feedstock production, such as corn for ethanol and soybeans for biodiesel, might, for example, result in the conversion of pastures and grasslands to actively managed croplands. In some areas, this might have a detrimental impact on soil quality, water quality, water availability, and land-use patterns. Adverse effects of electricity technologies include large amounts of water consumption during the operation of biomass power generation systems, increased bird and bat mortality and disrupted migration patterns from wind turbines, conversion of land from agriculture and other uses to host utility-scale PV systems, and the introduction of hazardous materials into the environment if PV panels and batteries are not disposed of or recycled properly. Secondly, [3] argues that increased biofuel production will most likely result in habitat loss, increased and enhanced dispersion of invasive species, and pollution, whereas the biodiversity consequences of increased biofuel production will most likely result in habitat loss, increased and enhanced dispersion of invasive species, and pollution

Thirdly, according to Selassi *et al.* [12], even as the production of bioenergy feedstock crops in the United States increases in response to the continued growth and advancement of the biofuel and bioenergy industries, so will competition for agricultural land for the production of feedstock crops compared to conventional crops. Due to the viability of soil and climate to potential feedstock crops, as well as other factors, competition for agricultural land is expected to be more predominant in some regions of the country than others. The intensity of this growing demand for cropland is also anticipated to be strongly influenced by alternative governmental programs and policies that may develop relating to proposed national renewable portfolio standards, policies regulating carbon dioxide, and other factors. The global demand for biofuels, which could reach 20% to 30% of total energy demand, will increase land use competition between traditional and newly developed biofuel feedstock crops. Also, the production of biofuel feedstock crops that meet stringent sustainability criteria will remain significant, with both supportive and competitive implications for food security [12].

Kim and Day [13] also argue that developing an economically viable and sustainable biorefinery is a challenge for the biofuel industry. The prospective new biorefineries in Louisiana, raw sugar mills, are only operational for three months out of the year. Other feedstocks, besides sugar cane, must be used as complementary feedstocks to operate throughout the year.

2. Materials and Methods

2.1. Materials

The data used were collected from the United States Department of Agriculture, National Agricultural Statistical Service [14] [15]. The Agricultural census data [16] [17] [18] [19] [20] from the Louisiana State on district levels were used to obtain the analysis of this research. In addition, gasoline price data from 1993-2022 was obtained from U.S. Energy Information Administration [21]. The agricultural districts map in Louisiana State is represented with district codes as shown in **Figure 1** below.

2.2. Methods

The commodities under study were measured in their various units: corn (bushels), cotton (bales), sugarcane (tons), and soybeans (bushels), and sorghum (bushels). In order to make an accurate comparison and a uniform decision, all the units were converted to Pounds (lbs), using the United States Department of Agriculture conversion factors for the aagricultural commodities [23]. One bale of cotton equals 480 lbs, one bushel of corn and sorghum equals 56 lbs, one bushel of soybean equals 60 lbs, and one ton of sugarcane equals 2000 lbs [23]. After the conversion, descriptive statistics was employed to discuss the production of bioenergy crops in Louisiana. The data from the agricultural census were converted into relative measures. These measures established changes in production within districts and over time, as well as the percentage production, increasing and decreasing characteristics, and crop production patterns from each district.

Additionally, the research develops a Geographic Information System (GIS) methodology to assess the availability and potential of bioenergy crops for energy production in Louisiana. Using ArcGIS, the data on the quantities of the various crops produced in Louisiana in 2017 was loaded into the attribute table

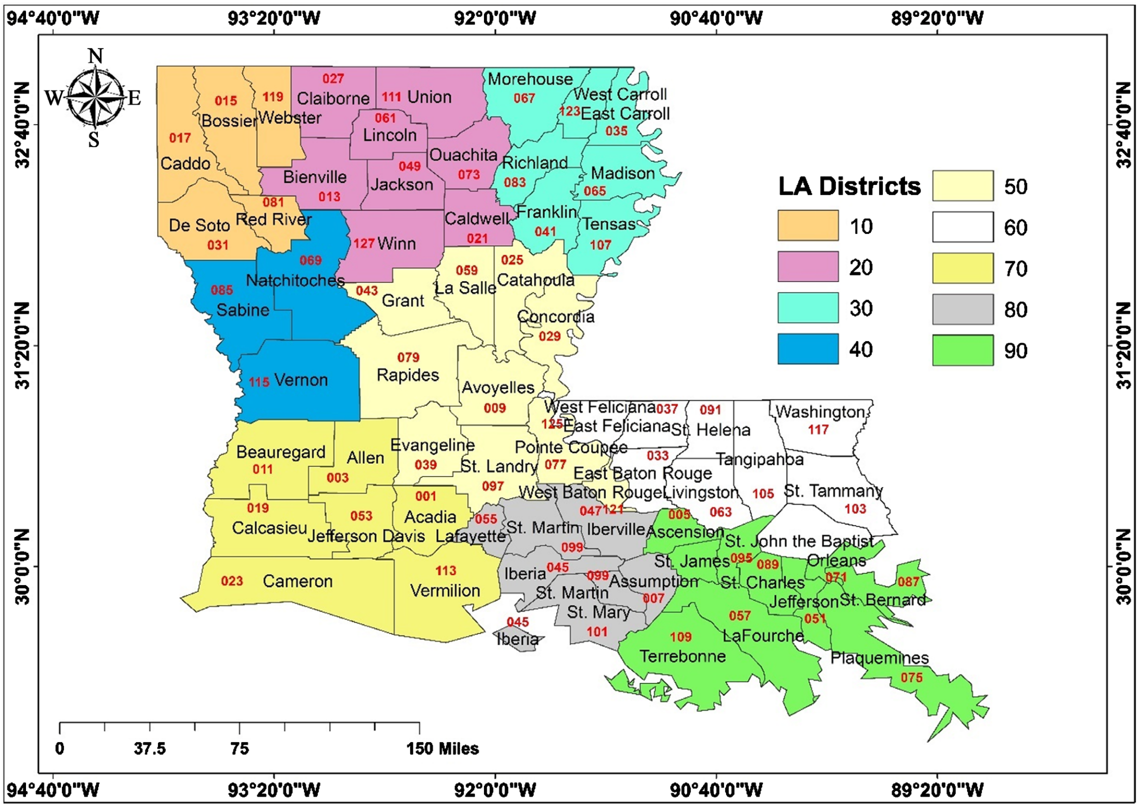

Figure 1. A map of Louisiana agricultural districts showing the various codes and parishes in the district [22].

and joined to a shapefile. Thereafter, the symbology tool's graduated color option was used to create five different maps to represent the production of each crop in Louisiana. Choropleth maps, tables, and bar charts were used to represent the data graphically. According to [24], choropleth maps are typically used to display statistical interpretation among map enumeration units. They show the variation in quantitative data among enumeration units such as countries, states, or counties [25]. Choropleth maps depict geographically divided areas or regions that are colored, shaded, or patterned with regard to a data variable. This enables the visualization of values over a geographical area, revealing variations or patterns across the displayed location [26]. [27] also argues that choropleth maps work best when showing only one variable.

Furthermore, a model for the average annual gasoline price versus years was produced by polynomial curve fitting using Microsoft Excel. Also, Excel statistical tool kit was used to determine the significance of the model.

3. Results

3.1. Historical Highlights of Crops Produced in Louisiana

Table 1 displays the historical highlights of the crops produced in Louisiana from 1964 to 1997. In 1964, sugarcane was produced the most, followed by cotton, then soybean. Corn was the least produced crop. The results are similar to the previous years. Among the four crops, sugarcane was harvested the most in 1978, 1982, 1987, 1992, and 1997.

Similarly, cotton was the second most-produced crop in all the years. However, considering that the data on the quantity of sugarcane harvested in 1969 and 1974 are not available, cotton appears to be the most harvested crop within those years. Similarly, more bales of soybean were produced than bushels of corn in all the years. Unfortunately, the data on the historical highlights of harvested sorghum in Louisiana is not available.

3.2. Total and Harvested Croplands in Louisiana

Table 2 displays the total cropland and harvested cropland in Louisiana from 1997 to 2007. It is evident that there is a decreasing trend in the total cropland and harvested cropland from 1997 to 2007 and further from 2007 to 2017. The acres of total cropland and harvested cropland in Louisiana have reduced over the years. In 2007, the total cropland reduced by 640,067 acres from 5,331,411 acres in 1997 to 4,691,344 acres in 2007. In 2017, the total cropland also reduced by 345,501 acres from 4,691,344 acres to 4,345,843 acres. Similarly, in 2007, the harvested cropland declined by 510,600 acres from 3,852,648 acres in 1997 to 3,342,048 acres. In 2017, the harvested cropland also decreased by 27,093 from 3,342,048 in 2007 to 3,314,955. However, the decrease is not significant because the state still has a significant production of the crops.

In 1997, out of the 5,331,411 acres of total cropland, 3,852,648 acres were used for harvesting with 1,478,763 acres of total cropland remaining. In 2007, out of the 4,691,344 acres of total cropland 3,342,048 acres represented the harvested cropland with 1,349,296 remaining. Lastly, in 2017, out of the 4,345,843 acres of total cropland, 314,955 acres constituted the harvested cropland with 1,030,888 remaining.

3.3. The Total and Percentages of Bioenergy Crop Production in Louisiana

Table 3 portrays the total bioenergy crops harvested in 1997, 2007, and 2017.

Table 1. Historical highlights of harvested crops in Louisiana [19].

Crops (lbs)	1964	1969	1974	1978	1982	1987	1992	1997
Corn	10,611,048	6,237,480	2,460,472	1,941,408	1,892,352	10,627,232	15,099,952	23,020,032
Soybeans	26,803,680	89,405,340	96,484,200	178,142,940	158,294,940	92,422,320	66,768,900	75,631,380
Cotton	245,385,120	217,826,400	280,711,680	244,851,360	270,038,880	283,323,360	397,340,160	310,731,360
Sugarcane	636,354,000	N/A	N/A	594,722,000	502,474,000	528,932,000	712,698,000	631,176,000

Table 2. Total and harvested croplands (acres) in Louisiana [17] [18] [20] [21].

Year	Total Cropland (acres)	Harvested Cropland (acres)
1997	5,331,411	3,852,648
2007	4,691,344	3,342,048
2017	4,345,843	3,314,955

The percentage of bioenergy crops produced in 1997, 2007, and 2017 are also displayed in Table 4. The total production of corn, sugarcane, cotton, soybean and sorghum are 90,834,240 lbs, 2,433,044,000 lbs, 574,910,880 lbs, 186,265,860 lbs and 1,629,322,240 lbs respectively. From 1997 to 2007, sorghum was produced the most, followed by sugarcane, then cotton, before soybean. Corn was the least produced crop.

The percentage change in all the crops recorded in this study is presented accordingly in Table 5. A positive percentage signifies an increase in crop production within the range under consideration, while a negative percentage signifies a decrease in crop production. Corn production observed a decrease of 19.19% from 1997 to 2007 whilst production increased by 14.41 % from 2007 to 2017. The production of sugarcane declined by 0.81% which is an indication that less sugarcane was produced between 1997-2007 than in the previous decade. Unfortunately, sugarcane production also decreased slightly from 2007 to 2017 by 0.82%. It is fascinating to note that cotton production increased in both decades, by 26.14% from 1997 to 2007 and 9.81% from 2007 to 2017. Soybean production

Table 3. Total bioenergy crop production in Louisiana [16] [17] [18] [20].

Crop (lbs)	1997	2007	2017	Total
Corn	23,020,032	40,453,672	27,360,536	90,834,240
Sugarcane	791,176,000	810,866,000	831,002,000	2,433,044,000
Cotton	310,683,360	160,225,920	104,001,600	574,910,880
Soybean	75,631,380	35,628,900	75,005,580	186,265,860
Sorghum	311,247,776	1,254,287,552	63,786,912	1,629,322,240

Table 4. Percentages of bioenergy crop production in Louisiana [16] [17] [19] [20].

Crop	1997 (%)	2007 (%)	2017 (%)
Corn	25.34	44.53	30.12
Sugarcane	32.52	33.33	34.15
Cotton	54.04	27.90	18.09
Soybean	40.60	19.12	40.26
Sorghum	19.10	76.98	3.91

Table 5. Percentage change in bioenergy crop production in Louisiana [16] [18] [19].

Crop	1997-2007 (%)	2007-2017 (%)
Corn	−19.19	14.41
Sugarcane	−0.81	−0.82
Cotton	26.14	9.81
Soybean	21.48	−21.14
Sorghum	−57.88	73.07

also increased by 21.48% from 1997 to 2007 but slightly decreased from 2007 to 2017 at 21.14%. The percentage change in sorghum production is very unusual considering that the state saw a whooping 57.88% decrease from 1997 to 2007 and a sharp increase from 2007 to 2017. These are noteworthy results that require further investigation to determine the factors responsible for the dramatic reduction in crop production in Louisiana.

3.4. Bioenergy Crop Production in Louisiana in 2018 (Acres)

Table 6 displays the production of five bioenergy energy crops in Louisiana for the census year 2018. The total production of corn, sugarcane, soybean, cotton, and sorghum in acres in 2018 was 570,000, 425,000, 1,190,000, 189,000, and 6000 respectively. The production of corn was least in the other districts with 7600 bushels whereas the most production occurred in district 30 on 329,000 acres of land. There was no record of corn production in districts 60, 70, 80, and 90. The other districts combined produced the most sugarcane, with 337,300 tons within the census year. District 70 produced the least tons of sugarcane within that year, with 39,000 tons. There was no record of sugarcane production in districts 10, 20, 30, 40, and 50. Concerning soybean production in Louisiana, district 30 produced the most soybeans, with 561,000 bushels, whereas district 60 produced the least with 7500 bushels. There was no record of soybean production in other districts. District 30 contributed the most to cotton production with, 113,300 acres, whereas district 40 contributed the least with 6000 acres. There was no record of cotton production in districts 20, 60, 70, 80, and 90. Finally, the majority of sorghum was produced on 3900 acres of land in district 50 whereas the least was produced on 2100 acres of land in the other districts. There was no record of sorghum production in districts 10, 20, 30, 40, 60, 70, 80, and 90.

Table 6. Bioenergy crop production in Louisiana in 2018 (acres) [17] [19].

Districts	Corn	Sugarcane	Soybean	Cotton	Sorghum
10	20,100	-	19,400	21,000	-
20	15,900	-	18,300	-	-
30	329,000	-	561,000	113,300	-
40	9900	-	22,300	6000	-
50	67,500	81,500	474,000	42,500	3900
60	-	-	7500	-	-
70	-	39,000	43,700	-	-
80	-	215,000	36,000	-	-
90	-	78,500	8500	-	-
Other Districts	7600	337,300	-	6100	2100
State Total	570,000	425,000	1,190,000	189,000	6000

4. Discussion

4.1. Crop Production in Louisiana

Using Arc GIS, this section maps out the production of corn, cotton, sugarcane, soybean, and sorghum for analysis. From Figure 2, it is observed that there are only two parishes that harvested between 8,884,087 bushels and 13,795,416 bushels of corn. They are Franklin (13,795,416) and Morehouse (12,103,029), located in the northeastern part of Louisiana. Also located in the northeast corner of Louisiana are parishes that harvested between 4,921,047 and 8,884,086 bushels of corn. They include Richland (6,482,504), Tensas (7,619,502), Madison (8,884,086), West Carroll (5,684,222) and East Carroll (7,490,051). Parishes that harvested between 2,582,845 and 4,921,046 bushels of crops are also scattered in the north of Louisiana. They are Caddo (3,690,862), Catahoula (4,921,046), Concordia (3,104,569) and Avoyelles (2,962,924). Interestingly, parishes that harvested between 927,968 and 2,582,844 bushels of corn are also concentrated in the north of Louisiana. They include Natchitoches (2,056,618), Ouachita (2,582,844), Rapides (1,690,642), Pointe Coupee (1,792,779) and St. Landry (1,562,974). Also, parishes that harvested between 182,041 and 927,967 bushels of corn, such as Bossier (246,590), Red River (438,642), Grant (239,325), Caldwell (927,967), Beauregard (224,900) and Washington (312,334) are spread in both the northern and southern parts of Louisiana. Finally, most of the parishes harvested between 0- and 182,040-bushels of corn. These parishes are concentrated in some part of

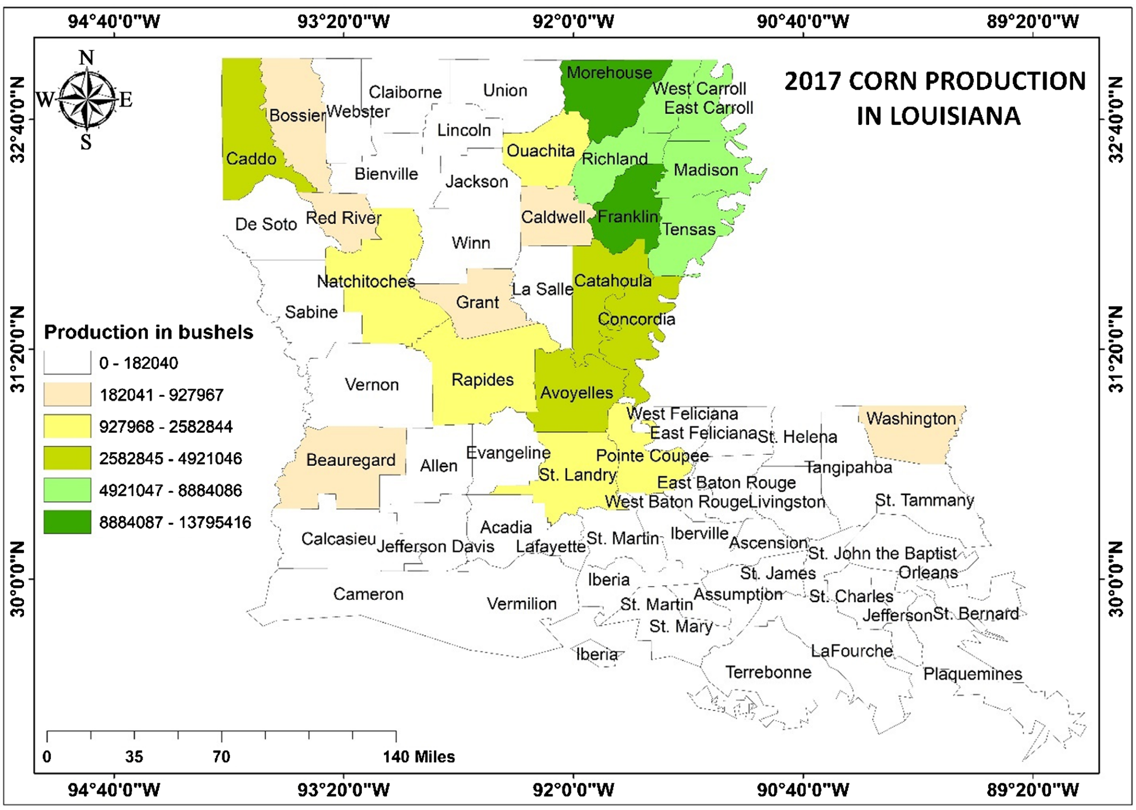

Figure 2. A map showing the production of corn (bushels) in Louisiana by Parish, 2017 [19] [20].

southern Louisiana and the central part of northern Louisiana. They include St. Bernard, St. Charles, St. Tammany, and Union.

Generally, the majority of the parishes that harvested tons of sugarcane are clustered in the southern-eastern part of Ontario as shown in **Figure 3**. On the other hand, the majority of parishes that did not produce any ton of sugarcane are mostly found in the northern and southeastern parts of Louisiana. The parishes that harvested between 1,243,614 tons and 1,697,980 tons of sugarcane are Iberia (1,697,980), St. Mary (1,510,142) and Assumption (1,456,604). Also, parishes that harvested between 967,635 tons and 1,243,613 tons of sugarcane are Iberville (1,243,613) and Pointe Coupee (1,067,079). Some parishes also produced between 541,413 tons and 967,634 tons of sugarcane. They include St. Martin (967,634), Vermilion (743,326), St. James (898,828), and LaForce (817,342). Additionally, some parishes that harvested between 338,374 tons and 541,412 tons of sugarcane are Avoyelles (450,232), St. Landry (396,282), Terrebonne (541,412), and West Baton Rouge (406,406). Again, the parishes that harvested between 1 ton and 338,373 tons of sugarcane in Louisiana are Ascension (338,373), Acadia (163,530), Lafayette (209,445), Rapides (294,288) and St. John the Baptist (289,132). Finally, Tensas, Union, Webster, Vernon, and Washington are some parishes that did not harvest and any ton of sugarcane in the state.

It is fascinating to note that the parishes that produced the most soybean are located in the southeastern part of Louisiana whereas those that produced the

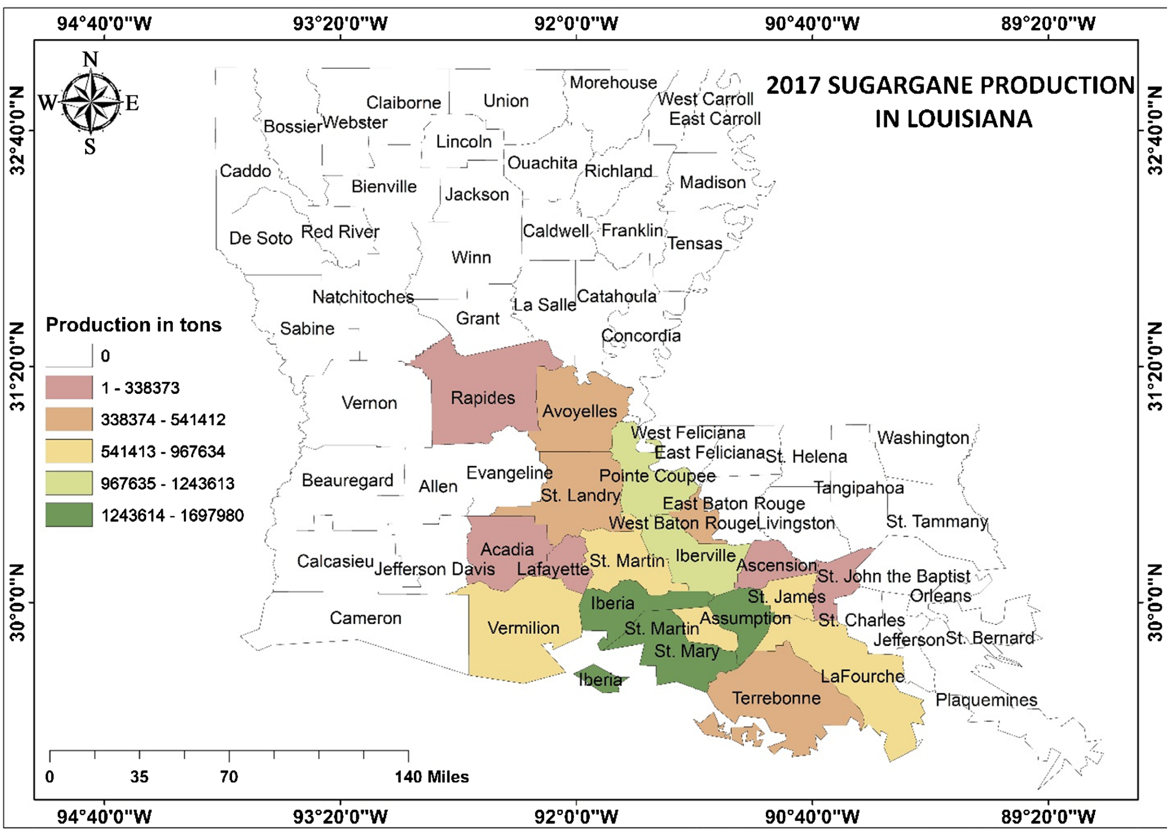

Figure 3. A map showing the production of sugarcane (tons) in Louisiana by Parish, 2017 [19] [20].

least are scattered in the northern, south-western, and south-eastern parts of the state, as displayed in **Figure 4**. Parishes that harvested between 4,613,110 bushels and 8,237,991 bushels of soybean include Madison (5,734,523), Concordia (7,014,583) and East Carroll (8,237,991). Those that harvested between 1,232,672 bushels and 4,613,109 bushels of soybean include Avoyelles (4,471,930), Catahoula (3,722,696), Franklin (3,061,560), Morehouse (4,613,109), Pointe Coupee (3,073,816), Richland (2,468,216), Tensas (3,906,149) and West Carroll (3,115,697). Also, some parishes that produced between 520,405 bushels and 1,232671 bushels of soybean include Acadia (1,232,671), Evangeline (992,056), Iberville (873,320) and Natchitoches (981,070). Additionally, the parishes that produced between 295,213 and 520,404 bushels of soybean include Bossier (424,782), St. Martins (382,965), and West Baton Rouge (520,404). Furthermore, some parishes that harvested between 42,001 bushels and 295,212 bushels are Washington (153,480), Vermilion (268,923), St. Mary (214,449), and St. James (217,018). Finally, some parishes that harvested between 0 and 42,000 bushels include Claiborne (42,000), with St. Helena, Sabine, St. Charles, and Webster producing no soybean.

Figure 5 represents the total bales of cotton produced in Louisiana in 2017. Interestingly, the majority of the parishes that harvested the most bales of cotton are located in north-eastern Louisiana whereas the majority of parishes that harvested the least bales of cotton are clustered in southern Louisiana. Two of

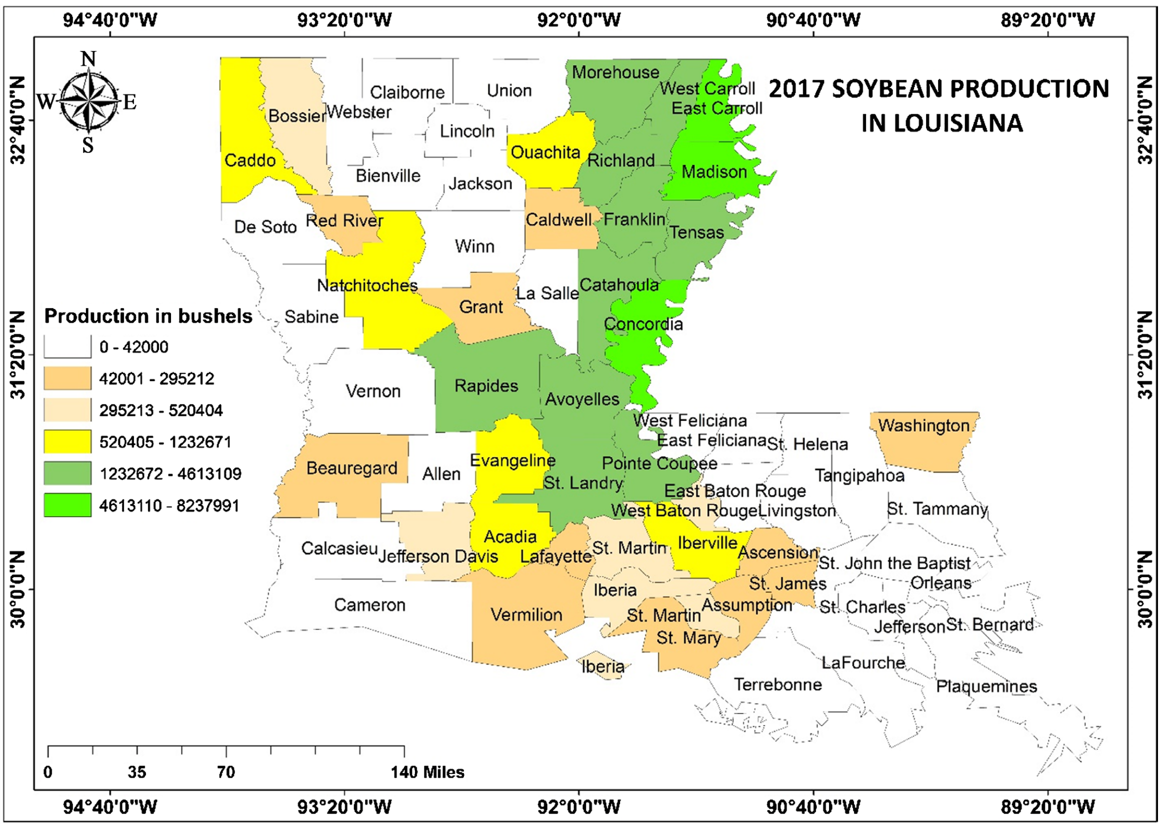

Figure 4. A map showing the production of Soybean (bushels) in Louisiana by Parish, 2017 [19] [20] [28].

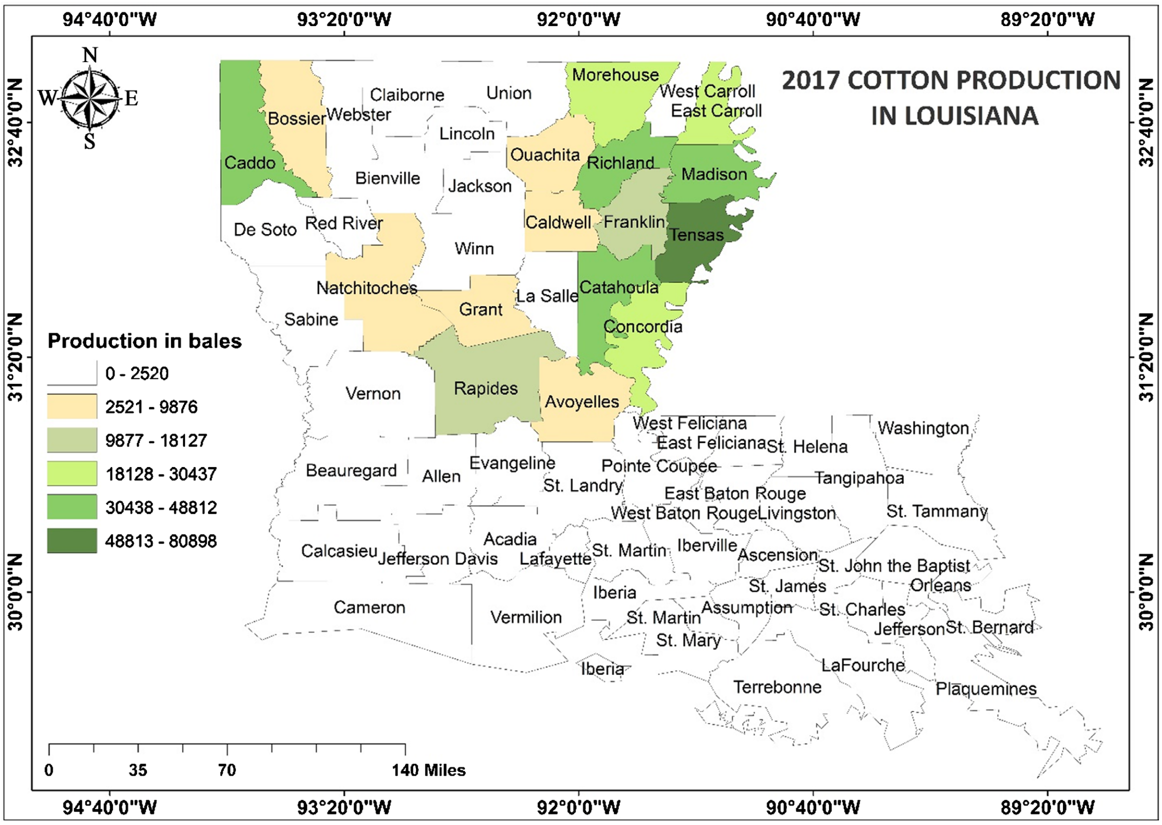

Figure 5. A map showing the production of cotton (bales) in Louisiana by Parish, 2017 [19] [20] [29].

the parishes that produced between 44,813 and 80,898 bales of cotton are Richland (48,812) and Tensas (80,898). Those that produced between 30,438 and 48,812 bales of cotton are Catahoula (38,887) and Madison (43,202). Some parishes that harvested between 18,128 and 30,437 bales of cotton include Concordia (30,437), East Carrol (23,673), and Morehouse (29,153). Also, some parishes that harvested between 9877 and 18,127 bales of cotton are Rapides (13,790) and Franklin (18,127). Furthermore, some parishes that harvested between 2521 and 9876 bales of cotton are Avoyelles (7194), Bossier (6194), Caldwell (3662), Grant (6998), Natchitoches (8900) and Ouachita (9876). Finally, the parishes that produced between 0 and 2520 bales of cotton are West Carroll (2520) and Pointe Coupee (2267), whereas parishes such as Jackson, Jefferson, Acadia, and Allen did not record any production of sugarcane.

Figure 6 represents the total bushels of sorghum produced in Louisiana in 2017. Avoyelles, located in central Louisiana, produced the most sorghum in 2017 (630,694 bushels). Catahoula (53,365), St. Landry (396,282), and Tensas (151,656) harvested between 0 and 151,656 bushels of sorghum. These parishes are also located in the central part of Louisiana, surrounding Avoyelles. Tensas and Catahoula are north of Avoyelles, whereas St. Landry is south of Avoyelles.

4.2. Gasoline Prices in the U.S.

Table 7 describes the monthly retail gasoline prices (dollars per gallon) in the

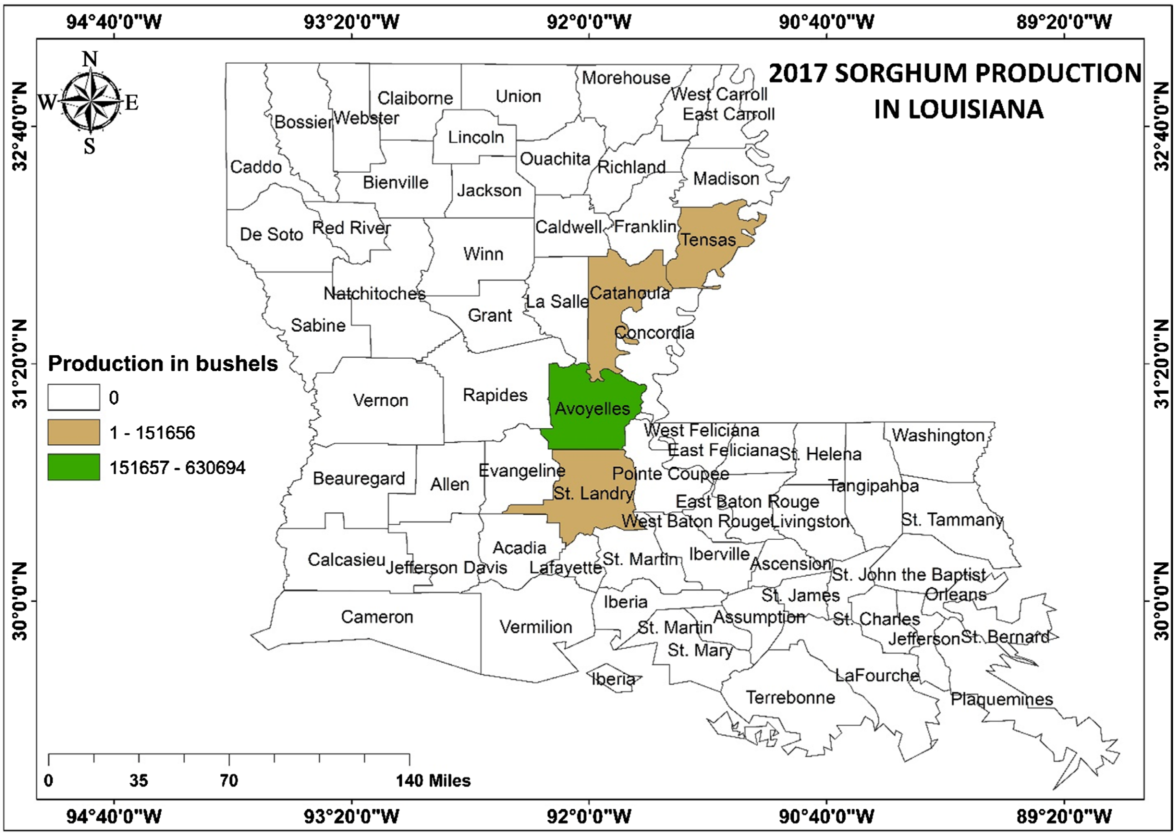

Figure 6. A map showing the production of sorghum (bushels) in Louisiana by Parish, 2017.

Table 7. U.S. all grades all formulations retail gasoline prices (dollars per gallon) [21].

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1993	-	-	-	1.078	1.100	1.097	1.078	1.062	1.050	1.092	1.066	1.014
1994	0.998	1.009	1.008	1.027	1.047	1.078	1.106	1.155	1.144	1.114	1.119	1.129
1995	1.130	1.120	1.119	1.157	1.225	1.239	1.201	1.170	1.158	1.134	1.109	1.118
1996	1.137	1.136	1.183	1.275	1.324	1.300	1.272	1.251	1.247	1.249	1.278	1.282
1997	1.283	1.276	1.251	1.244	1.245	1.242	1.220	1.268	1.276	1.242	1.216	1.177
1998	1.132	1.096	1.064	1.077	1.105	1.103	1.094	1.065	1.049	1.059	1.036	1.987
1999	0.980	0.962	1.022	1.171	1.171	1.154	1.197	1.260	1.295	1.285	1.292	1.313
2000	1.329	1.415	1.566	1.506	1.526	1.666	1.591	1.506	1.588	1.571	1.557	1.483
2001	1.487	1.490	1.450	1.591	1.738	1.658	1.466	1.461	1.557	1.357	1.212	1.127
2002	1.148	1.155	1.289	1.439	1.434	1.424	1.438	1.438	1.441	1.486	1.461	1.429
2003	1.500	1.655	1.734	1.633	1.539	1.533	1.554	1.661	1.721	1.606	1.555	1.522
2004	1.614	1.690	1.778	1.839	2.123	2.013	1.954	1.920	1.412	2.042	2.023	1.887
2005	1.875	1.953	2.120	2.285	2.205	2.198	2.333	2.529	2.951	2.765	2.303	2.229
2006	2.360	2.326	2.468	2.787	2.953	2.930	3.025	2.999	2.606	2.293	2.275	2.359
2007	2.289	2.323	2.609	2.891	3.187	3.102	3.011	2.834	2.849	2.853	3.128	3.070

Continued

2008	3.095	3.078	3.293	3.507	3.815	4.105	4.114	3.833	3.756	3.112	2.208	1.745
2009	1.840	1.975	2.011	2.102	2.316	2.681	2.582	2.670	2.609	2.605	2.706	2.663
2010	2.769	2.699	2.824	2.900	2.890	2.785	2.782	2.783	2.757	2.853	2.913	3.048
2011	3.148	3.264	3.615	3.852	3.960	3.735	3.705	3.696	3.667	3.506	3.443	3.326
2012	3.440	3.640	3.907	3.958	3.791	3.596	3.498	3.780	3.910	3.812	3.521	3.381
2013	3.391	3.736	3.779	3.638	3.675	3.689	3.661	3.645	3.604	3.420	3.322	3.357
2014	3.392	3.434	3.606	3.735	3.750	3.766	3.688	2.565	3.484	3.255	2.997	2.632
2015	2.208	2.301	2.546	2.555	2.802	2.885	2.880	2.726	2.462	2.387	2.260	2.194
2016	2.057	1.872	2.071	2.216	2.371	2.467	2.345	2.284	2.327	2.359	2.295	2.366
2017	2.458	2.416	2.437	2.528	2.503	2.460	2.414	2.494	2.761	2.621	2.678	2.594
2018	2.671	2.705	2.709	2.873	2.987	2.970	2.928	2.914	2.915	2.943	2.736	2.457
2019	2.338	2.393	2.594	2.881	2.946	2.804	2.823	2.707	2.681	2.724	2.693	2.645
2020	2.636	2.533	2.329	1.938	1.961	2.170	2.272	2.272	2.274	2.248	2.200	2.284
2021	2.420	2.587	2.898	2.948	3.076	3.157	3.201	3.255	3.272	3.384	3.491	3.406
2022	3.413	3.611	4.322	4.213	-	-	-	-	-	-	-	-

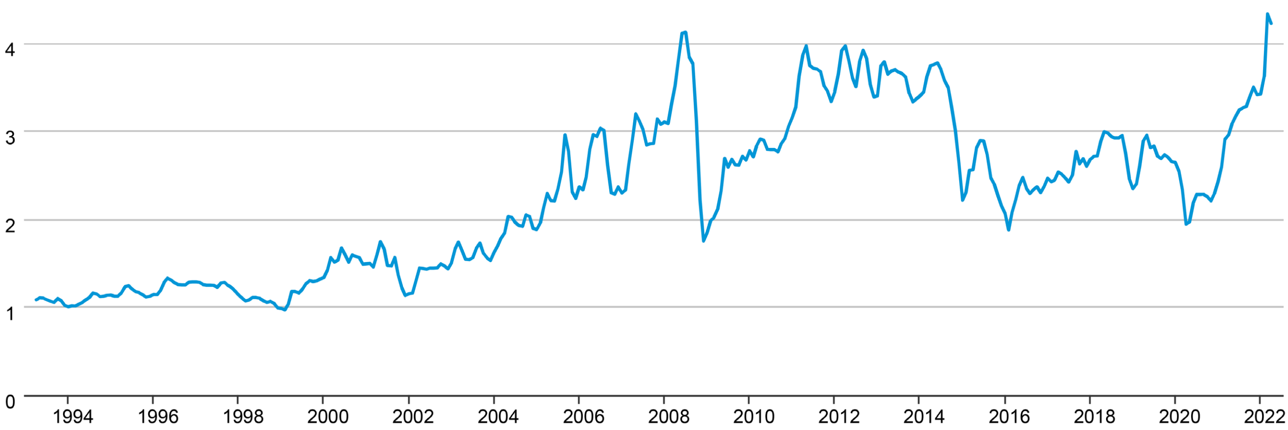

Figure 7. A time graph of all formulations retail gasoline prices (dollars per gallon) in the U.S. [21].

U.S. from 1993 to 2022. **Figure 7** also shows a time graph of all formations of retail gasoline prices (dollars per gallon) in the U.S. There is a fluctuation in the prices of gasoline from 1993 to 2019. The price of gasoline per gallon was slightly above $1 in 1993 and drops to $1 in 1999. The price begins to increase slightly above $1 again in 2000 and declines in 2002. The prices fluctuate from 2000 to 2007 and sharply increase to more than $4 per gallon in 2008. The price sharply declines to almost $2 per gallon from 2008 to 2009 and rises above $2 in 2010. From 2010 to 2014, the price of gasoline per gallon rises and falls between $2 and $3 dollars and declines in 2015. Similarly, the price continues to fluctuate between $2 and $3 dollars and dramatically increases from $2 in 2020 to over $4 in 2022, showing an upward trend. The average annual fuel price for each year was computed using the data from Table 7 and presented in Table 8.

The variation of gasoline price presented in Table 8 depended on factors such as market dynamics. A model for the average annual gasoline price versus years was produced by curve by polynomial curve fitting using Microsoft Excel and presented in Figure 8.

Table 8. Average annual fuel price, 1994-2022.

Year	Average price
1994	1.077833
1995	1.156667
1996	1.2445
1997	1.245
1998	1.155583
1999	1.175167
2000	1.525333
2001	1.466167
2002	1.381833
2003	1.601083
2004	1.857917
2005	2.312167
2006	2.615083
2007	2.8455
2008	3.305083
2009	2.396667
2010	2.833583
2011	3.576417
2012	3.686167
2013	3.576417
2014	3.358667
2015	2.517167
2016	2.2525
2017	2.530333
2018	2.817333
2019	2.68575
2020	2.25975
2021	3.09125
2022	4.4436

The R square for the model is almost 62.5%. Hence, it explains about 62.5% of the average annual gasoline prices. Microsoft Excel statistical tool kit was used to determine the significance of the model and the results presented in **Table 9**.

From **Table 9**, the variation of the average annual gasoline price with respect to years is statistically significant ($p < 0.05$). The model suggests that the price of gasoline per gallon will continue to generally rise despite a drop in prices during

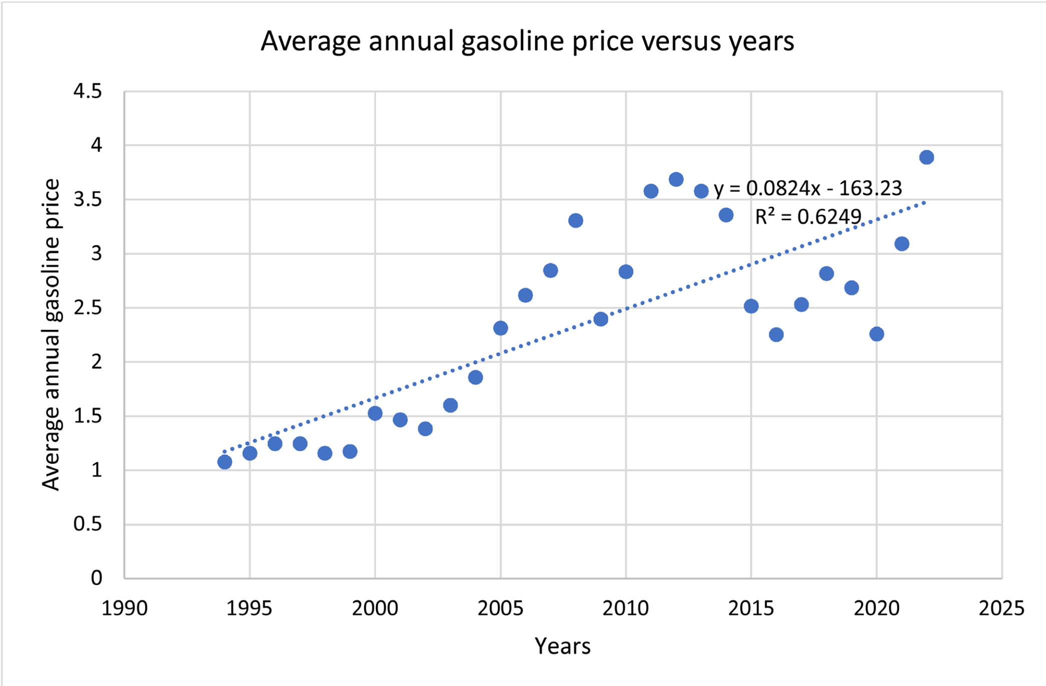

Figure 8. Average annual gasoline price (dollars per gallon) versus years.

Table 9. Summary table for regression model for the average annual gasoline price versus years.

Regression Statistics	
Multiple R	0.790496
R Square	0.624884
Adjusted R Square	0.610991
Standard Error	5.310663
Observations	29

ANOVA	*df*	*SS*	*MS*	*F*	*Significance F*
Regression	1	1268.515	1268.515	44.97779	3.36E−07
Residual	27	761.4848	28.20314		
Total	28	2030			

	Coefficients	*Standard Error*	*t Stat*	*P-value*	*Lower 95%*	*Upper 95%*	*Lower 95.0%*	*Upper 95.0%*
Intercept	1990.375	2.806927	709.094	3.44E−59	1984.616	1996.135	1984.616	1996.135
Average price	7.579217	1.130122	6.706549	3.36E−07	5.260398	9.898035	5.260398	9.898035

various months and years. According to **Figure 7**, the highest annual average rate of gasoline price was experienced from 2020 to 2022.

$$\begin{aligned}&\text{Highest annual average price of gasoline}\\&=\left(\text{Average annual gasoline price}_{2022}-\text{Average annual gasoline price}_{2020}\right)/2\\&=\left(4.4436-2.25975\right)/2\\&=1.09193\end{aligned}$$

where, Average annual gasoline price_{2022} and Average annual gasoline price_{2020} represent the average annual gasoline prices for 2020 and 2022, respectively.

Russia's invasion of Ukraine has impacted the price of crude oil and, hence, the amount paid at pumps [30]. Weather extremes, which happen yearly in the United States of America are also associated with a fuel price increase [31] [32]. Hence, gasoline prices will generally continue to rise in the long run. By the end of 2022, there is a possibility that the price of gasoline could rise to more than 4.4436 dollars per Gallon.

4.3. Potential Utilization of Bioenergy Crops for Energy Production: Justification

Avoyelles was the only parish that produced all the five crops in Louisiana in 2017. Pointe Coupee (sugarcane, soybean, corn, cotton), Rapides (sugarcane, soybean, corn, cotton), Tensas (soybean, corn, cotton, sorghum), St. Landry (sugarcane, soybean, corn, sorghum) and Catahoula (soybean, corn, cotton, sorghum) were the only parishes that produced four out of the five crops in 2017. A number of the parishes produced three out of the five crops. They include Bossier (soybean, corn, and cotton), Caldwell (soybean, corn, and cotton), Catahoula (soybean, corn, and cotton), Concordia (soybean, corn, and cotton), East Carroll (soybean, corn, and cotton), Franklin (soybean, corn, and cotton), Grant (soybean, corn, and cotton), Lafayette (sugarcane, soybean, and corn), Madison (soybean, corn, and cotton), Morehouse (soybean, corn, and cotton), Natchitoches (soybean, corn, and cotton), Ouachita (soybean, corn, and cotton), Richland (soybean, corn, and cotton), St. Landry (soybean, corn, and sugarcane), Tensas (soybean, corn, and cotton), and West Carroll (soybean, corn, and cotton). The majority of the parishes also produced two out of the five crops. They are Acadia (sugarcane and soybean), Ascension (sugarcane and soybean), Assumption (sugarcane and soybean), Beauregard (soybean and corn), Caddo (soybean and corn), Calcasieu (soybean and corn), Claiborne (soybean and corn), Evangeline (soybean and corn), Iberia (sugarcane and soybean), Iberville (sugarcane and soybean), Red River (soybean and corn), St. James (sugarcane and soybean), St. Martin (sugarcane and soybean), St. Mary (sugarcane and soybean), Tangipahoa (soybean and corn), Vermilion (sugarcane and soybean), Washington (soybean and corn), and West Baton Rouge (sugarcane and soybean). Additionally, several parishes produced only one type of crop in 2017. They comprise Cameron (soybean), East Baton Rouge (corn), Jefferson Davis (soybean), Livingston (corn), St. John the Baptist (sugarcane), Lafourche (sugarcane), and Terrebonne. Finally, there were some parishes that did not produce any of the crops. They include Bienville, Jackson, Jefferson, La salle, Lincoln, Orleans, Plaquemines, Sabine, St. Bernard, St. Charles, St. Helena, St. Tammany, Webster, East Feliciana, West Feliciana, and Winn. The abundance and availability of crops as raw materials for energy production will translate into lower prices in terms of energy use, making bioenergy crops a promising alternative to fossil fuels.

Figure 7 depicts that the price of a gallon of gasoline has risen over the years, from 1 dollar in 1994 to over $4 in 2022. There is a likelihood that the price of gasoline will continue to increase in the years to come. From the data collected in the study, the abundance of bioenergy crops in Louisiana such as sugarcane, soybean, corn, and cotton depicts that, the state has the potential to use bioenergy crops as an alternative renewable resource for the production of energy. The literature review confirms that bioenergy crops will be a viable option to replace fossil fuels in energy production in the future since they are more environmentally friendly and sustainable. However, bioenergy cannot completely replace fossil fuels at this time due to the large cropping areas required but has the potential to reduce total fossil fuel consumption. To completely replace fossil fuels, it is imperative to increase crop production to make this goal a reality in the future.

5. Conclusion

Considering that bioenergy crops are one energy source that might positively influence the environment by lowering carbon dioxide levels, greenhouse gas emissions, and soil erosion and require fewer biological, chemical, or physical pre-treatments, lowering biomass processing costs, as highlighted in the literature review confirm that in fact, Louisiana has a great potential of bioenergy crop cultivation. Also, as a result of increased fuel demand, gas prices are expected to rise further. This research concludes that looking at the availability and abundance of bioenergy crops in Louisiana and the rising prices of gasoline over the years, it will be reasonable to invest in Louisiana's agricultural sector to produce more crops for the production of bioenergy. In view of this, parishes that have been producing the majority of one or more of the main bioenergy crop types must be targeted and invested in to increase the production of bioenergy crops in Louisiana. Bioenergy is already significantly contributing to meeting the world's energy needs. This contribution has the potential to grow significantly in the coming years, culminating in lower greenhouse gas emissions and other ecological benefits, as well as enhanced energy security, trade balances, opportunities for socio-economic development in rural communities, and better resource and waste management. It is expected that the results of this research would be acknowledged, and policies regarding the use of bioenergy crops for bioenergy production will be implemented. The results of the study indicate that there is a decreasing trend in the acres of total and harvested croplands in Louisiana. It is recommended future research should also investigate other crop types such as wheat, oat, and rice, among others, and assess their availability and viability for energy production in the state.

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Conflicts of Interest

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

References

[1] Owusu, P.A. and Asumadu-Sarkodie, S. (2016) A Review of Renewable Energy Sources, Sustainability Issues, and Climate Change Mitigation. *Cogent Engineering*, **3**, Article ID: 1167990. https://doi.org/10.1080/23311916.2016.1167990

[2] International Energy Agency Bioenergy (2007) Potential Contribution of Bioenergy to the World's Future Energy Demand. https://www.ieabioenergy.com/wp-content/uploads/2013/10/Potential-Contribution-of-Bioenergy-to-the-Worlds-Future-Energy-Demand.pdf

[3] Dipti, P. (2013) Bioenergy Crops an Alternative Energy. *International Journal of Environmental Engineering and Management*, **4**, 265-272.

[4] Schwartz, E. (2021) Bioenergy: A Promising Alternative to Fossil Fuels. https://viewpointpatriot.org/1753/features/bioenergy-a-promising-alternative-to-fossil-fuels

[5] Bauen, A., Berndes, G., Junginger, M., Londo, M., Vuille, F., Ball, R. and Mozaffarian, H. (2009) Bioenergy: A Sustainable and Reliable Energy Source. A Review of Status and Prospects.

[6] Union of Concerned Scientists (2014) Turning Agricultural Residues and Manure into Bioenergy. https://doczz.net/doc/8939175/turning-agricultural-residues-and-manure-into-bioenergy

[7] Schultz, C., Man, D., Rosenfeld, J., McCurdy, M., Anderson, M., Jaglo, K., Goossen, B., Kaffel, M., Farrell, J.M., Wissell, F., Hendrickson, T., Lukas, J., Buchholz, T., Xiarchos, M.I., Hanson, W., Lewandrowski, J. and Pape, D. (2021) Renewable Energy Trends, Options, and Potentials for Agriculture, Forestry, and Rural America. U.S. Department of Agriculture, Office of the Chief Economist, Washington DC.

[8] Benedict, L., Zapata, H.O. and Huizhen, N. (2021) Crop Residue Biomass Production in Louisiana.

https://www.lsuagcenter.com/portals/communications/publications/agmag/archive/2012/winter/crop-residue-biomass-production-in-louisiana#:~:text=Crop%20residue%20biomass%20production%20in%20Louisiana%20Louisiana%20has,produce%20ethanol%20and%20electricity.%20Skip%20to%20Main%20Content

[9] Twumasi, Y.A., Merem, E.C., Namwamba, J.B., *et al.* (2021) Land Resource Areas and Spatial Analysis of Potential Location of Bioenergy Crops Production in Mississippi. *Journal of Sustainable Bioenergy Systems*, **11**, 187-214. https://doi.org/10.4236/jsbs.2021.114013

[10] Yadav, P., Priyanka, P., Kumar, D., Yadav, A. and Yadav, K. (2019) Bioenergy Crops: Recent Advances and Future Outlook. In: Rastegari, A.A., Yadav, A.N. and Gupta, A., Eds., *Prospects of Renewable Bioprocessing in Future Energy Systems*, Springer, Berlin, 315-335. https://doi.org/10.1007/978-3-030-14463-0_12

[11] Hazell, P. and Pachauri, R.K. (2006) Bioenergy and Agriculture: Promises and Challenges Overview. Focus 14, Brief 1 of 12. International Food Policy Research Institute, Washington DC. https://doi.org/10.2499/Focus14CH3

[12] Salassi, M.E., Holzapfel, A., Hilbun, B.M., Deliberto, M.A., Gravois, K.A., Viator, H.P. and Mark, T.B. (2017) Feedstock Crop Production Costs and Biofuel Feedstock Input Costs Associated with the Production of Energy Cane and Sweet Sorghum in the Southeastern USA. *BioEnergy Research*, **10**, 772-782. https://doi.org/10.1007/s12155-017-9838-3

[13] Kim, M. and Day, D.F. (2011) Composition of Sugar Cane, Energy Cane, and Sweet Sorghum Suitable for Ethanol Production at Louisiana Sugar Mills. *Journal of Industrial Microbiology and Biotechnology*, **38**, 803-807. https://doi.org/10.1007/s10295-010-0812-8

[14] U.S. Department of Agriculture (2019) Louisiana Sugarcane Parish Estimates. Crop Production: 2021 Summary (January 2022). Cornell University Library, 68. https://downloads.usda.library.cornell.edu/usda-esmis/files/k3569432s/sn00c1252/g158cj98r/cropan22.pdf

[15] U.S. Department of Agriculture (2020) Louisiana Corn Parish Estimates. https://www.nass.usda.gov/Statistics_by_State/Louisiana/Publications/Parish_Estimates/2019/19_LA_corn.pdf

[16] U.S. Department of Agriculture (1999) Louisiana State and Parish Data: 1997 Census of Agriculture. *Geographic Area Series*, **18**, 1-439.

[17] U.S. Department of Agriculture (2009) Louisiana State and Parish Data: 2009 Census of Agriculture. *Geographic Area Series*, **18**, 1-635.

[18] U.S. Department of Agriculture (2008) National Agricultural Statistics Service (NASS) Sugarcane. Crop Production: 2010 Summary (January 2011). https://downloads.usda.library.cornell.edu/usda-esmis/files/k3569432s/7w62fb538/2r36v1139/CropProdSu-01-12-2011_revision.pdf

[19] U.S. Department of Agriculture (2019) Louisiana State and Parish Data: 1997 Census of Agriculture. *Geographic Area Series*, **18**, 1-712.

[20] United States Department of Agriculture (2021) Louisiana Crop Production. https://www.nass.usda.gov/Statistics_by_State/Louisiana/Publications/Crop_Releases/Crop_Production_Monthly/2021/lacropsept21.pdf

[21] U.S. Energy Information Administration (2022) U.S. All Grades All Formulations Retail Gasoline Prices (Dollars per Gallon). https://www.eia.gov/dnav/pet/hist/LeafHandler.ashx?n=pet&s=emm_epm0_pte_nus_dpg&f=m

[22] Sourceforge (2016) Distmap. https://sourceforge.net/projects/distmap

[23] The United States Department of Agriculture (USDA) (1992) Weights, Measures, and Conversion Factors for Agricultural Commodities and Their Products. USDA Economic Research Service in Cooperation with the Agricultural Marketing Service, the Agricultural Research Service, and the National Agricultural Statistics Service, U.S. Department of Agriculture. Agricultural Handbook No. 697, Washington DC, 20005-4788. https://www.ers.usda.gov/webdocs/publications/41880/33132_ah697_002.pdf

[24] Stewart, J. and Kennelly, P.J. (2010) Illuminated Choropleth Maps. *Annals of the Association of American Geographers*, **100**, 513-534. https://doi.org/10.1080/00045608.2010.485449

[25] Robinson, A.H., Morrison, J.L., Muehrcke, P.C., Kimerling, A.J. and Guptill, C.S. (1995) Elements of Cartography. 6th Edition, Wiley, New York.

[26] Flynn, A. (2019) What Are the Advantages and Disadvantages of a Choropleth Map? https://greedhead.net/what-are-the-advantages-and-disadvantages-of-choropleth-map

[27] Muth, L.C. (2018) What to Consider When Creating Choropleth Maps. https://blog.datawrapper.de/choroplethmaps

[28] U.S. Department of Agriculture (2020) Louisiana Soybean Parish Estimates. https://www.nass.usda.gov/Statistics_by_State/Louisiana/Publications/Parish_Estimates/2019/19_LA_soybean_all.pdf

[29] U.S. Department of Agriculture (2020) Louisiana Cotton Parish Estimates. https://www.nass.usda.gov/Statistics_by_State/Louisiana/Publications/Parish_Estimates/2019/19_LA_cotton_all.pdf

[30] Reynolds, A. (2022, April) Yes, Russia's War on Ukraine Did Raise the Price of Gasoline. CATO Institute, Washington DC. https://www.cato.org/blog/yes-russias-war-ukraine-did-raise-price-gasoline-0

[31] DTN Team (2022, May 12) Weather and Your Fuel Price Forecast. https://www.dtn.com/weather-and-your-fuel-price-forecast

[32] Evans, M. (2022, February 8) Global Power Outages, High Prices, Extreme Weather and Supply Chain Issues Arose in 2021. https://www.naturalgasintel.com/global-power-outages-high-prices-extreme-weather-and-supply-chain-issues-arose-in-2021