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Bioenergy: Examining the Efficient Utilization of Agricultural Biomass as a Source of Sustainable Renewable Energy in Louisiana

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Abstract

The use of renewable energy is steadily being adopted as a mitigative measure for reducing greenhouse gas emissions. By assessing biomass production and consumption estimates from Louisiana parishes, this study examines the utilization of agricultural biomass as a convenient renewable energy source, and the potential of marginal lands for growing bioenergy crops in Louisiana. This was achieved by retrieving parish-level acreage production of some biofuel crops recorded in 2021 using the Quick Stats Database, to map out the spatial locations and distribution of the biofuel crops. To examine the potential of Louisiana's marginal lands in bioenergy crop production, data was obtained from the Soil Survey Geographic (SSURGO) database and mapped-out according to the eight Land Capability Classes numbered I-VIII. The results of the mapped-out acreage data revealed that 25% of the 64 parishes including Morehouse recorded high corn production estimates, while 43%, such as East Carroll, recorded high soybean production. Meanwhile, cotton production estimates were relatively low, as recorded in only 9 parishes, with one parish, Tensas, having the highest acreage production of around 23,000. Although the identified marginal lands in parishes such as Allen and Vernon had no records of corn, soybean, or cotton production, the soil survey database revealed that these marginal lands have high nutrient soils like Alfisols, Entisols and Inceptisols with optimal nutrient balance essential for high yield bioenergy crop production. Hence, this paper highlights Louisiana's agricultural biomass to be leveraged as sustainable renewable sources while adhering to clear production guidelines, biofuel sustainability certification, and internationally agreed sustainability criteria.

Keywords

Biofuels, Agricultural Crops, Ethanol, Biodiesel, Marginal Lands, Louisiana

1. Introduction

Global efforts to address the effects of climate change include measures to primarily reduce the emission of harmful greenhouse gases into the atmosphere. That is, the Environmental Protection Agency [1] has listed a few Carbon dioxide reduction opportunities which highlight fuel switching, by producing more energy from renewable sources and using fuels with lower carbon contents to reduce carbon emissions. Agreeably, [2] emphasizes that sustainably harvested biomass plays a significant role in mitigating climate change, and ensuring energy supply security while promoting economic growth and employment. In fact, agricultural biomass which are resources derived from crop residues like bagasse, straw, stem, stalk, husk, shells, leaves, and all other plant-based residues present as one of the ideal renewable energy alternatives that can be utilized as a source of energy to supplement and limit the high dependence on fossil fuels. For instance, corn is known as a popular feedstock for ethanol production in the United States due to its abundance and relative ease of conversion to ethyl alcohol [3] while soybean has an equally great potential for use as a biofuel since its oil is considered a major feedstock for biodiesel production.

Notably, most of the states in the U.S. are relying on the use of biomass for instance in the Northwest, oilseed crops such as canola and sunflowers are used for biofuels. To further promote the potential in the utilization of biomass to produce biofuels, the Renewable Fuel Standard was designed to boost energy independence by increasing domestic fuel production (this was prior to the oil and gas boom that followed the widespread adoption of hydraulic fracking in fossil fuel drilling technology) [4]. However, with reference to Louisiana, the renewable sources provided almost 4% of the state's electricity net generation in 2021 [5] which is relatively low considering the country's rate of energy utilization. Nonetheless, the state is noted for containing a wealth of resources, especially corn, soybeans, and other resources such as timber, sugarcane, rice, and cotton which can be leveraged as ideal renewable energy sources. That is, these resources can be used to provide bioenergy and lead the way in biomass utilization considering Louisiana's diverse industrial advantage.

[6] admits that, based on some of these crops that Louisiana produce, the state is poised to become a major player in the bioproducts industry which could be an ideal biofuel hub potential that efficiently utilizes its agricultural biomass. Notably, the state's climate is characterized by relatively short and mild winters, hot summers, and year-round precipitation whereby the Gulf of Mexico helps to

moderate the climate especially in the south portion [7]. Aside Louisiana's climate supporting an extended growing season for the growth of traditional crops, the state with its rich agricultural heritage and robust infrastructure also demonstrates a remarkable capacity for the efficient utilization of agricultural biomass as a renewable energy source [8]. Additionally, Louisiana's expertise in chemical manufacturing and well-established energy and fuel distribution infrastructure further contribute to its ability to effectively harness biofuels from agricultural resources [8].

More so, even though most of these energy growing crops do not necessarily need viable soils to thrive, having a conducive soil and environment is enough to boost its growth. That is, in addition to the physical and economic characteristics of the state, Louisiana can also take advantage of the lands that are not arable but available to support energy growing crops. That is, crops used for biofuel production can be planted on what is known as "marginal land", which are typically not used for food production due to its less favorable soil characteristics [9]. Agreeably, [10] have expressed that, marginal lands have received wide attention for their potential to improve food security and support bioenergy production because they are typically characterized by low productivity and reduced economic return or by severe limitations for agricultural use. Several researchers have additionally opined about the use of marginal lands for bioenergy production of which [11] established that, converting land that is socially marginal for food crops could support biomass production while limiting adverse impacts on food crop production, minimizing opportunity costs of bioenergy crop production, and improving ecosystem services.

Certain biomass crops such as corn, cotton and soybean may therefore require fewer nutrient inputs such as nitrogen fertilizer and will thrive well on marginal lands located in Louisiana. Generally, marginal lands, sometimes referred to as reserved lands, are associated with low productivity returns and do not support crop production have been recognized as a potential to produce bioenergy feedstocks because they do not necessarily require nutrient input. Louisiana can leverage some marginal lands to increase production rates of the traditional crops that can be used as renewable feedstocks. Agreeably, the state could produce about 18.7% of its transportation energy needs from biofuels using Louisiana resources if the entire crop production is utilized for biofuel production, one-half of the Conservation Reserve Program (CRP) land is utilized for energy crop production, and all the cellulosic component of municipal solid waste is converted to ethanol [12].

Therefore, this study seeks to emphasize some of Louisiana's resources and favorable factors that can be harnessed to enable sustainable utilization of agricultural biomass as a source of renewable energy. That is by identifying according to parishes the acre production rates of the traditional crops for ethanol and biodiesel in Louisiana in relation to the potential of marginal lands in the parishes for growing bioenergy crops in Louisiana. The results of this study will fill the gap concerning the absence in research of current locations supporting the growth of these traditional energy crops, as well as the potential land areas that can support energy growing crops in Louisiana. Basically, this study will put into a better perspective the benefits that can be derived from relying on agricultural biomass as far as the environment and the economy are concerned.

2. Research Methodology

2.1. Research Study Area

The main study area for this research, Louisiana as seen in **Figure 1**, is located between the Gulf of Mexico and the southern end of the vast, relatively flat plains of central North America, which extend from the Arctic Circle to the Gulf of Mexico [7]. It is a deep south and south-central state bordered by the states of Texas to the west, Arkansas to the North, Mississippi to the east and the Gulf of Mexico to the South. The state is exposed to the influences of diverse air masses, including the warm, moist air over the Gulf of Mexico and the drier continental air masses, which are cold in the winter and warm in the summer [7]. The state receives abundant precipitation throughout the year ranging from around 50 inches in the north to around 70 inches at some locations in the southeast [7] which are essential for agricultural crop production.

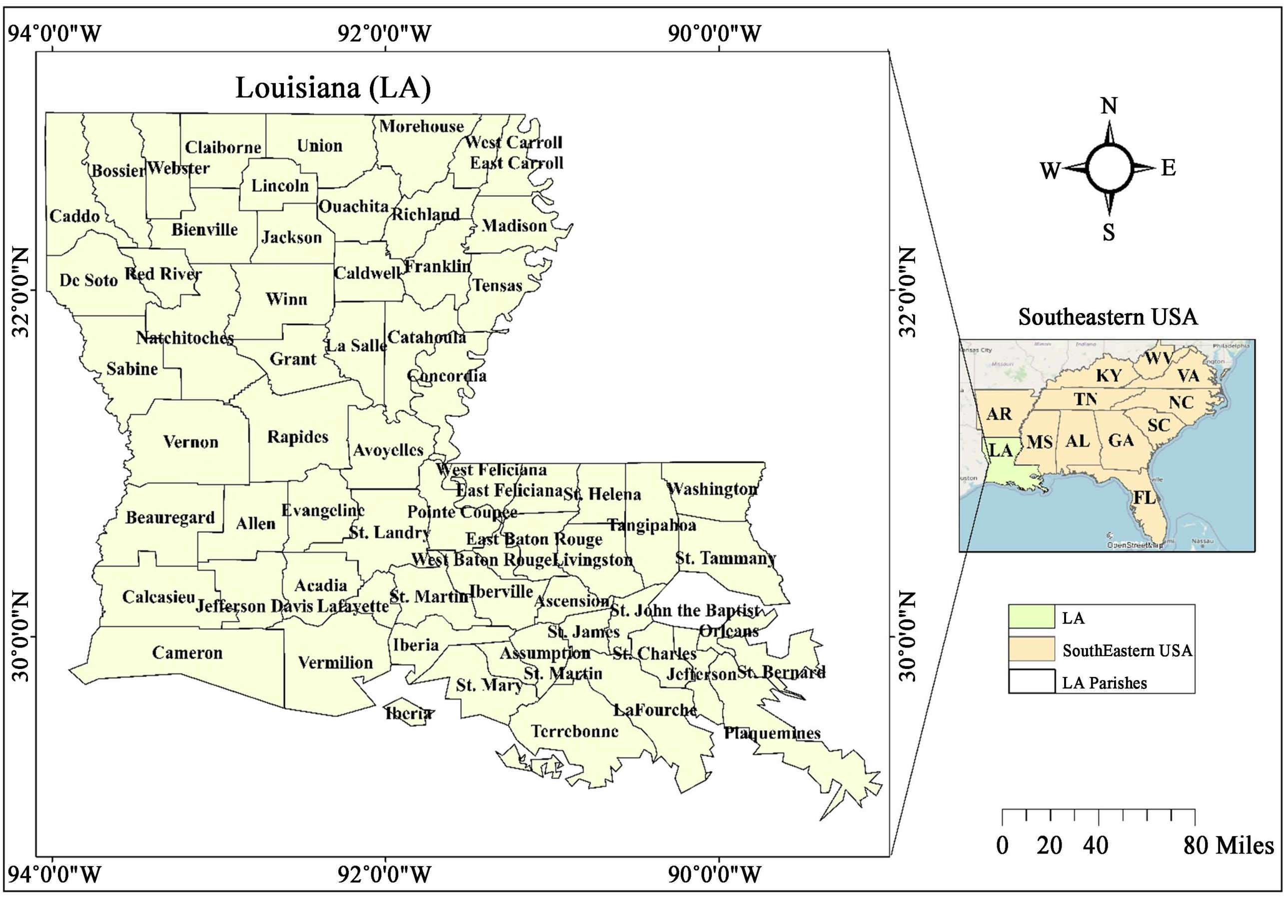


Figure 1. A study area map of Louisiana and its parishes.

2.2. Materials and Methods

From the United States Department of Agriculture (USDA) and National Agricultural Statistics Service (NASS), parish-level acreage data recorded in 2021 for the biofuel crops were retrieved. The data was then accessed using the Quick Stats Database, a comprehensive tool for accessing agricultural data published by the USDA NASS. The acreage data for corn, soybean, and cotton production obtained from the data was then imported into ArcMap as an Excel file and joined to a Louisiana shapefile layer in ArcMap using the "Join tool" to map their spatial locations and varied acreages per parish. This was done to identify the parishes in Louisiana and their corresponding acres of corn, soybean and cotton production in the year 2021. The Symbology tab in ArcMap was then used to map the spatial distribution of the biofuel crops according to the number of acres of production. The maps generated therefore show the parishes in Louisiana that produce each biofuel crop discussed based on their acreage ranges. The energy consumption data set discussed is based on information taken from the U.S Energy Information Administration (EIA) database called States Energy Data System (SEDS). These were Microsoft Excel files that were downloaded into CSV files containing energy consumption estimates (coal, natural gas, renewable energy, nuclear electric power and petroleum) and specific renewable energy consumption sources (biofuels, wood and waste, fuel ethanol, biodiesel, geothermal, hydropower and solar energy) for Louisiana from 2010 to 2020. This was projected in a cross-tabulation format and established in British thermal units (Btu). Louisiana Energy Consumption and the Renewable Energy Consumptions from 2010 to 2020 were analyzed using descriptive statistics to understand the energy consumption rates in the state with more concentration on renewable energy. The relative sum of the energy consumption measures for each year was converted into percentages and charted to visualize the percentage contribution of each energy source in Louisiana's energy consumption rate. For the marginal lands, data was retrieved from the Soil Survey Geographic (SSURGO) database based on land capability classes data from USDA National Resource Conservation Service using the Web Soil Survey tool. The Soil Survey Geographic (SSURGO) database also provides an interpretive classification variable according to the classification of lands.

3. Results and Discussion

3.1. Acreage of Agricultural Crops Produced in Louisiana in 2021

The results show the acreage production of three main bioenergy crops grown in Louisiana namely corn, soybean and cotton. Figure 2 shows the acres of corn production recorded in Louisiana in the year 2021. Evidently most of the parishes in Louisiana did not record acres of corn production especially along the south eastern and southwestern part of the region. That is, out of the 64 parishes, only 16 parishes, representing 25% of the total parishes recorded some acres for corn

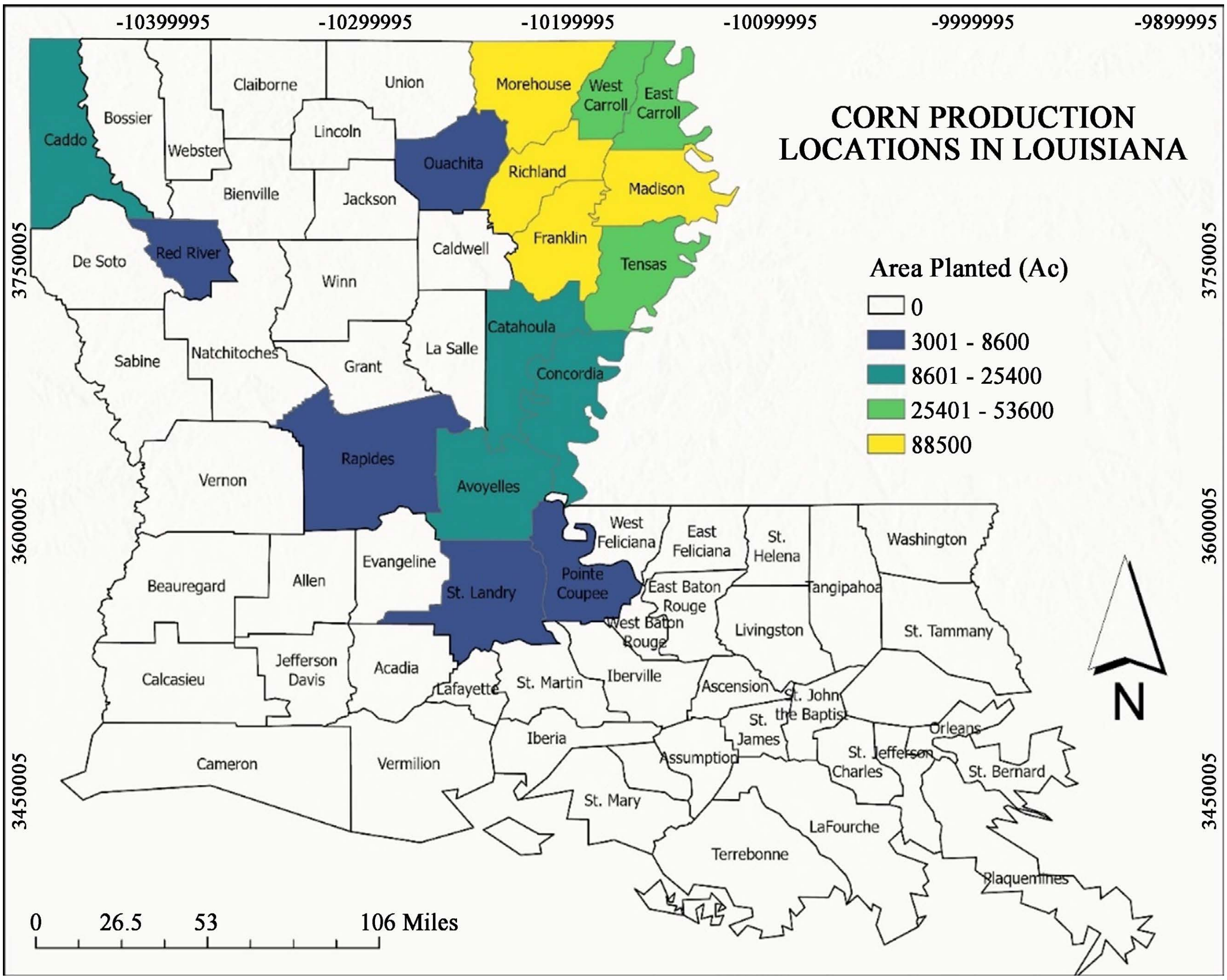


Figure 2. 2021 total acreage of corn production in Louisiana.

production in the year 2021. Further observations reveal that, out of these 16 active corn production acres, only four of the parishes produce the highest recording about 80,000 acres which are Morehouse, Richland, Franklin and Madison. Following this are only three parishes that record about 25,000 to 50,000 acres which are East and West Caroll as well as Tensas.

Figure 3 shows the acres of soybean production recorded in Louisiana in the year 2021. It also shows that most of the parishes especially in the central north and western part of the state do not record acres of soybean production. However compared to the acres of corn production, the soybean acreage are more in terms of the number of parishes. This implies that out of the 64 parishes, only 28 parishes have acres of soybean production which represents about 43% of the total parishes of the state. Also from the 28, only two parishes such as East Caroll and Concordia record the highest of about 123,000 acres. In comparison with the corn acre production, the parishes that also record relatively high acreage of Soybean are only two parishes which will be Morehouse and Madison.

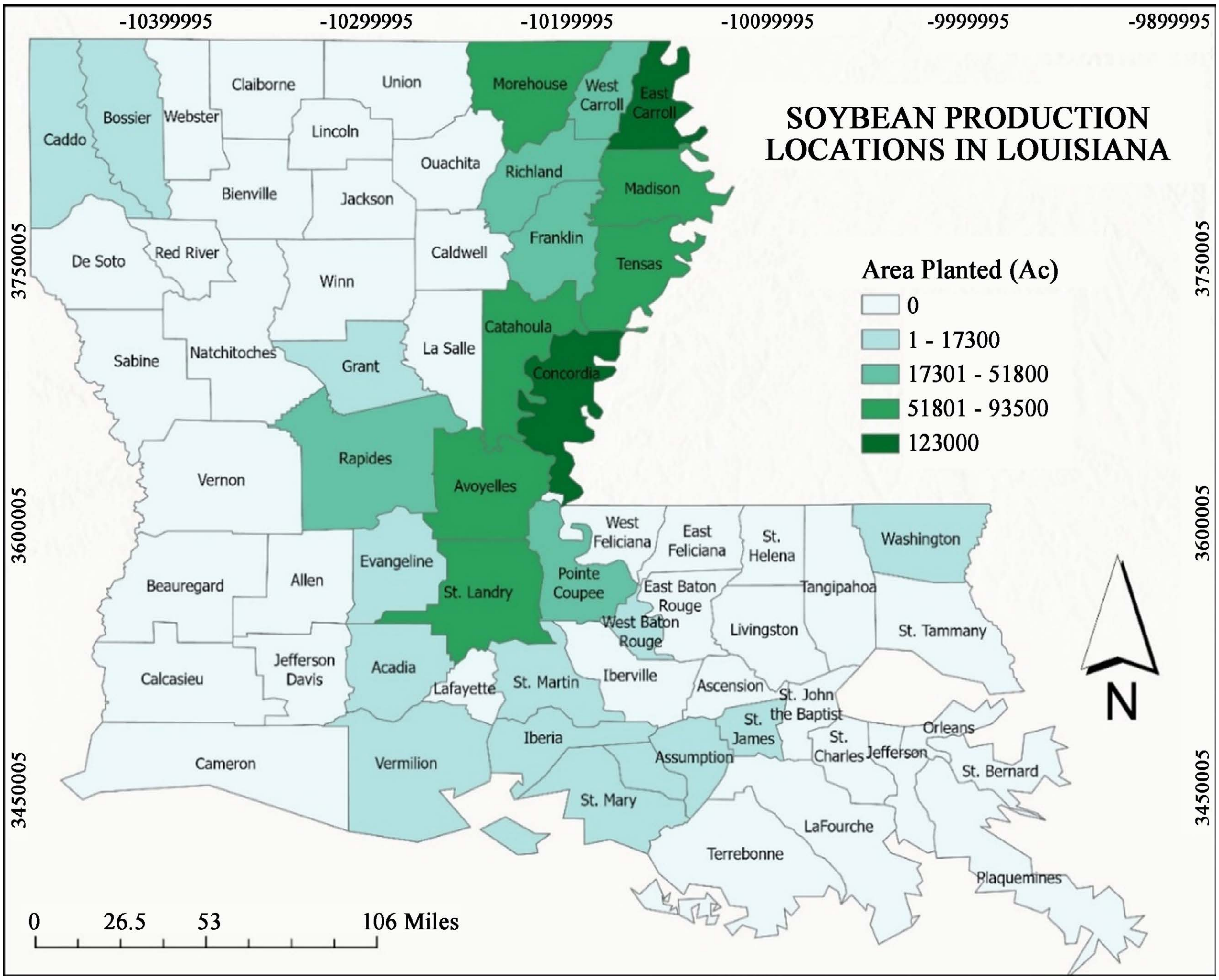


Figure 3. 2021 total acreage of soybean production in Louisiana.

Also, parishes such as Acadia, Evangeline, St.Mary and Martin and West Baton Rouge, are among the parishes that do not have any record of corn acres but just Soybean acres ranging between 1 and about 17,000. Parishes such as Cameron, Jackson, St. Helena, Union and De Soto record neither corn or soybean acres of production. Similarly, Figure 4 also shows parishes with acres of cotton production recorded in Louisiana in 2021. The overall acres of cotton production are relatively low as compared to the corn and soybean records. In terms of the highest, Tensas records the highest number of cotton acre production and happens to be the only parish with the highest number. Compared to the other two traditional crops corn and soybean, Tensas also records a relatively high number of production in terms of acreage.

Madison and Catohoula also record relatively high acres of cotton production just as the parish did for soybeans and corn. However notably, the total number of parishes that have acres of cotton production is few compared to the soybeans and corn-producing parishes. That is, out of the 64 parishes, only 9 parishes record acres of cotton production with only one parish recording the

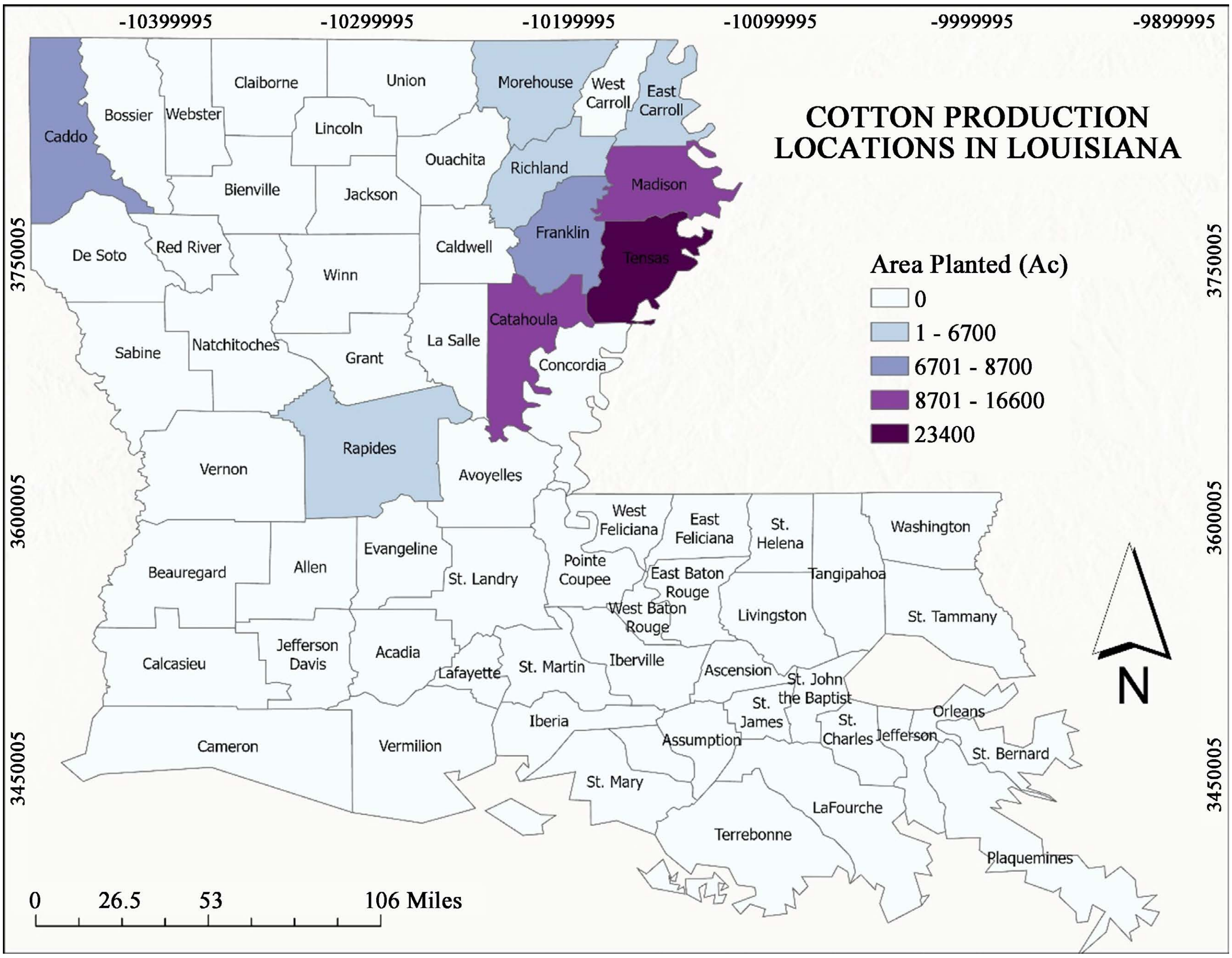


Figure 4. 2021 total acreage of cotton production in Louisiana.

highest of about 23,000 acres. Also, similar to the corn and soybean analysis, most of the parishes in Louisiana that did not record acres of corn production especially along the southeastern and southwestern part of the region include Cameron, Vernon, Terrebonne, LaFourche and St. Tammary.

3.2. Results from Soil Survey Geographic Showing Dominant Soils in LA Parishes

From the three acre production maps, the results show that parishes such as Madison, Morehouse and East Caroll record relatively high acres of all the traditional crops, that is, Corn, Cotton and Soybean. From the Web Soil Survey, the dominant soil types in three of the most widely known locations for corn, cotton and soybean production in three Louisiana parishes thus, Morehouse Parish, Madison Parish and East Carroll Parish are depicted as maps in Figures 5-7.

Just like Figure 5, Figure 6 also shows a soil map of Morehouse, one of the parishes that have high acres of corn, cotton and soybean production. The dominant soil according to Figure 5 & Figure 6 are the alfisols just as seen in the Madison Parish soil map in Figure 5 and East Caroll parish map in Figure 7.

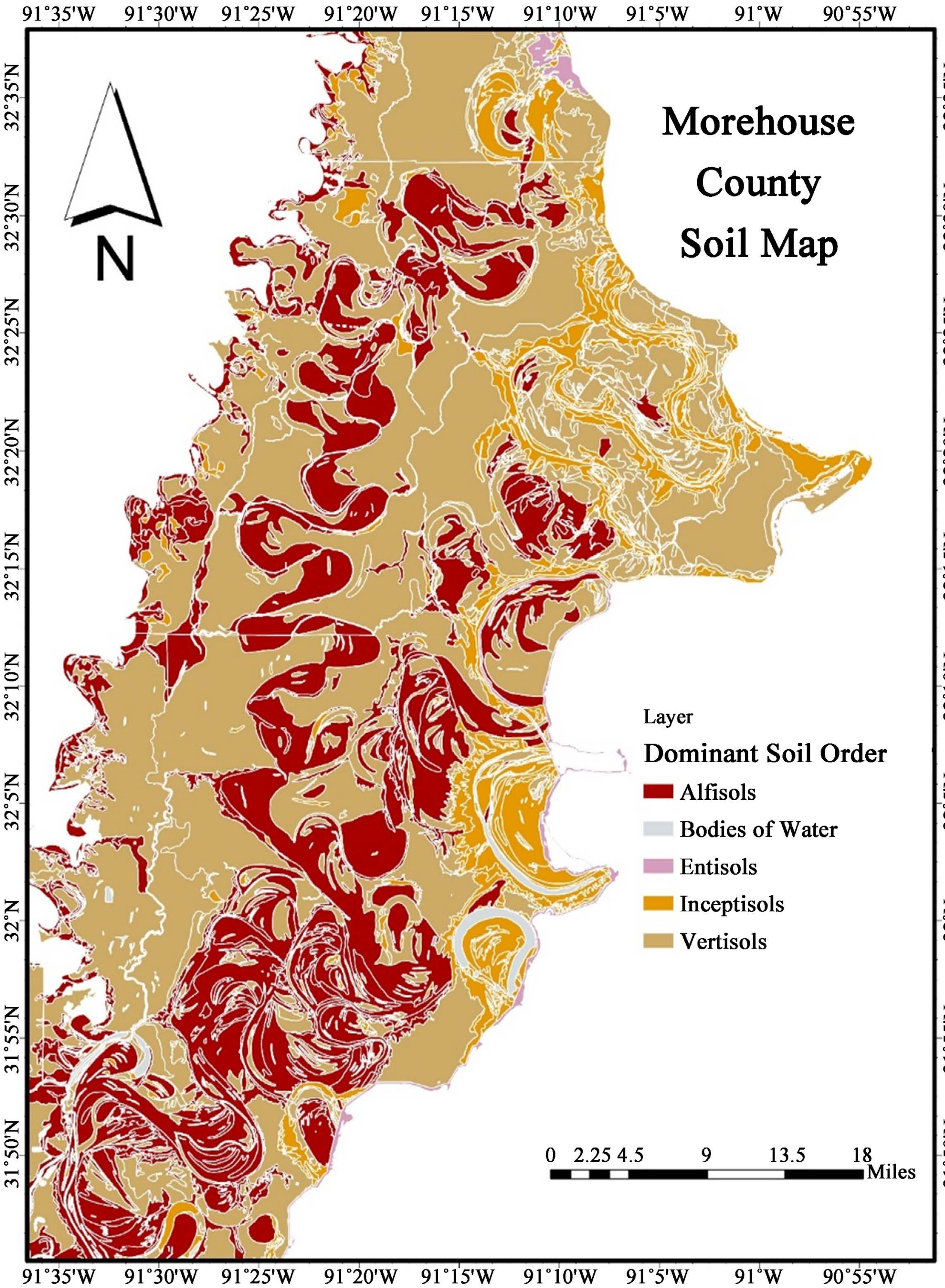


Figure 5. Madison county soil map.

The other soil types are the entisols, inceptisols and vertisols that are also prominent in all the three parishes that record high acres of crop production.

As seen in **Figure 5** and **Figure 6**, the major soils in **Figure 7** are the Alfisols, Entisols, Inceptisols and the Vertisols. Alfisols are clay-enriched subsoil with

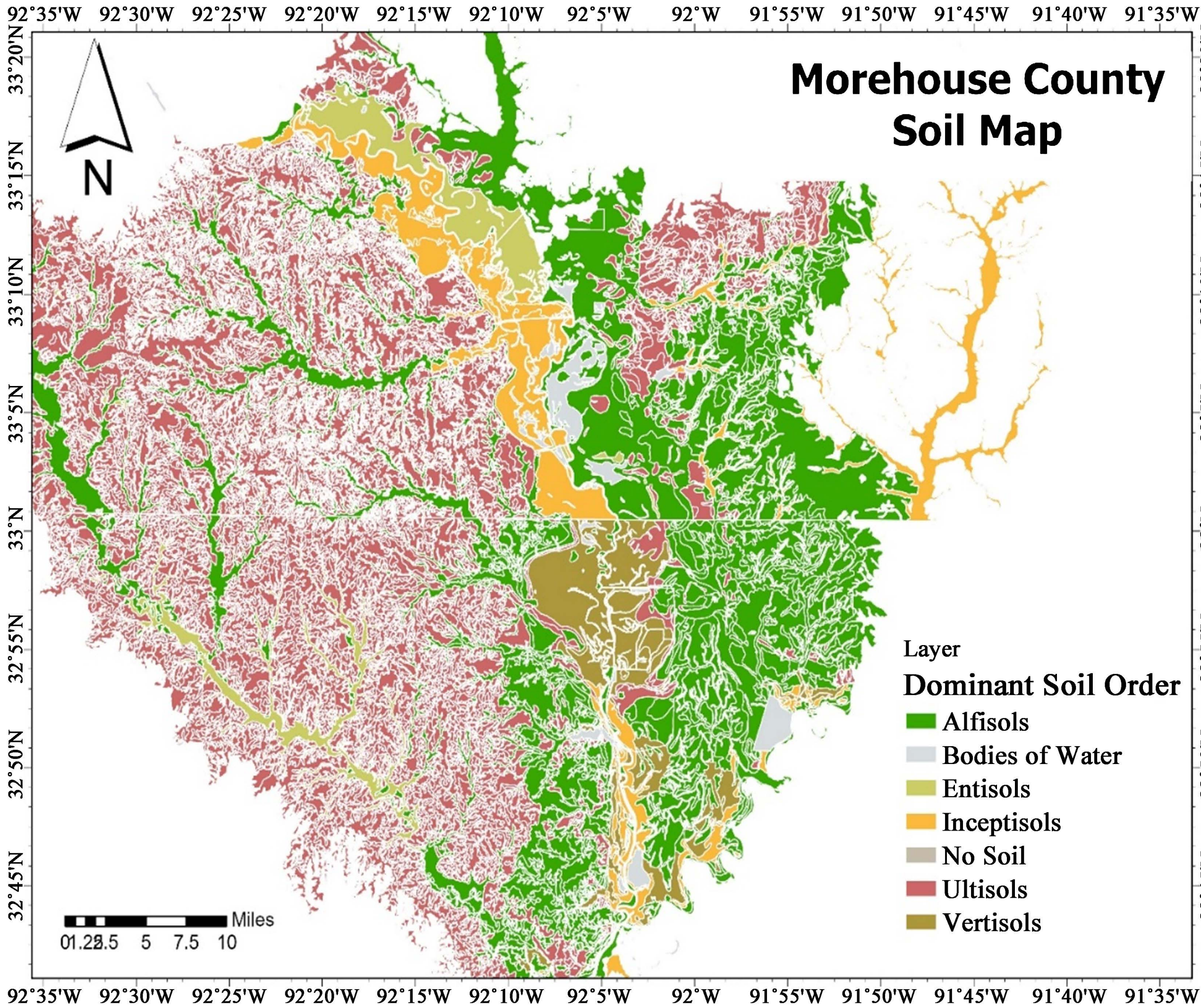


Figure 6. Morehouse county soil map.

high native fertility, Entisols are soils that have no profile development, Inceptisols are draining soils that form through the alteration of parent materials whereas Vertisols are enriched clay soils with little organic matter [13]. It can therefore be postulated that, the presence of these soils in the three high acre recording parishes have influenced the growth and high production rates of the three traditional crops.

3.3. Results from USDA Showing Louisiana Parishes with Marginal Lands

The results of the marginal lands data were mapped based on the eight Land Capability classes that were classified by [14] from data that was retrieved from the Soil Survey Geographic (SSURGO) database. The eight classes are numbered from I-VIII whereby Class I is (prime) land without any limitations for use and Class VIII is land that can only support wildlife, not agriculture. On the other hand, Classes I-IV can support cropland agriculture, whereas classes V-VIII

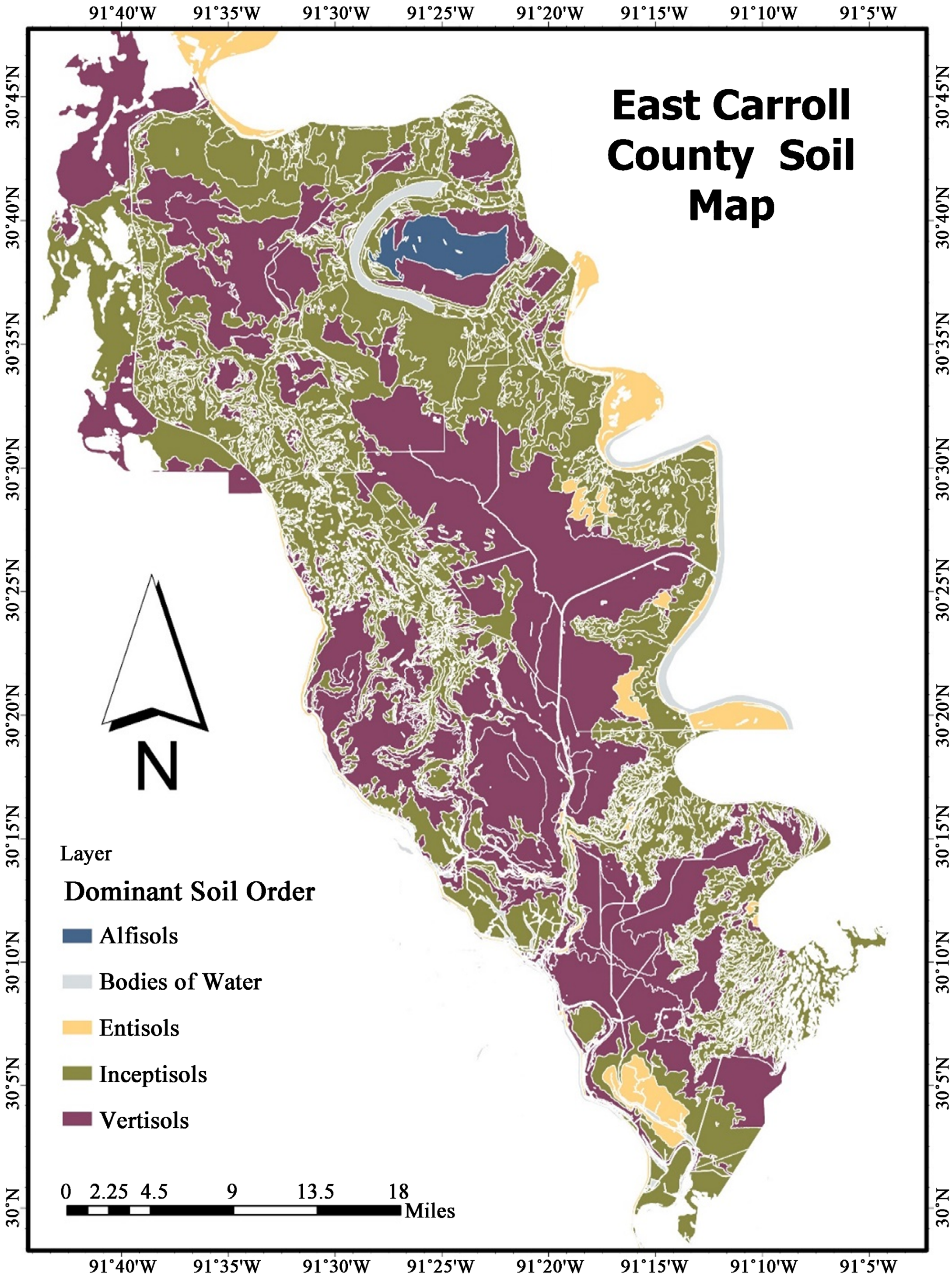


Figure 7. East Carroll county soil map.

contain non-arable land. [14] went on to explain that the Land Capability classes can be used for two purposes that is to identify marginal lands for biofuel production and to qualitatively validate the results of biophysical and biogeochemical modeling. These capability classes were therefore used to map out the marginal land locations in Louisiana as seen in **Figure 8**.

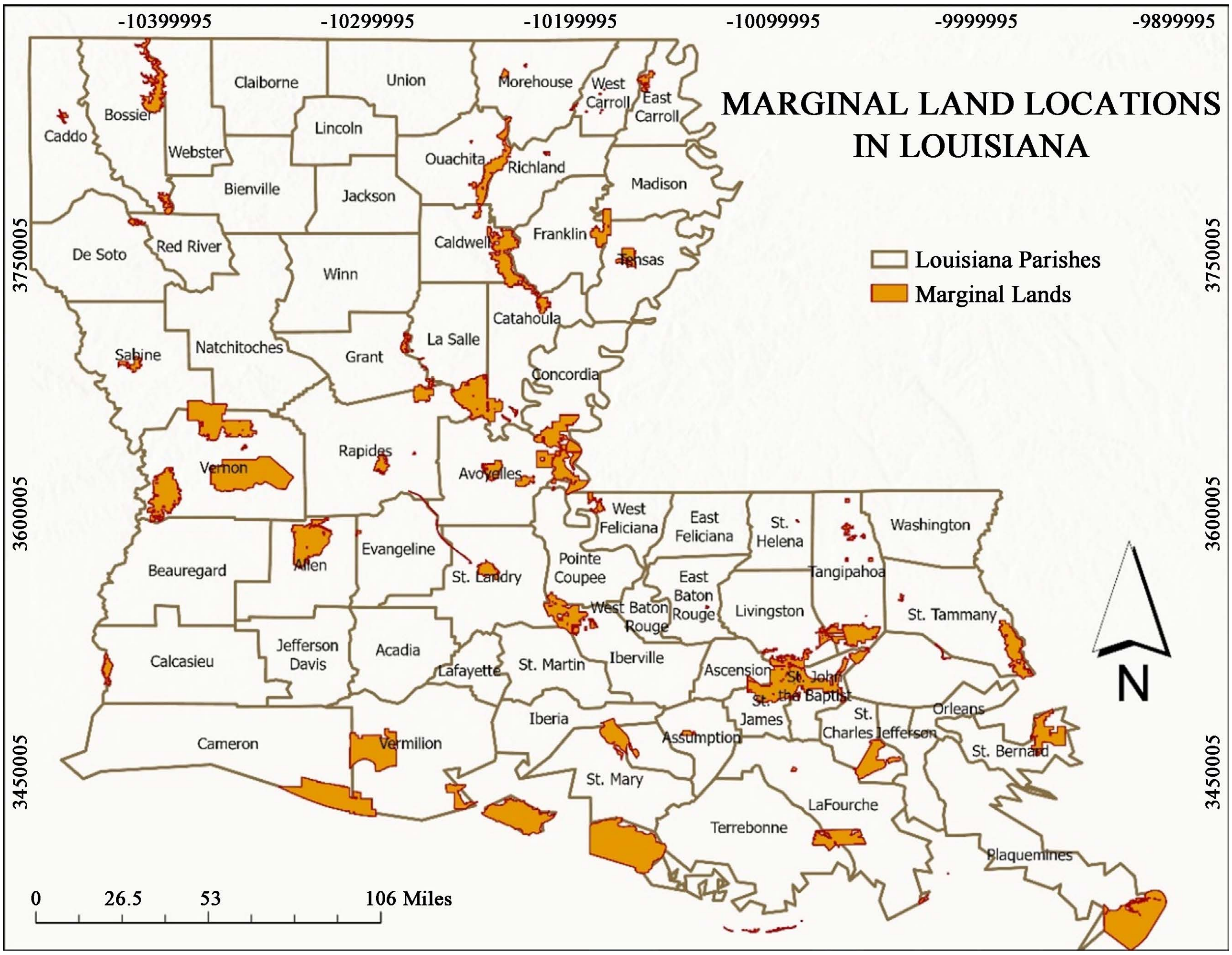


Figure 8. Marginal lands located in Louisiana counties.

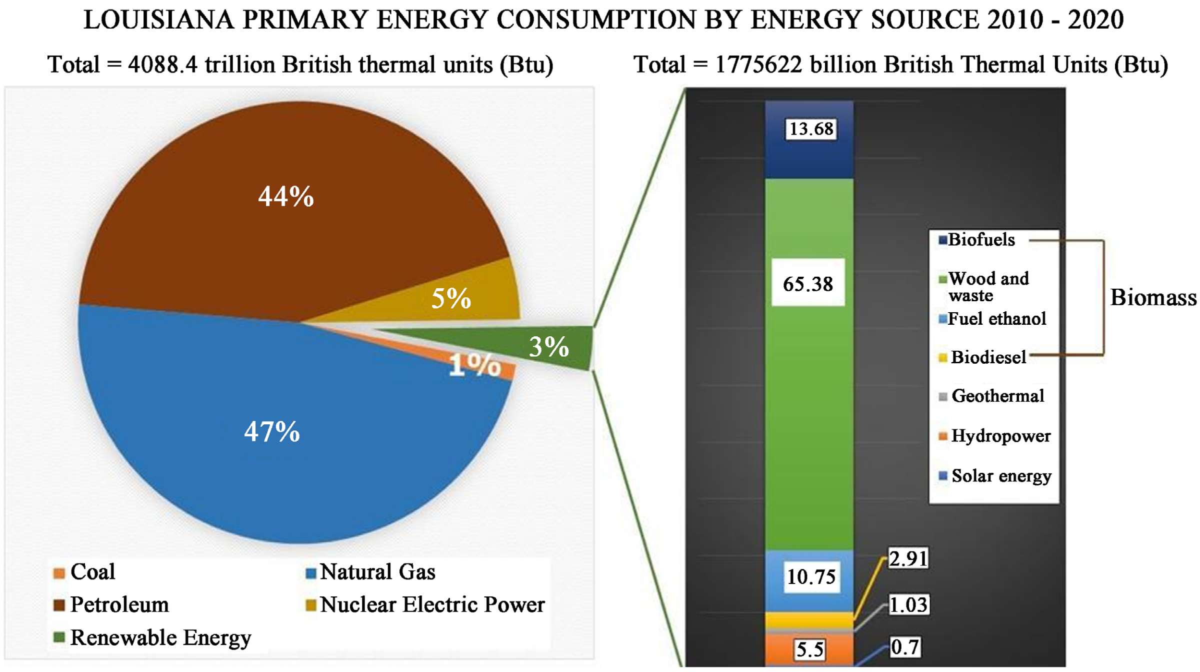
Based on this, the marginal lands were identified as rural lands falling into Land Capability Classes V-VII that have the potential to support bioenergy production. That is, from this data source, marginal land areas were delineated according to the Land Capability class V-VII within other parishes in Louisiana as seen in **Figure 8**. The map shows a few marginal lands located in some parishes such as Vernon, St. Mary, St. Tammary, Lafourche, St. John the Baptist, Plaquemines and Allen. Per the traditional crop acres of production data, these parishes with marginal lands recorded zero (0) acres of crop production. However, based on the land capability classifications that were used to delineate the marginal lands, Classification V-VIII contains soils Alfisols, Entisols, Inceptisols and Vertisols that are dominant in the three high acre recording parishes. This implies that, these marginal lands possess the equal potential of supporting the growth of energy crops that can be used for biofuel production.

3.4. Results from US-Energy Information Administration

As reported by the United States-Energy Information Administration, Louisiana depends on Coal, Natural Gas, Petroleum, Nuclear Electric Power and Renewable sources of energy as seen in **Figure 9**, to provide the transportation, industrial, commercial, and residential sectors with energy. These sources of energy are grouped into general categories such as primary and secondary, renewable and nonrenewable, and fossil fuels [5]. The primary sources of energy include fossil fuels (petroleum, natural gas, and coal), nuclear energy, and renewable sources of energy whereas electricity is a secondary energy source that is generated from primary energy sources [5]. Based on this, the graph shows that Louisiana consumes high amounts of Natural Gas and Petroleum of 47% and 44% respectively. Compared to Renewable Energy, the state only consumes 3% of renewable energy which comprises Solar Energy, Hydropower, Geothermal, Biodiesel, Fuel Ethanol, Wood and waste as well as Biofuels. Out of these renewable energy sources, the state utilizes about 2% and 14% of biodiesel and biofuels respectively.

3.5. Discussion

The Environmental and Energy Study Institute has opined that globally, bioenergy makes up half of all renewable consumption, and includes biofuels, biomass power, and waste-to-energy technologies [15]. Biomass can substitute for fossil fuels in the production of energy and serve as an alternative for the many industrial products and materials made from petroleum or natural gas. According to the US-EIA, this relates to Louisiana being one of the top five states in both natural gas production and proved reserves. That is for instance, the state accounted for 9% of U.S. total marketed gas production in 2020 and has about 8% of the nation's gas reserves. Based on the energy consumption rates in Louisiana, it is



Data Source: [5].

Figure 9. Louisiana energy consumption estimates and sources.

therefore evident that Louisiana highly depends on natural gases as a source of energy compared to biomass and other renewable sources of energy. This also confirms the hypothesis about the state's less dependence on biofuel and other sources of renewable energy.

Notably, Louisiana has a diverse resource base which could be exploited to produce ethanol and biodiesel [12]. In 1980, it was recorded that the United States produced 175 million gallons of ethanol for use as a transportation fuel and by 1995, the annual production level had risen to 1.4 billion gallons [16]. The potential for Louisiana to become a biomass production hub is not far-fetched as predictions have been made by [8] concerning an estimated 367 million gallons of ethanol which could be produced annually from sugarcane and grains (corn, grain sorghum, oats, and wheat) assuming the entire resource was used for biofuel production. In terms of biodiesel, [8] estimated a production potential of around 64 million gallons per year of biodiesel from oil crops and waste cooking oil or grease. Based on these estimates and some feedstock utilization assumptions, Louisiana could produce 18.7% of its transportation energy needs [8]. For instance in the United States, in the year 2000, only 2 million gallons of biodiesel were produced in the United States but 2008, this annual production value increased to 683 million gallons [16]. Generally, fuels particularly from these plants have also been identified as being among the cleanest energy sources due to the minimal impact their oxidation products have on the environment [17].

Based on the results of the study, the data gathered point to the fact that most of the parishes in Louisiana such as Allen, Vernon, St. Mary, St. Tammary, Lafourche, St. John the Baptist and Plaquemines do not have acres of land designated for corn, soybeans and cotton production. To understand this lag in bioenergy production in Louisiana, it is opined that, the state may be challenged with competition with conventional fossil fuels, other renewable energy sources, the appalling state of technology, state of the economy and other intrinsic bioenergy challenges such as the food versus fuel controversy [8]. For instance, concerning the food security controversy, it is assumed that the increased use of ethanol for fuel accounted for about 10% to 15% of the rise in food prices between April 2007 and April 2008 whereby the rising demand for corn also increased the demand for cropland and the price of animal feed.

On the other hand, the parishes that recorded relatively high acres of corn, soybean and cotton production have a great potential in enhancing the bioenergy sector. It implies that all the three traditional crops that Louisiana depends on as bioenergy crops thrive in these parishes, making it ideal to provide the required feedstocks. Unfortunately, given the current circumstances both nationally and locally, the near-term outlook does not look promising for bioenergy production in Louisiana, especially for 1st generation biofuels such as corn ethanol and soy biodiesel [8]. Rather, it is assumed that intermediate and longer-term effects will be realized if the state promotes the production of second generation or advanced biofuels which will substantially benefit the state's long-term economic development.

Considering the state of Louisiana's energy consumption estimates and traditional crop production, it can be inferred that there is a lag in the bioenergy production and consumption rate. However, it is not conclusive that the bioenergy industry cannot be revived to support the energy industry while taking into consideration a clean energy initiative. Hence, growing biomass for generating biofuels allows the United States as a whole and Louisiana as an industrial state, to develop a new industry that combines sustainable agriculture, biotechnology, and energy production which allows farmers to grow enough biomass without damaging the local soil and the environment [9].

4. Conclusion

In a nutshell, ethanol and biodiesel provide alternatives to petroleum-based fuels which can be produced from renewable and domestic resources. Thus, biodiesel can be derived from a range of feedstock such as soybean oil, canola oil, vegetable oils or animal fats which are viable alternatives to petroleum-based diesel fuel. Ethanol on the other hand can be made from crops such as corn and sugarcane which can be usually blended with gasoline to serve as transportation fuel. The blend of ethanol and use of biodiesel has always been considered as an alternative even before the gas prices started to rise indiscriminately. Louisiana stands a chance of leading the biofuel industry due to its substantial feedstock resources, good potential for producing energy growing crops such as sweet sorghum, sugarcane, switchgrass, soybean, corn and cotton. Aside from these crops, a wide variety of biomass feedstocks are available, and biomass can be produced anywhere that plants or animals live. For corn production, the state can leverage on the potential of utilizing this crop as an efficient renewable biofuel especially in the southeastern and western parts of the state. Aside from corn being the highest producer of ethanol, it is also one of the best crop residues which increases soil moisture, nutrient and organic matter content of soils while reducing soil erosion. Since this renewable energy alternative aims at reducing greenhouse gas emissions into the atmosphere, the EIA suggests a sustainability certification of biofuels, following internationally agreed sustainability criteria. This is a relevant step towards ensuring that biofuel production and use will have a positive environmental, social, and economic impact especially in Louisiana.

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Conflicts of Interest

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

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